<u>In Defence of sensible economics</u>

Uncertainty in climate and in the Stern Report

Michel Armatte provides an excellent and learned overview of the development of modeling in the area of climate change. Armatte is quite critical of the role of conventional economics in integrated assessments of large scale, risky issues such as climate change. While I share many of his concerns and agree with many of his points, I would lean somewhat in the other direction. As suggested by the title of this paper, I believe that economic models can help clarify some of the very difficult ethical and philosophical issues involved, at least if done sensibly.

One key phenomenon that has been the subject of much discussion in this area is the degree of uncertainty and the handling of this uncertainty. Although it should also be said, at the outset, that quite a few things are fairly certain: There is with reasonable certainty, an anthropogenic increase in the natural level of radiative forcing which is gradually leading to an increase in average global temperatures. The rate of warming that corresponds to any given increase in greenhouse gases is however quite uncertain, and the biological and other effects of this warming even more so. The highest degree of uncertainty concerns the economic costs of this human induced climate change.

In the Stern Review (Stern 2006) – and even more so in the debate that the review has sparked- there is a very wide range of costs of climate change. Some of this uncertainty is due to bio-geophysical uncertainties. These uncertainties build in part on physical feedback effects such as for instance the possible release of giant amounts of methane that is currently trapped in permafrost. As climate change thaws the permafrost, it may lead to the release of the methane which would positively reinforce the warming itself in a form of vicious circle. Similar mechanisms and uncertainties pertain to the changing albedo of Earth, particularly as ice-caps melt, changes in cloud formation, biological feedback mechanisms and so forth.

In the face of all these natural science uncertainties, it is a striking fact that the biggest source of uncertainty in this kind of integrated assessment actually comes from the discount rate. The reason for this is of course that virtually all the costs being discussed will occur far into the future and thus they must be discounted.

Discounting but also relative prices

Discounting builds on the simple fact that money earns interest. In a growing economy, an investment of say 100 units will in general be expected to give a return such that the accumulated value of the capital invested plus dividends grows exponentially. With a real interest rate of 6%, (we assume zero inflation here) the capital will have increased to 106 units after one year. For this reason we say that a cost of 106 units in one years time is equivalent to 100 units today.

The rest is arithmetic – but powerful nonetheless. Capital will double within 12 years and multiply more than 300 times in a century. Discounting in its simplest form can be thought of as the inverse of this growth. Thus the value of a cost of one billion USD in 500 years with 6% discounting would be 0.02 cents today. Not only is this clearly insignificant but there are alarming details such as the apparent non-linearity of the effects. If we had used a 5% discount instead the value of the billion $ would have been 2 cents instead. Still insignificant but still we should note that the difference between a 5 and a 6% discount rate can change the present value, as in this case, by a factor one hundred. This should clearly drive home the point that this is an area where we need to be quite careful.

Discounting appears to remove the concerns raised by environmentalists concerning future environmental damages caused by activities today. For some people this motivates a rejection of the concept of discounting or of Cost Benefit Analysis in general. In my view this is throwing out the baby with the bathwater. Instead we should think carefully about two issues. First of all: is growth possible for many hundreds of years? Such growth is the fundamental mechanism behind discounting and hence a necessary requirement for discounting. A second – and as I will show, somewhat related, thought is if there are counteracting forces. One such possibility is of course changes in prices over time. Suppose we are interested in a correct economic valuation today of a future cost of V at a time t years hence. If we agree to the principle of discounting we might still argue that the costs will follow the formula (1)

$$V_t = V_0(1+r)^{-t}(1+p)^t \qquad (1)$$

In this formula we see clearly the possibility that the effect of discounting could be counteracted by changes in relative price, if we had reason to believe that the object in question would be appreciating rapidly in value.

The effect of relative prices could be as big as that of discounting! We turn now to the issue of when and if this may be a reasonable assumption. We will start by a general speculative discussion before coming to a more formal argument.

What will the future look like?

Ultimately this is a matter of what view we have of the distant future. In normal projects that only concern a few years, these issues do not necessarily surface with such intensity but when we speak of problems that will unfold over centuries we need to go back to first principles. With 3% growth we would be twice as rich in 24 years and almost 20 times as rich in a century. We need to reflect on what this would mean? Would we really be consuming 20 times as much of all the goods and services? Do we today consume 20 times as much of all goods and services as we did a hundred years ago? It is immediately clear that there are some exceptions such as food. We do not eat twenty times as much food (although our consumption of meat has increased which does mean that the indirect amount of acreage appropriated – through pasture etc. - has increased more than we might think). I will argue that there are many fundamental changes to our consumption basket.

When will everyone have a maid?

Let us take the example of domestic labour and other personal assistants, maids, servants, errand boys and private secretaries. A hundred years ago I estimate that some 5% of the population in European metropolies such as London or Paris had a maid and often a number of other personal employees such as gardeners, secretaries, chauffeurs etc etc (I will use the word "maids" as shorthand for all of the above). Since then incomes have been rising rapidly and today the middle classes comprising up to maybe half the population have in many ways attained incomes and living standards that only the richest had around the turn of the past century (1900). "Even" for the working class, for factory workers, carpenters or nurses it is not exceptional to be able to afford vacations abroad, cars or houses. The citation marks round the word even do not indicate any value judgment by the author but they are there to remind the reader just how unthinkable this big increase in consumption and living standard was in the nineteenth century – and still is in low income countries today).So consumption has soared - yet the number of people who have maids has probably decreased quite significantly. All this is well known and appears trivial but I want to dwell on the mechanism so that we can learn from it for the future.

There may in fact be several factors at play. The idea of having maids may be "out of date". There may be changes in preferences that are related to historical and social circumstances but in my understanding the main mechanism, why the "consumption" of maids does not go up when income goes up, is simply one of relative price: the cost of maids is going up at least as fast as incomes are! The example is chosen to be clear and pedagogical because of course the "price" to the buyer is almost exactly equivalent to the "income" of the maid. Assuming that the income distribution is unchanged then the price of (domestic) labour would be rising exactly at the speed of the general increase in incomes. If anything the past century saw some decrease in inequality. This (together with other factors such as tax wedges created by an increasing public sector, social security etc) probably implied that the price of maids increased faster than average incomes explaining a decline rather than an increase in the extent of domestic services[1].

The value of food

A further illustration of the importance of relative prices is afforded by considering the value of food. According to the statistics cited in the Stern Review the share of the agricultural sector in GPD for the World as a whole is about 24%. This figure builds of course on marginal cost pricing and we can use it to calculate the value of a very small increase or decrease in the sector. Suppose we loose 1% of the produce say next year. The loss could very approximately be calculated as one percent of 24% - ie 0.024% of World GDP.

Now assume we loose 95% of World Agriculture. Using the same method of calculation we would get 0.95*0.24 = 23 % GDP. This is just about as much nonsense as the idea that everyone in a society could have a maid – and for the same reason, that we have again neglected the role of relative prices. A situation in which we really did loose 95 of World agriculture would be an unprecendet disaster and calamity leading to gigantic strife and suffering and most likely war. A cool headed economist would say that the price of the remaining food would rise so fast that this – now very small physical amount of food – would be worth more than all the food before and would in fact come to occupy virtually the whole of "GDP" in that situation.

Future ecosystem scarcities

[1] Furthermore some private goods have emerged that are "substitutes" for domestic labour . such as "fast food". Also some "domestic services" have been professionalized and are provided by public agencies or private firms (pre-school care, dry cleaners).

As we look into the future, we have in fact little exact knowledge but from the IPCC we now that there are a considerable number of ecosystems threatened to an extent which depends largely on the extent of radiative forcing – or in other words the total quantity of green house gases emitted. Among the more obvious or direct are the change in temperature which in turn will cause changes in precipitation, melting of snow and ice and storm patterns.

There is already quite a visible trend towards winters without snow which will reduce the opportunity for skiing for those who enjoy – or live off – this and other winter sports. The industry strives to survive by making "artificial" snow by freezing water from lakes or other sources. This is done on a large scale – it is reportedly one of the biggest cost items for some ski resorts in Sweden – using much more electricity than the lifts and incurring costs that approach a third of the income of some resorts. Even as far North as in Piteå – on the Arctic Circle, artificial snow is made to keep the skiers happy! More seriously, it is also virtually certain that a majority of coral reefs will disappear. This is not only a tragedy for beauty, recreation and tourism but also for storm protection, biodiversity and fish production. Furthermore the changes in climate are likely to negatively affect water availability in Africa through increased drought making agriculture virtually impossible in large parts of the continent and in Asia through the disappearance of glaciers that regulate flow in the major rivers supplying large parts of India, Bangladesh and China with water.

The effects mentioned concern primary biogeophysical systems that regulate the conditions on Earth that are vital for human life. They are not "goods" in any ordinary sense of the word. If anything they are factors of production or common pool resources – sometimes producing what we term as "ecosystem services" to humanity. We need therefore to use the word "price" carefully. In many cases there are no prices (indeed the lack of pricing for carbon dioxide disposal in the atmosphere can be seen as a root cause of the problem). On the other hand it is also clear that we are facing an increased scarcity and in this sense a number of shadow "values" are or sould be increasing.

The Ramsey Rule generalized to two sectors

To be more formal, the derivation of discounting in simple economic textbooks usually builds on a model of intertemporal optimization of the type

$W = \int_0^T e^{-\rho t} U(C(t))dt$ where $C(t)$ is consumption at time t and U a measure of utility. The tradeoffs between consumption at different points of time are given by two factors: the "utility discount rate" ρ, and by the concavity of the utility function U which measures "inequality aversion": In a situation with economic growth, the future is thus given lower weight the more concave U is.

With a concave utility function, *U'* is declining over time when consumption is growing, so that both terms in this expression are positive for this case. It is often assumed that the utility function has the simple form (1)

(1) $U(C) = \frac{1}{1-\alpha} C^{1-\alpha}$ for $\alpha > 0$ and $U(C) = LnC$ for $\alpha = 1$.

This specification has the advantage that the elasticity of utility with respect to consumption is constant. In this case, the appropriate discount rate r is (2) often called the "Ramsey" rate:

(2) $$r(t) = \rho + \alpha g_C(t)$$

where $g_C(t)$ is the growth rate of consumption. This discount rate will be constant over time if and only if the growth rate is constant. If we believe that growth rates will fall due to "limits to growth" then discount rates would also fall over time, see for instance Azar & Sterner (1996).

In the debate on limits to growth and sustainability, the "pessimists" assert that eternal growth is "obviously" impossible due to limited resources on a finite planet. However "optimists" (to which economists nowadays regularly belong) point to technology and new sectors as sources of growth. Clearly communication and computing are two examples of phenomenal economic growth that use few scarce natural resources.

This author would thus tend to reject the notion of limited economic growth. But, on the other hand, the arguments about a finite globe obviously carry some weight and if future growth is concentrated only to some sectors (that use little or no material resources) while others have constant (or even diminishing) levels then this growth implies a changing output composition and presumably rising prices in the sectors that do not grow. This brings us to the heart of the subject matter of this paper.

If discounting, and hence growth, is essential for the valuation of future damage to environmental systems and if this growth will be highly differential between sectors then this should be modelled explicitly. Let us build a two sector model with E to represent some aggregate measure of the environmental quality in society, while C is an aggregate measure of all other goods. The utility function (1) will be replaced by U=U(C,E) and we keep the constant elasticity of utility formulation from (1) but insert a constant elasticity of substitution (CES) kernel to account for the interaction between C and E. This gives us the utility function (3) where σ is the elasticity of substitution.

(3) $$U(C,E)=\frac{1}{1-\alpha}\left[(1-\gamma)C^{1-\frac{1}{\sigma}}+\gamma E^{1-\frac{1}{\sigma}}\right]^{\frac{(1-\alpha)\sigma}{\sigma-1}}$$

Going through the exact analog to the traditional procedure outlined above, the discount rate r is changed from (2) to (4), See Hoel & Sterner (2007) or Guesnerie (2004) or a more general analysis in Gollier (2008).

(4) $$r=\rho+\left[(1-\gamma^*)\alpha+\gamma^*\frac{1}{\sigma}\right]g_C+\left[\gamma^*\left(\alpha-\frac{1}{\sigma}\right)\right]g_E$$

It will be readily appreciated that (4) is a generalisation of (2) with the two sectors growing at growth rates g_C and g_E. The discount rate still depends (as before) on the pure rate of time preferences ρ but now on a weighted average of the two growth rates. The weighting depends on the elasticity of substitution and on γ^* which can be interpreted as the "value share of environmental quality". (The share of their total consumption expenditures consumers would use on environmental quality if environmental quality was a good that could be purchased in the same manner as other consumption goods).

Notice that the two discount rates coincide if either $\gamma^*=0$ or $g_C = g_E$ (which basically means that there is no separate environmental sector) or in a number of other circumstances, for instance if the elasticities of utility and substitution are unitary. Otherwise the discount rate can be either higher or lower. For the reasonable case of $g_C > g_E$ and limited substitution (4) gives a lower interest rate than if $\alpha\sigma > 1$. Notice also that if $\sigma \neq 1$ and $\alpha\sigma \neq 1$ the discount rate will not be constant over time even if the growth rates for *C* and *E* are constant (since γ^* changes over time when $\sigma \neq 1$).

As argued earlier, to calculate the future value of a change in environmental quality we must consider both discounting and the change in the relative price (or valuation) of the environmental quality. The valuation of the environmental good is given by U_E/U_C. This fraction tells us by how much current consumption must increase to just offset a deterioration in current environmental quality of one unit (i.e. to make current utility or wellbeing the same before and after the change in environmental quality and consumption). The relative change in this price, is given by (5)

(5) $$p = \frac{\frac{d}{dt}\left(\frac{U_E}{U_C}\right)}{\left(\frac{U_E}{U_C}\right)} = \frac{1}{\sigma}(g_C - g_E)$$

This price change will depend on the development over time of the two sectors in the economy C and E. The price change is positive provided consumption increases relative to environmental quality over time, and is larger the smaller is the elasticity of substitution. If e.g. the environmental quality is constant and consumption increases by 2.5% a year, and the elasticity of substitution is 0.5, this price will increase by a yearly rate of 5%.

The relative price effect will normally counteract the effect of discounting. The combined effect of discounting and the relative price increase of environmental goods is given by r-p. If both r and p are positive, the sign of the combined effect is ambiguous.

The effect of relative prices for Integrated Assessment of Climate Damage

The Stern Review led to a heated debate with quite a large number of critical articles, (see e.g., Dasgupta (2006), Nordhaus (2007), Weitzman (2007a), Yohe (2006)). Nordhaus is generally considered one of the most prominent climate modelers and his model DICE, has to some extent acquired the status of being the "standard" Integrated Assessment Model (IAM). The Stern Review has been accused by Nordhaus among others of acquiring its radical results merely through the artifact of using low discount rates. Nordhaus (2007) uses the DICE model to reproduce results that are quite similar to those of the Stern Review – and quite different to those Nordhaus normally presents – simply by changing the discount rate used in the DICE model.

The issues of which discount rate to use is particularly complex – and depends significantly on the context in which it is to be used. I will not enter into the whole debate here but keep to the subject matter of this paper by saying that if a relatively high rate is chosen – such as those preferred by Nordhaus, then this builds on the notion of continued high economic growth and remembering that we are dealing in this case with a time horizon of several centuries, our point is that this we must take into account that such growth would only be possible in some sectors. Other sectors will not grow and some are doomed to decline – in particular because of climate change. This will imply significant changes in relative prices that ought to be taken into account.

Sterner and Persson (2008) carry out such an analysis by slightly modifying Norhaus DICE model to contain two sectors. They amend the DICE model so that utility is dependent not only on material consumption goods, but also on environmental goods that are assumed to account initially for ten percent of utility. The environmental sector is assumed to have no inherent growth but services from it are lowered through climate damage (the damage function is assumed to be quadratic in temperature). The authors show that this alternative approach - that builds on the same high discount rates as in Nordhaus - still yields results that are broadly in line with those of the Stern Review.

Summary and Discussion

The use of Cost Benefit Analysis for such large, long-run and irreversible changes as Climate change has been criticized on several grounds – among other things that it is too partial an approach. One vital sense in which it needs to be broadened is through the possibility that prices may change radically in the future. This paper tries to take as its starting point a realistic view of the future: that cannot be one of constant unwaivering growth – equal for all sectors. Both logic and historic evidence shows us that growth typically is concentrated to some sectors, determined by resource availability, technical innovations and the evolution of consumer preferences. Since discounting is so intimately tied to growth, we find that if sectoral growth is differential then discounting needs to be complemented with relative price change. This insight is not new (see for instance Krutilla), but Hoel and Sterner (2007) formalize it and show relative price change and discounting can be deduced from the same coherent two sector model framework. Sterner and Persson (2008) use this insight to discuss climate costs. Where Nordhaus (2007) criticizes the Stern Review for getting its high costs merely through the artifact of an arbitrarily low discount rate, Sterner and Persson (2008) show that very similar results can be obtained even with Nordhaus' higher discount rates if only due consideration is taken of the price appreciation of scarce ecosystem services that will be damaged by future climate change.

The future value of ecosystem services is of course very hard to know. It depends on the interplay of at least three different sets of factors:

- Technical parameters governing the development and interplay of ecosystem services
- Relative scarcity among sectors
- The evolution of preferences over time

The first of these hinges on scientific knowledge that is as yet far from complete and this uncertainty is for instance well analyzed by Weitzman in this book. This analysis leads to a separate and strong argument for precaution when it comes to potentially catastrophic effects of climate change. The second factor has been the topic of this article: the fact that sectors will grow at very different growth rates will lead – due to the very long time frame involved – to large changes in sectoral composition. Depending on the crucial nature of the elasticities of substitution between, the products and services from these different sectors, there may be considerable price effects. Finally there is a third factor in the list above which will also have an important – but separate – effect on these relative prices. That is our preferences (which may possibly evolve over time).

With rising income (and other societal changes over time) preferences for nature may change. It is quite often asserted that only the rich care for environmental "amenities" and that the income elasticity of environmental services thus is larger than one. Against this picture however, one may very well argue that it is the very poorest who are most dependent on environmental resources. If for instance the water goes bad on Manhattan then (most of) the citizens will simply switch to drinking something else while it is painfully clear just how big the welfare losses are of poor water in say Calcutta. This can be seen as an argument for a negative income elasticity of environmental services. My opinion is that both phenomena coexist. It is true on the one hand that people who have already secured the basic needs in life of food and protection, can turn a greater portion of their attention to environmental amenities such as scenic beauty, altruistic and existence values of rare species in distant countries etc. On the other hand it is also true that the poorest, who have little private capital, are the ones who are most heavily dependent on "public" capital in the shape of common pool resources that provide ecosystem services such as water, firewood, fodder, building materials, medicinal herbs, small game and so forth. They are simply different types of ecosystem service and the issue of whether poor or rich have the higher share of utility from "the" environment is partly a futile discussion that is better resolved by disaggregating "the" environment into separate parts.

It is true that income elasticity effects such as those discussed in the preceeding paragraph are important in general, and for relative prices of environmental services in particular. However, the effect discussed in this paper is conceptually a *separate* effect: The changes in relative price, that in our opinion , should be incorporated and that will dampen the effects of discounting, are *not* the effect of (changing) tastes over time or income – but the result of scarcity from the supply side. Irrespective of our preferences, the value of productive coral reefs, land and water will rise if these become scarcer in the future – as is at least quite likely to be the effect of climate change.

References

Arrow, KJ, WR Cline, K-G Mäler, m fl (1996), "Intertemporal Equity, Discounting, and economic Efficiency", i JP Bruce och and EF Haites (red), *Economic and Social Dimensions of Climate Change. Contribution of Working Group III to the Second Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge University Press, Cambridge, s 129-144.

Azar, C och T Sterner (1996), "Discounting and Distributional Considerations in the Context of Global Warming", Ecological Economics, vol 19, s 169-184.

Beckerman W och C Hepburn (2007), "Ethics of the Discount Rate in the Stern Review on the Economics of Climate Change", *World Economics*, vol 8, s 187-210.

Dasgupta, P (2006) "Comments on the Stern Review of the Economics of Climate Change", mimeo, University of Cambridge.

Frederick, S, G Loewenstein och T O'Donoghue (2002), "Time Discounting and Time Preference: A Critical Review", *Journal of Economic Literature*, vol 40, s 351-401.

Gollier, C., (2007), 'Comment intégrer le risque dans le calcul économique', *Revue d'économie politique*, 117(2) 209-223.

Guesnerie, R., (2004), 'Calcul économique et Développment Durable', *La Revue Economique*, Heal, G. (2008), "Climate Change Economics: A Meta-Review and Some Suggestions", http://www2.gsb.columbia.edu/faculty/gheal/Climate-Change-Review.pdf

Hoel, M. and T. Sterner (2007), 'Discounting and relative prices", *Climatic Change*, vol. 84, PP 265-280)

IPCC, (2007), *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, Parry M.L., O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson (eds.), Cambridge University Press, Cambridge, UK, 1000pp.

Nordhaus, WD (2007), "A Review of the Stern Review on the Economics of Climate Change", Journal of Economic Literature, vol 45, s 686-702.

Stern, N (2006), *The Economics of Climate Change: The Stern Review. Cambridge University Press, Cambridge*.

Sterner, T och UM Persson (2008), "An Even Sterner Review: Introducing Relative Prices into the Discounting Debate", Review of Environmental Economics and Policy, i tryck.

Weitzman, ML (2007), "A Review of the Stern Review on the Economics of Climate Change", Journal of Economic Literature, vol 45, s 703-724.

Weitzman, ML (2008), "On Modeling and Interpreting the Economics of Catastrophic Climate Change, mimeo Feb. 8 at www.economics.harvard.edu/faculty/weitzman/papers_weitzman

Yohe, G. (2006), Some thoughts on the damage estimates presented in the Stern Review—An Editorial, The Integrated Assessment Journal, Vol. 6, Iss. 3, Pp. 65–72