# Valuing the Future

## Recent advances in social discounting

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### The perplexing issue of discounting

Prescriptive economics requires that, unless there are very good reasons to the contrary, economic policy should be based on the principle that individuals' preferences should count. Indeed, the entire body of 'welfare economics' centres round the formal identity of the statement "X prefers A to B" and the statement "X has higher welfare in A rather than B". This combination of a seemingly innocuous and democratic value judgement—preferences should count—and a formal definition about the *meaning* of welfare improvement involves many complications. The entire history of policy analysis focuses on those complications. Whose preferences should count? Over what time period? What constitutes a legitimate attenuation of the basic value judgement? One of the problem areas concerns time-discounting—the process whereby society places a lower value on a future gain or loss than on the same gain or loss occurring now. The rationale for time-discounting follows logically from the basic value judgement of welfare economics. If people's preferences count and if people prefer now to the future, those preferences must be integrated into social policy formulation. Time-discounting is thus universal in economic analysis, but it remains, as it always has, controversial.

The controversy has a parallel in another form of discounting—spatial discounting. When translated into economic terms, the ethical principle

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that "all men and women are equal" is not one that is practised anywhere in the world. If everyone was equal in an economic sense, for example, expenditure by rich countries on saving lives in poor countries would be higher than expenditure on saving the rich countries' 'own' lives. The extra (marginal) cost of life saving in poor countries is very much lower than the extra cost of saving lives in rich countries. Yet the opposite is the case: no rich country spends more on saving lives abroad than it does at home. Think of the difference between health care costs domestically and overseas aid. In the same vein, ethical principles would seem to dictate that a future life has the same value as a current life: lives should not be discounted. John Broome (1992) has argued this case eloquently: "In overall good, judged from a universal point of view, good at one time cannot count differently from good at another. Nor can the good of a person born at one time count differently from the good of a person born at another" (p.92). Yet we *do* discount future lives, both in terms of our own lives, and the lives of people yet to come. A wide body of evidence now exists to show that individuals discount risks in their own lives—future risks being regarded as of lower consequence than current risks in both rich countries (Moore and Viscusi, 1990a, 1990b; Johannesson and Johanson, 1996) and in poor countries (Poulos and Whittington, 2000). And if others' lives are just as valuable in the future as lives are today, the world would have acted far more dramatically and with hugely increased expenditures to prevent global warming from getting any worse. It is future generations' lives that are at risk from global warming, not ours.

The brute fact is that we do discount for time and for space. What people do appears to be quite inconsistent with seemingly reasonable ethical criteria which suggest that people should not be treated differently simply because of their location in time and space. This inconsistency underscores the problems produced by the basic value judgement in welfare economics. If what people do reflects what they prefer, and if preferences are to count morally (the basis of the utilitarian view), then discounting is morally justified. This moral justification contradicts the seemingly equal moral view set out by Broome, and many other philosophers. Note that the utilitarian view links 'is' statements to 'ought' statements because of the assumption that behaviour reflects preferences. Without this assumption, David Hume's famous dictum that one cannot derive ought from is would hold.

Is there an escape from this dilemma? In what follows we review some recent contributions to the literature on discounting. We believe these contributions go a long way to preserving the ethical underpinnings of welfare economics, whilst at the same time overcoming the bias against the future that arises from the practice of discounting.

## The tyranny of discounting

It is comparatively easy to illustrate the moral dilemma in discounting. Let the weight that is attached to a gain or loss in any future year, t, be $w_t$. Discounting implies that $w_t \prec 1$. Moreover, discounting implies that the weight attached to, say, 50 years hence should be lower than the weight attached to 40 years hence. The discounting formula is then:

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

Inspection of this equation shows that it is simply compound interest upside down. This is why the approach is often called 'exponential discounting'. The weight $w_t$ is the *discount factor* and $s$ is the *discount rate*. It is important to distinguish the two, as we will see. The discount factor is often represented as a fraction, and the discount rate as a percentage. For example, if $s$ = 4%, then the discount factor for 50 years hence would be:

$$w_{50} = \frac{1}{(1.04)^{50}} = 0.14$$

In practical terms, this would mean that a gain or loss 50 years hence would be valued at only 14% of its value now. Transposed to the kinds of global environmental problems now faced by the world, the arithmetic illustrates the 'tyranny' of discounting. Keeping to the 4% discount rate, global warming damage one hundred years from now would be valued at just one-fiftieth of the value that would be assigned to it if it occurred today. Imagine a cost of $1 billion one hundred years from now. The use of discounting means that this loss would appear as just £20 million in any appraisal of the costs and benefits of global warming control. Indeed, cost–benefit models of global warming have been shown to be highly sensitive to assumptions about the discount rate. In the Fund 1.6 model of Tol (Tol, 1999), for example, the marginal damage from carbon dioxide emissions increases from \$20/tC to \$42/tC to \$109/tC, as the discount rate declines from rates of 5% to 3% to 1% respectively. Discounting appears to be inconsistent with the rhetoric and spirit of 'sustainable development'—economic and social development paths that treat future generations with far greater sensitivity than has hitherto been the case.

## Not discounting is discounting at 0%, and it isn't good

The dilemma of discounting seems easily resolvable—simply don't do it. But not discounting is formally equivalent to discounting at a particular number which happens to be zero per cent. In terms of the discounting equation, if $s = 0$, $w_t = 1$ and everyone is 'equal' now and in the future. This outcome would not matter much for the debate but for some very unnerving implications of using zero discount rates. The first is transparently simple. Zero discounting means that we care as much for someone not just one hundred years from now as we do for someone now, but also someone one thousand years from now, or even one million years from now. It seems at least legitimate to ask: *do* we care about someone one million years hence (we already know we do not), and *should* we care about someone one million years from now? We suspect that the answer to the second question would also be negative if there was a poll of people to determine it.

A more involved argument that rejects zero discounting goes as follows. As long as interest rates are positive, zero discounting implies that there are situations in which current generations should reduce their incomes to subsistence level in order to benefit future generations. The effect of lowering the discount rate towards zero is to increase the amount of saving that the current generation should undertake. The lower the discount rate, the more future consumption matters, and hence more savings and investment should take place in the current generation's time period. Thus, while lowering the discount rate appears to take account of the well-being of future generations, it implies bigger and bigger sacrifices of current well-being. Indeed, Koopmans (1965) showed that however low the current level of consumption is, further reductions in consumption would be justified in the name of increasing future generations' consumption. The logic here is that there will be a lot of future generations, so that whatever the increment in savings now, and whatever the cost to the current generation, the future gains will substantially outweigh current losses in foregone consumption. The logical implication of zero discounting is the impoverishment of the current generation (Olsen and Bailey, 1982). This finding would of course relate to every generation, so that, in effect, each successive generation would find itself being impoverished in order to further the well-being of the next. The Rawls criterion (Rawls, 1971)—that we should aim to maximise the well-being of the poorest individual in society—would reject such a policy of current sacrifice, since the sacrifice would be made by the poorest generation. Thus zero discounting has its own ethical implications that few would find comforting or acceptable. 'Not discounting' is not an answer to the discounting dilemma.

## Early resolutions to the discounting dilemma

Before encountering the recent contributions that we consider have revolutionised the approach to discounting, two other approaches deserve a brief mention.

The first approach preserves the basic value judgement in welfare economics about individuals' preferences. If what people do reflects their preferences, then what they do must be relevant to social decision-making. But, until recently, few studies made any attempt to find out how people *actually* discount the future. It was simply *assumed* that they engaged in activities consistent with the discounting formula set out above. The feature of that formula that may not be immediately obvious is that it assumes $s$, *the discount rate*, *remains the same over time*. There are good reasons why this assumption has always been made and they have to do with a complex issue of 'dynamic time consistency', which we address shortly. But there is nothing in the assumption that means this is how people actually have to behave. A significant body of evidence now exists to suggest that people do not behave as if their own discount rates are a constant (Frederick *et al.* 2002). Rather, their discount equations are 'hyperbolic' (to contrast them with the former equation which behaves exponentially). Simply put, individuals' discount rates are likely to decline as time goes on. Discount rates are said to be 'time varying'. Instead of $s$ in the previous equation, we need to write $s_t$ to signal that the value of $s$ will change with the time period. Moreover, $s$ will fall the larger is $t$.

Although it is fair to say that the empirical evidence is not overwhelming, hyperbolic discounting emerges as an empirical discovery, a description of how people actually behave. If this form of discounting reflects preferences, then hyperbolic discounting could legitimately be used in policy and investment appraisal. The effect of hyperbolic discounting is generally to raise the initial discount rate relative to the exponential rate (the constant value of $s$) and then lower the rate in later years. By observing how people choose between options located in different future periods, it is possible to estimate the rate at which such rates decline. Of course, the social discount rate is a *normative* construct—it tells us what we should do. Deriving a normative rule from an empirical observation contradicts Hume's dictum that 'ought' cannot be derived from 'is'. However, if what people do (the 'is') reflects preferences and preferences count, then, what *is* becomes relevant to what *ought* to be.

The second early approach to address the discounting dilemma starts from the observation that our willingness to pay for environmental (and other) goods and services is likely to increase over time. Think of disappearing rain forests: the value of those that remain is likely to rise over time as there are fewer of them. In addition, as income rises, so willingness to pay for natural assets is likely to rise (Krutilla and Fisher, 1975; Porter, 1982). This approach asserts that in order to account for increases in willingness to pay, a lower 'net discount rate' should be applied to costs and benefits, leaving the discount rate itself unaffected.

The process is simple. Welfare economics argues that decisions should be at least influenced by, if not decided by, cost-benefit analysis (CBA). In CBA preferences for a benefit are measured by individuals' willingness to pay for the benefit, and 'dispreferences' for costs are measured by willingness to pay to avoid the cost (we ignore yet another debate which suggests that, in many cases, costs should be measured by willingness to accept compensation to tolerate the cost). Since benefits (B) and costs (C) accrue over time, discounting is relevant, and the formal requirement for a policy or investment to be declared 'good' is that the discounted value of the benefits should exceed the discounted value of the costs. Formally:

$$\sum_t \frac{[B_t - C_t]}{(1+s)^t} > 0$$

But, as noted above, for many applications of CBA, willingness to pay for benefits will increase over time relative to the general price level. The effect is to change the cost–benefit formula so that $B_t$ increases with time. If that rate of increase is given by the product, e.g., where *g* is the growth rate of per capita incomes, and *e* is an elasticity linking willingness to pay to that growth (formally, it is the 'income elasticity of willingness to pay'), then the cost–benefit equation can be modified as follows:

$$\sum_t \frac{[B_t - C_t]}{(1+s-e.g)^t} > 0$$

The effect of the adjustment is to *lower* the 'net' discount rate, although the discount rate itself, *s*, is unaffected.[1] The adjustment does not produce a net discount rate that varies with time, but it is possible to see how this might come about if either *e* or *g* increases over time. Looking at very long run economic growth rates there is evidence that in an economy such as the UK's, economic growth has increased. Angus Maddison's monumental study, *The World Economy* (Maddison, 2001), computes an annual growth rate of UK GDP of 0.8% p.a. for 1500–1820, around 2.0% p.a. for 1820–1913, and 2.9% p.a. for 1950–73. In other periods, however, growth fell below the levels for 1950–73. More of an argument might be made for supposing that the value of *e* will rise with time, although there is little evidence on this at the moment. Our own view of this approach to resolving the discounting problem is that it confuses relative valuations of costs and benefits with the valuation of time. For analytical and didactic reasons, it is best to keep the two separate.

## Just keep discounting, but…

The heading for this section is the title of a brief chapter on discounting by Martin Weitzman, a Professor of Economics at Harvard University (Weitzman, 1999).[2] In his chapter, Weitzman speaks of attending a conference and being puzzled by the procedures economists use when dealing with uncertainty about the future, and in particular, uncertainties about

[1] Krutilla and Fisher (1975) argued that a parallel approach applies to the benefits of any development project that causes environmental costs to occur. In this case, however, they proposed that technological change would make the development project generate less benefits than might first appear to be the case. If so, the 'net' discount rate for the benefits of development (i.e. the costs of conservation) would rise over time.
[2] Weitzman's full model can be found in Weitzman (1998).

future interest rates. Like the rest of us, Weitzman accepted that we should carry out some kind of averaging procedure. If we think future interest rates have a 50% chance of being 3%, and a 50% chance of being 5%, then the weighted average (or expected value) is 0.5*3 + 0.5*5 = 4.0%. Weitzman writes, "…something started gnawing at me about the peculiar way in which uncertain interest rates need to be averaged over time, and how that might conceivably force a revision in how we conceptualize the problem for the very long run. Then…the light bulb that signals the 'Eureka' experience finally flashed on my head" (p.28). Weitzman's insight had in fact already been shared by a French economist Christian Gollier, at the University of Toulouse, but approached from a different direction (Gollier, 1997). While the details of these approaches quickly become extremely complex, it is possible to gain some idea of the resulting revolution in thinking about discounting. For both Weitzman and Gollier, the clue lies in how we treat uncertainty about the future. For Weitzman, that uncertainty is reflected in uncertainty about future interest rates, as the quotations from his chapter show. For Gollier, the uncertainty is about the state of the economy.

Consider Weitzman's problem again. Interest rates provide relative valuations of the future relative to the present. But these relative valuations are uncertain. Formally, this uncertainty shows up in our lack of certainty about the weights to be attached to future time. But we saw that the weights are the discount *factors*, $w_t$. Rather than averaging likely future discount *rates* what should be averaged are the probabilistic discount *factors*. Somewhat counter-intuitively, this process produces discount *rates* that decline with time. A numerical example shows this (see Table 1).

In Table 1, there are ten potential scenarios, and each scenario is manifested with equal probability: $p_1 = p_2 = \ldots = p_{10} = 0.1$. Consider the first cell where $t = 10$ and the discount rate is 1%. The corresponding discount factor is 0.9053, shown in Table 1 as 0.91. Compute the relevant discount factors for all the discount rates and time periods shown. This produces the rest of the entries in the main body of the table. Now take the average of these discount factors for any given time period. Since we have assumed equal probabilities of occurrence a simple average produces, for example, a value of 0.61 for the t = 10 column. This value of 0.61 is the 'certainty equivalent discount factor'. Notice that this declines as $t$ gets bigger. We now want the discount rate that corresponds to the averaged discount

**Table 1: Numerical example of Weitzman's declining certainty-equivalent discount rate**

| | Discount factors in period *t* | | | | |
|---|---|---|---|---|---|
| Interest rate scenarios | 10 | 50 | 100 | 200 | 500 |
| 1% | 0.91 | 0.61 | 0.37 | 0.14 | 0.01 |
| 2% | 0.82 | 0.37 | 0.14 | 0.02 | 0.00 |
| 3% | 0.74 | 0.23 | 0.05 | 0.00 | 0.00 |
| 4% | 0.68 | 0.14 | 0.02 | 0.00 | 0.00 |
| 5% | 0.61 | 0.09 | 0.01 | 0.00 | 0.00 |
| 6% | 0.56 | 0.05 | 0.00 | 0.00 | 0.00 |
| 7% | 0.51 | 0.03 | 0.00 | 0.00 | 0.00 |
| 8% | 0.46 | 0.02 | 0.00 | 0.00 | 0.00 |
| 9% | 0.42 | 0.01 | 0.00 | 0.00 | 0.00 |
| 10% | 0.39 | 0.01 | 0.00 | 0.00 | 0.00 |
| Certainty-equivalent discount factor | 0.61 | 0.16 | 0.06 | 0.02 | 0.00 |
| Certainty-equivalent discount rate (%) | 4.73 | 2.54 | 1.61 | 1.16 | 1.01 |

factor and this is shown in the final row of Table 1. For example, for $t = 10$, we would get a 'certainty equivalent discount rate', $s^*$, given by the equation:

$$\frac{1}{(1+s^*)^{10}} = 0.61$$

to give a value of $s^*$ of 4.73%. It is easy to see that the certainty-equivalent discount rate approaches the lowest discount rate of the ten scenarios considered—1%. In year 200 the rate has fallen to 1.16%, and by year 500 this rate has fallen 1.01%. This is Weitzman's key result—in the limit, as $t$ goes to infinity, the discount rate converges on the lowest possible discount rate (1% in this example).

Weitzman's model has been applied in important work by Newell and Pizer (2000, 2001). Newell and Pizer use past data on interest rates in the USA to create a simulation of future interest rates, with the same uncertainty observed in historical interest rates. Two of the crucial conditions underlying Weitzman's result are that the discount rate is *uncertain* and that it is *highly persistent*; i.e. the expectation must be that periods of low (high) rates will tend to be followed by additional periods of low (high) rates. Newell and Pizer found significant empirical evidence that this had been the case historically. In simulating the future certainty-equivalent rates, Newell and Pizer found that from a starting value of 4%, the certainty-equivalent rate falls below 1% 400 years hence. In the Newell and Pizer work, certainty equivalent discount rates decline with immediate effect from the present. Recalling that the driving force behind the Weitzman result is uncertainty about interest rates, a case could be made for having a constant short-term rate up to a period beyond which financial markets do not reveal expectations about future rates, perhaps 30 or 40 years at most.

## Uncertainty about the economy

Weitzman's result follows from a very reasonable assumption that we are uncertain about the future. In his case, it is interest rates themselves that are uncertain. The contribution of Gollier (2002a, 2002b) is to treat uncertainty about the future of the economy in general. Gollier's work is complex and the results depend on various factors some of which are never likely to be capable of estimation in practice. The central result can be found by looking at the 'normal' way in which the theory of social discounting is presented. The notion of a social discount rate is usually presented in the form of the following equation, known as a Ramsey equation (after Frank Ramsey, (Ramsey, 1928)):

$$s = \rho + \mu.g$$

What this says is that the social discount rate is equal to the sum of two factors: $\rho$ which is the 'pure' rate of time preference, reflecting people's impatience; and the product of $\mu$ (to be explained) and $g$, the growth rate of future (per capita) consumption. $\mu$ is known as the elasticity of the marginal utility of consumption, the percentage change in the well-being derived from a percentage change in consumption (or income). The intuition behind $\mu$ is that it expresses individuals' aversion to fluctuations in their income levels. While there is a substantial debate about the value of $\mu$, recent reviews suggest that it takes a convenient value of about 1.0 (Cowell and Gardiner, 1999). Notice that there is a simple intuition behind $\mu.g$. People in the future will (almost certainly) be richer and hence the 'utility' they attach to one more dollar of income is likely to be lower than that attached to the same dollar today. Effectively, then, discounting is justified simply by the fact that future people will be better off than today's people.

Rates of impatience are also notoriously difficult to estimate, but recent work suggests a value of, at most, 0.5% (Pearce and Ulph, 1999). So, for an economy growing at 2% per annum, the Ramsey formula suggests a discount rate of 2.5% at most. But the Ramsey formula tells us nothing about the effects of the kind of uncertainty that Gollier (and Weitzman) are interested in. What Gollier shows is that, once we recognise that future income is uncertain, there will be two effects rather than the single effect shown by $\mu$ in the Ramsey formula. Whereas $\mu$ is picking up individuals' aversion to uncertainty about future income (the 'wealth effect'), there is a second effect not in the formula, namely precautionary saving. Where people are unsure about future income they will save for a 'rainy day'—a prudence effect. What Gollier shows is that this prudence effect lowers the discount rate, whereas the bigger is $\mu$, the higher the discount rate. Two effects now compete for an influence on the overall discount rate: the desire to 'smooth' fluctuations in income, and attitudes to risk.

In a situation in which economic growth rates are similar across time periods, the rationale for declining social optimal discount rates is driven by the preferences of the individuals in the economy, rather than expectations of growth. Gollier derives the conditions under which the discount rate declines under different assumptions concerning the likelihood of recession (negative growth). When it is assumed that there is no risk of recession, the discount rate will decline where individuals exhibit decreasing relative aversion to risk as wealth increases. Many studies have found empirical evidence to show that people have such preferences. For example, the share of wealth invested in risky assets increases with income in most developed countries. However, these observations are insufficient for the result to hold when the risk of recession is introduced. Indeed, the conditions on individual preferences required for the economy to exhibit discount rates which decline with time become increasingly complex, unintuitive, and empirically difficult to test.

In Gollier's approach, then, two important effects drive the level of the social discount rate: the wealth effect; and the prudence effect. These effects act in opposition to one another in determining the discount rate. When individuals in the economy are prudent (that is, their response to uncertainty is to save more), the wealth effect is offset, and the optimal discount rate is lowered. Gollier (2002b) recommends that, given growth is an uncertain phenomenon, the long-run discount rate should decline, due to the cumulative effects of risk over time. He goes on to recommend using the risk free rate for medium term horizons (5% in the case of France), dropping to 1.5% for costs and benefits that accrue in the very long run, e.g, 200 years.

## The thorny problem of time-inconsistency

The major advance in the theory of discounting is easily summarised. Once uncertainty about the future—whether about interest rates or economic prospects—is introduced, there are realistic situations in which the socially correct discount rate, to be used by governments in investment and policy appraisal, is one that declines with time. Not only is there a theoretical rationale for time-varying discount rates, but their practical use does much to overcome the 'tyranny' of discounting which is so widely noted by philosophers and environmentalists. But time-varying discount rates have their own problems and chief among them is 'time inconsistency'.

Time inconsistency, or 'incongruence', refers to a situation where plans that are made at one point in time are contradicted by later behaviour. The identification of this possibility is usually credited to Robert Strotz (1956). Time consistency requires that generation A chooses a policy, and generation B acts in accordance with it. Generation B does not revise what generation A planned. If generation A's plans are revised by generation B, then generation A will not have optimised its behaviour— what it intended for generation B will turn out to have been wrong. So, as fast as time-declining discount rates solve the 'tyranny' issue, they create another problem.

But how serious is time inconsistency? Henderson and Bateman (1995) see the process of changing the discount rate as time moves on as legitimate. People, they say, do not see themselves living in absolute, but in relative time. Revising and re-evaluating plans as time moves on is consistent with psychological and behavioural studies, and with the value judgment that what ought to be done by way of discounting should reflect what people actually prefer. If we should not expect individuals to behave consistently, we should not expect it of societies—the general theory of preference aggregation shows that societies usually satisfy weaker rationality conditions than individuals. Heal (1998) therefore argues that from a social choice perspective, time consistency is a "most unnatural requirement".

Unless government can make a once-and-for-all self-binding commitment to a policy rule, private sector agents will expect government to re-optimise at later dates. In other words, private sector agents anticipate that government will deviate from the policy rule even in the absence of external shocks to the economy. When faced with such dynamic inconsistency, a government without a commitment mechanism can formulate policy in a 'naïve' or 'sophisticated' manner. The 'naïve' government behaves as though it is unaware of its time-inconsistent preferences, while the 'sophisticated' government is aware. Neither situation is satisfactory. The sophisticated government takes into account the fact that private agents will anticipate the government's incentive to deviate from its optimal (committed) policy, and must therefore formulate policy which is less than optimal. In other words, the government makes policy, which is the best response to successive governments' best responses. For the 'naïve' government, which presses ahead regardless with dynamically inconsistent policy, the consequences might be particularly severe. For instance, Hepburn (2003) shows that a naïve government employing a hyperbolic (declining) discount rate in the management of a renewable resource may unwittingly manage the resource into extinction. Time inconsistency does seem to matter.

There is no easy resolution of this issue. Heal (1998) proves that almost all types of declining discount rates result in time-inconsistency, so the problem is not easy to avoid. As a practical matter, however, the dynamic inconsistency inherent in declining discount rates may not be any more troubling than policy inconsistencies and changes that are prompted by external shocks or political shifts. At the end of the day, few, if any, policies are 'optimal' in an unqualified sense.

## Social choice and declining discount rates

So far, several rationales for declining discount rates have been advanced. Since people do appear to discount the future at a non-constant rate, this empirical observation alone is sufficient to justify time-varying rates. But the Weitzman and Gollier arguments, based on uncertainty about key features of the economy, are perhaps more powerful still as rationales. Here we briefly outline yet another approach: the 'social choice' approach in which the inter-generational problem is confronted head on. Rather than arguing that time-varying discount rates have their own rationale, and that this happens to help overcome the 'tyranny of the present' issue, the social choice approach simply says that such tyranny is not acceptable and that the discount rate issue should be determined by specific axioms that make tyranny impossible. The contributions of Chichilnisky (1996), and Li and Löfgren (2000), while different in approach, show that a declining discount rate (more specifically, the $\rho$ in the Ramsey equation above) is consistent with a rule whereby current (future) generations must always take into account the well-being of future (current) generations; there must be no 'dictatorship' of one generation over another. In the Chichilnisky approach, present-day decision-makers adopt a mixed goal: maximising the discounted value of net benefits, and a 'sustainability' requirement that effectively amounts to a requirement to consider future generations' well-being. The Li and Löfgren approach assumes that society consists of two individuals, a utilitarian and a conservationist, each of which makes decisions over the inter-temporal allocation of resources. The important difference between these two decision-makers is that they are assumed to discount future utilities at different rates: the utilitarian discounting at a higher rate than the conservationist who may, for example, have a zero discount rate. What generate the time-declining discount rate from this situation are (a) the fact that there are two different discount rates, and (b) the weights to be attached to the conservationist and the utilitarian, i.e. the degree of power that each has to influence the final outcome. In a manner that parallels the Weitzman result, the long-run discount rate for society as a whole tends towards the lowest discount rate held by any party, in this case the conservationist.

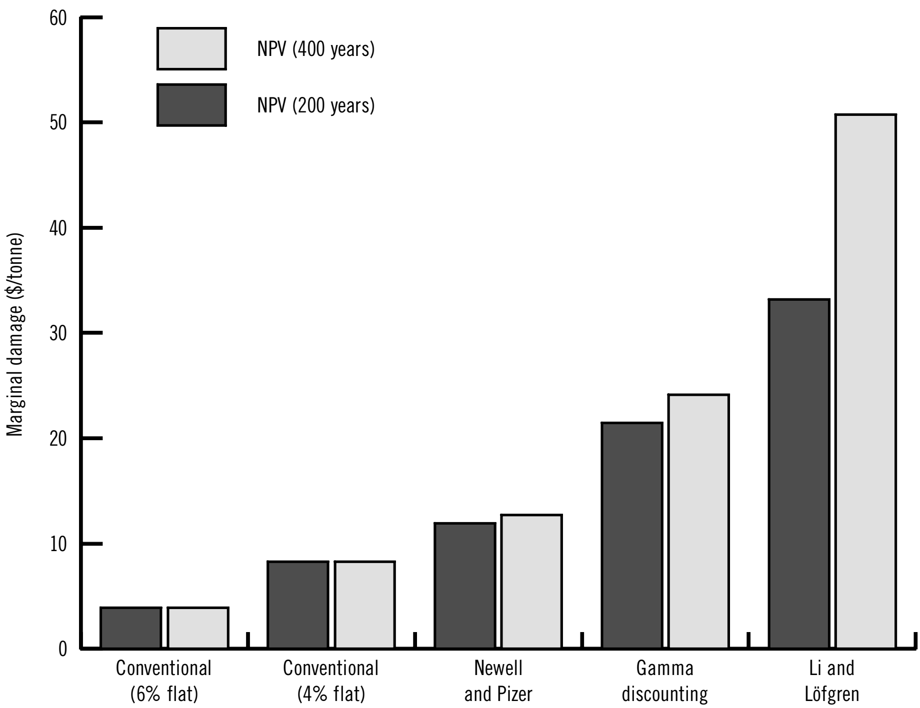
## Some practical implications of time-varying discount rates

While academics are often criticised for producing 'policy-irrelevant' research, few theoretical advances have greater practical relevance than the literature we have reviewed (for a technical review see OXERA, 2002). Policy-makers have long been uneasy about the effects of positive discounting on decisions. By and large, the effects did not matter too much as long as the problems being addressed by policy did not have very long-term consequences, or as long as the distant future was not regarded as being a legitimate concern of policy. Perhaps the only context causing concern in the past was forestry where, however hard foresters tried, the economics of afforestation in the UK never passed a cost–benefit test. Two events have combined to change this situation. First, many modern-day problems do have a distant future feature: e.g. global warming, stratospheric ozone depletion, loss of biological diversity, decommissioning of nuclear power plants, storage of nuclear waste. Second, governments and international organisations have become more sensitive to the effects of their decisions on the state of the world likely to be inherited by our descendants. This shows up in (admittedly ambiguous) goals such as 'sustainable development' and the espousal of rules-of-thumb such as the 'precautionary principle'. Conventional practice on discounting sits more than uneasily with these changed goals and changed problems. Time-varying discount rates are potentially therefore very important, and it is a tribute to the UK Government that it has quickly acknowledged the power of the arguments for time-varying rates, as it has done in its official guidance to Ministries on the appraisal of investments and policies (HM Treasury, 2003).

To illustrate just how important the implications of time-varying rates are, we consider two related issues: the 'price' of carbon, and nuclear power.

The social cost, or 'price' of carbon is an estimate of the present monetary value of damage done by anthropogenic carbon dioxide emissions. The UK has an 'official' value of this shadow price (Clarkson and Deyes, 2002) at £70 per tC, although the validity of the number if disputed (Pearce, 2003), and the official value is under review at the time of writing. Self-evidently, higher values of the social cost of carbon imply that investment in climate change mitigation is more attractive since policy aims at reducing damages. The discounting framework employed has a significant impact upon such estimates. It is obvious, for instance, that a lower (constant) discount rate will increase the present value of the marginal damage from emissions. As already noted, the marginal damage values from the Fund 1.6 model (Tol 1999) increase from \$20/tC to \$42/tC to \$109/tC, as the discount rate declines from rates of 5% to 3% to 1% respectively. If it costs, at the margin, less than £70/ tC to control global warming in line with the Kyoto Protocol, then a cost–benefit test requires that the damage avoided by greater than £70/tC. If the UK 'official' damage figure is correct, the UK's ratification of the Kyoto Protocol (via the European Union) passes a cost–benefit test. If, as others suggest, the relevant marginal damage figure is much lower, it may not. Clearly, for a government

**Figure 1: Discounted marginal damage of carbon emissions**




such as that of the UK, which believes in both the Kyoto Protocol and cost–benefit analysis, the answer matters.

Figure 1 shows what happens to the estimates of marginal damage under time-varying discount rates. Self-evidently, compared to a constant rate, time-varying rates will increase the level of damage (and hence the benefit from controlling warming). Figure 1 shows that the present value rises from just a few dollars per tonne carbon at conventional discounting (4% and 6%), to about twice or more under the Weitzman approach (following Newell and Pizer, 2001, and Weitzman's gamma discounting (Weitzman, 2001)). If the Li and Löfgren approach is adopted, damages could be around an order of magnitude higher than if conventional constant-rate discounting is used.

Clearly, time-varying discounting could transform the cost–benefit outcome in any analysis of global warming control. Given that cost–benefit approaches certainly had some influence on President Bush Jr in his decision to withdraw from the Kyoto Protocol, the numbers matter.

Our second illustration is nuclear power. Currently, the financial aspects of nuclear power are not conducive to an assured future in European countries at least. It simply does not compete with other fuel cycles. Environmentalists generally regard the environmental impacts of nuclear power as being additionally unacceptable, even though those problems tend to be long-term in nature and hence heavily influenced by positive discounting—permanent waste disposal and decommissioning for example. But nuclear power has some positive environmental attributes. It is carbon-free and also does not emit other more conventional pollutants such as sulphur oxides and particulates. In a socially efficient energy policy, fossil fuel cycles would be taxed according to the ‘externality’ (the uncompensated environmental damage) they generate. This can be turned on its head to argue that nuclear power deserves a credit for being carbon-free.

Time-varying discount rates affect the economics of nuclear power in several ways. First, decommissioning costs, which usually make little or no difference to financial appraisals, suddenly become important. Second, and offsetting this, any carbon credit given to nuclear power is greatly increased if time-declining rates are used. Third, there is an effect on the present value of revenue streams. Table 2 shows the results for different time-varying discount rates.

Our calculations suggest that under a constant discount rate of 6%, present value decommissioning and waste costs are a mere £90/kW. However, under a Li and Löfgren approach, decommissioning costs could rise to

**Table 2: Effects of time-declining discount rates on nuclear power costs and revenues**

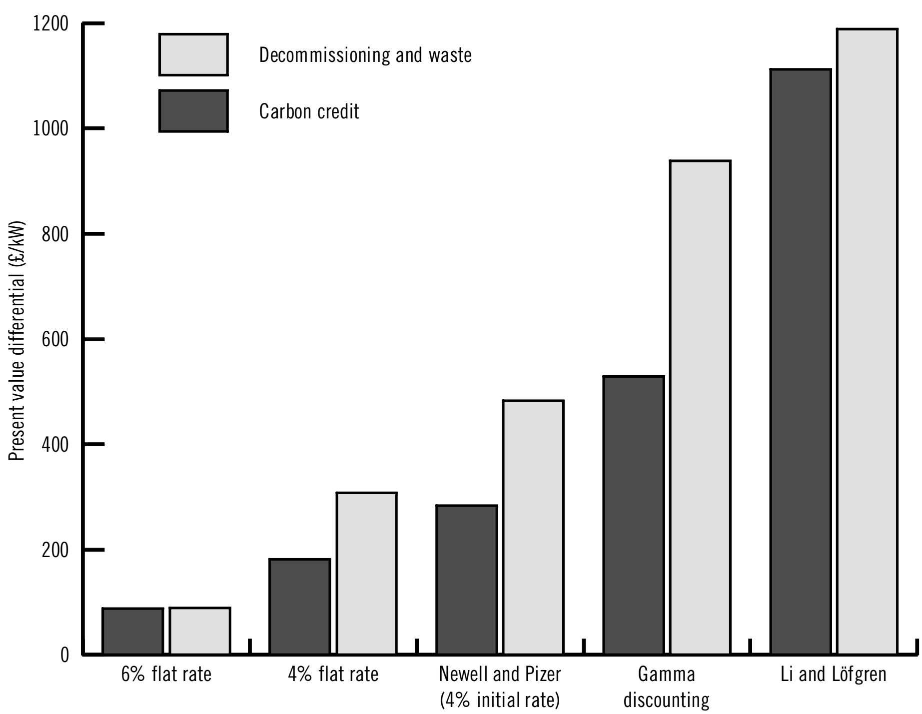
| Present value (£/kW) | 6% flat rate | 4% flat rate | Newell and Pizer (4% initial rate) | Gamma discounting | Li and Löfgren |
|---|---|---|---|---|---|
| Revenues | 2,530 | 3,670 | 3,770 | 4,340 | 3,850 |
| Carbon Credit | 90 | 180 | 280 | 530 | 1,110 |
| Capex | –2,050 | –2,150 | –2,150 | –2,150 | –2,120 |
| Opex | –1,450 | –2,110 | –2,170 | –2,500 | –2,220 |
| Decommissioning and wastes | –90 | –310 | –480 | –940 | –1,190 |
| Net Present Value | –980 | –720 | –750 | –720 | –560 |

£1,190/kW. At this level, decommissioning and waste costs are a major determinant of the economic viability of nuclear power and can no longer be relegated to the realm of politics.

However, the news for nuclear power is not all bad. Calculations show that the implicit carbon credit for nuclear power also increases under declining discount rates, partially offsetting the rise in present value decommissioning costs. As Figure 2 illustrates, however, the net result of these two effects is to reduce the competitiveness of nuclear power. The third effect—the increase in the present value of revenue—is also positive and quite large. However, it should be remembered that competing forms of electricity generation with long operating lives will also benefit from this positive revenue effect.

Declining discount rates, then, appear to be another small blow to competitiveness of nuclear power, despite the effect of an increased the carbon credit. With a higher social cost of carbon, though, the scales could tip back

**Figure 2: Nuclear fuel value differential**



the other way. Irrespective, the *economic* noose around the nuclear industry's neck will become the high costs of dealing with decommissioning and waste.

## Conclusions

Recent advances in the economic theory of discounting have potentially extremely important implications for policy on energy and on the environment. Whereas the conventional view has always been that there is a unique social discount rate—the value of which has been disputed over thirty years or so of debate—new work suggests powerful reasons why the discount rate is not a single number, but a number that varies in a declining fashion with time. This result emerges from several approaches: from an analysis of how people actually discount the future (hyperbolic discounting); from the implications of uncertainty about the future (the Weitzman and Gollier approaches); and from an explicit attempt to replace the traditional 'present value' maximand of policy appraisal with one that incorporates that goal along with a sustainability requirement. That any one of these approaches could be wrong cannot be doubted, but it seems unlikely that all three arguments can be rejected. Moreover, there is a 'political' argument in favour of the acceptance of time-varying discount rates: in one swoop they help to resolve the long standing tension between those who believe the distant future matters and those who want to continue discounting the future in the traditional way.

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