CHIPS
Climate Change Impacts and Policies in Heterogeneous Societies

New Welfare Metrics for a Comprehensive Assessment of Climate Impacts

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To guide climate policy and compute costs and benefits associated to specific plans, economists commonly use Integrated Assessment Models (IAMs), which are model combining descriptions of the economy and of the climate system. IAMs keep track of the evolution of the economy and the climate over time and across individuals. A social welfare function (SWF) is the part of the model that aggregates the well-being of different generations and individuals.

The SWF takes the role of society's value function. It can be used to rank different policy option. It is the tool that permits to aggregate costs and benefits of a policy, and thus compute a social cost of carbon. The SWF is also often the objective to be maximized when choosing a policy (at least in compact cost-benefit analysis models).

In this report, we review existing approaches to social welfare measurement in IAMs, and highlight some issues with the most common approach, namely the discounted utilitarian approach.

The prominent approach

Standard IAMs adopt a "discounted utilitarian" SWF, which gives an exponentially decreasing weight to individuals living in the future. Individuals derive utility only from a consumption variable that includes the value of nonmonetary climate impacts, measured in monetary equivalent. In most of these models, this discounted utilitarian SWF reads as follows:

$$\sum_t (1+\rho)^{-t} N_t u(c_t) \qquad (1)$$

where c_t is average per capita consumption in period t and N_t is total population size in period t. Function u is the utility function (transforming consumption levels into utility numbers) and ρ is the so-called `*utility discount rate*' or `rate of pure time preference'. The term $(1+\rho)^{-t}$ can be seen as a decreasing weight put on the utility of future generations.

Equation (1) is often further simplified by assuming that $u(c) = (c^{1-\eta} - 1)/(1-\eta)$. In that case, the η parameter measures how rapidly marginal utility decreases when consumption increases (the formula thus accepts that marginal utility is decreasing, a standard assumption in the utilitarian tradition).

This approach lays the foundation for the so-called "Ramey equation" that provides a value of the social discount rate:

$$\delta_t \approx \rho + \eta\, g_t \qquad (2)$$

where g_t is the average growth rate of consumption between the present period and period t.

The social discount rate is the tool used in economic cost-benefit analysis to aggregate costs and benefits occurring in different period in time. It is in particular used to compute the social cost of carbon, that is the implicit cost of emitting one additional of carbon (or sometimes CO2) in the atmosphere. In turn, the social cost of carbon plays a central role in setting climate policy: for instance, in an optimal equilibrium the carbon tax should be equal to the social cost of carbon.

The value of the social discount rate has given rise to heated debates in economics. This debate as famously been labelled the "Nordhaus-Stern debate", as the discount rate was described by Nordhaus (2007) as one of the main reasons for the different policy recommendations in his own work (Nordhaus 2008) and in the Stern report (Stern 2006). Nordhaus used the value $\delta = 5{,}5\%$ (with $\rho = 1{,}5\%$, $\eta = 2$ and $g = 2\%$), while Stern used the value $\delta = 1{,}4\%$ (with $\rho = 0{,}1\%$, $\eta = 1$ and $g = 1{,}3\%$). They actually had very different arguments for choosing these values: Nordhaus' approach was relying on evidence from interest rates (assuming that they represent equilibrium values for a representative agent), while Stern used ethical arguments.

Economists hold very diverse views regarding the value of the social discount rate (Drupp et al. 2018). In the next section, we discuss why there is so much heterogeneity. We also highlight other issues with the prominent approach.

Issues with the prominent approach and alternatives

Utility discounting

As revealed by the Nordhaus-Stern controversy, it is contentious to include a positive discount rate ρ in the social welfare function. The so-called "normative" or "prescriptive" approach endorsed by Stern argue in favour of near-zero utility discount rate. The line of argument is based on the principle of impartiality. This was hardly a new line of argument: it can be traced back to Sidgwick who argued that "[...] the time at which a man exists cannot affect the value of his happiness from a universal point of view" (Sidgwick 1907, p. 414).

This first approach is compatible with a possible rationale for discounting, which is that future generations may not exist. Several scholars have proposed to introduce an extinction risk (Dasgupta and Heal 1979; Stern 2006). In the utilitarian case, this risk provides a foundation for a utility discount rate $\boldsymbol{\delta}$ equal to the hazard rate of extinction.

This normative approach has faced several objections. A first line of argument in favour of a positive utility discount rate was provided by Koopmans (1960) who produced an influential axiomatization of discounted utilitarianism based on the Pareto principle combined with time consistency and invariance of social evaluation. From this initial contribution stemmed a very rich (but technical) literature showing the incompatibility between the Pareto and impartiality principles when one considers an infinite sequence of successive generations (Diamond 1965; Basu and Mitra 2003). However, this objection is still consistent with an arbitrarily small discount rate. And it assumes that a human population will exist for ever in the future, ignoring the possibility of an extinction mentioned before.

In another vein, Arrow (1999) argued that the present bias introduced by utility discounting is not only a mathematical necessity, related to the infinite horizon framework, but is also ethically justified, on the grounds that it reflects a permissible agent-relative preference for ourselves and our own projects. A similar form of agent-relative morality was defended by Dasgupta (2016) who proposed a form of generation-relative utilitarianism. One key intuition developed by Arrow and Dasgupta in favor of utility discounting is that it is not morally acceptable to demand excessively high savings rates of current generations: simple growth models with a value of δ close to zero typically imply very large savings rates. This drawback of undiscounted utilitarianism was also mentioned by John Rawls who declared that "the utilitarian doctrine may direct us to demand heavy sacrifices of the poorer generations for the sake of greater advantages for the later ones that are far better off"

(Rawls 1971, p. 253). The concern that undiscounted utilitarianism demands too large sacrifices from the current generation may however not be real: what matters for optimal savings is the whole consumption discount rate ρ_t, not simply the utility discount rate: reasonable levels of investments can be obtained in the undiscounted utilitarian framework if one chooses large enough values of η (see Asheim and Buchholz 2003).

Many economists have preferred to offer reasons for discounting that are not directly stated as ethical reasons. Some scholars have labelled approaches relying on these reasons as "descriptive" (see Arrow et al. 1996). They use a revealed preference argument: Most people do in fact discount their future utility, as revealed for instance by market interest rates; given that collective actions should be selected on the basis of aggregating individual preferences, a utility discount rate should reflect people's present bias (see Nordhaus 2007). Several objections can be made to the revealed preference argument. First, even if markets do aggregate preferences in some way they do so in a very specific way that may not be democratic. Indeed, the aggregation depends only the preferences of those people who are active on the market so that poorer people preferences are typically not represented. Furthermore, future people's interests and preferences are not represented (at least not directly: they may be partially represented only to the extent that current people care about them). Hence, even if the descriptive approaches do not explicitly take an ethical, they do implicitly rely on ethical assumptions (Caney 2014; Möllendorf 2014). These assumptions are broadly that only current generations, and among them mostly the wealthier people, may have a say on how to allocate goods between periods, even in the long term.

The many objections to arguments in favour of a strictly positive utility discount rate explain why the authors of the 5th Assessment report of the IPCC mention a "relative consensus in favor of $\delta = 0$" (Kolstad et al. 2014, p. 230). We believe that this consensus should guide approaches used within the CHIPS project.

Note also that several authors have argued that non-constant utility discounting should be used, one of the main arguments having to do with the uncertainty about the future or the aggregation of diverse normative views (Weitzman 2001; Gollier and Weitzman 2010; Arrow et al. 2013; Millner 2020). As we will not much consider issues of uncertainty in the CHIPS project, the assumption of a constant utility discount rate is a safe baseline hypothesis.

The 5th Assessment Report of the IPCC recommend a utility discount rate close to zero and proposes a range for inequality aversion between one and four

Inequality or risk aversion?

The second part of the Ramsey equation (2) has to do with the fact that future generations may be richer. It is the product of the growth rate of consumption, which is an empirical quantity (albeit a very uncertain one), with the elasticity parameter η. In the economic literature and in most presentations of the Ramsey rule, three main interpretations of this parameter have been offered (see for instance Greaves 2017).

It may represent:

- Individuals' relative risk aversion;
- Individuals' inverse elasticity of intertemporal substitution;
- society's aversion to inequality.

The choice of one of these interpretations is consequential. As highlighted in Atkinson et al. (2009), empirical estimates of these three quantities are usually very different, which may explain the very wide range of values found in the literature (from 1 to 3 or 4 according to Kolstad et al. 2014, p. 230). Although the economic literature mentions these three interpretations, it mainly presents them as three empirical strategies to calibrate η: however, they clearly have different ethical and policy interpretation.

The confusion between these different interpretations have yielded some economists to propose alternative welfare models disentangling the different types of aversions. Most work has been done in the literature on climate policy in the presence of risk. Several authors have used the Epstein-Zin procedure that aggregate recursively certain equivalent of future welfare, drawing on a proposal initial made by Kreps and Porteus (Epstein and Zin 1989; Kreps and Porteus 1978). Doing so, we can use calibrations of risk aversion to compute certainty equivalents and aggregate welfare across generation using elasticity of intertemporal substitution (or inequality aversion). This procedure has been used in influential papers (Crost and Traeger 2014; Jensen and Traeger 2014; Cai et al. 2016; Cai and Lontzek, 2019).

It should be noticed that the Epstein-Zin procedure is not the only one to disentangle inequality aversion and (social) risk aversion. Bommier et al. (2005), and Fleurbaey and Zuber (2015b) have proposed another formula taking the risk-averse expected value of intergenerational welfare and their application to discounting and climate policy. On the other hand, Adler and Treich (2015) and Adler et al. (2017) have proposed to use risk functions (VNM functions) has metrics of well-being and then transform them using a function embodying social inequality aversion: they propose ex ante and ex post versions of this procedure.

So far, we have assumed that there was only one coefficient of inequality aversion, which embodied an attitude to inequality in consumption across and within generations. But Schelling (1995) famously suggested that distance in time and distance in space might justify different degrees of receding priority. This suggests transforming the SWF to incorporate a different degree of inequality aversion within and across generations as proposed by Anthoff and Emmerling (2019). Similarly, one could want to disentangle inequality aversion within a country and inequality aversion between countries. But to be able to do so, we first need to model inequality within a generation.

Other issues

Including inequality

Both Eq. (1) and the Ramsey eq. (2) ignore within generation inequalities by focusing on average consumption. However, the question of how inequality affect the social discount rate and climate policy has been a long-standing issue in the literature.

One standard methodology to take inequality into account relies on *equity weights* when we compute the future costs and benefits of a policy (see Azar and Sterner 1996; Fankhauser et al. 1997; Anthoff et al. 2009 for applications to climate policy). In that case, we compute future impacts accounting for inequalities by weighting damages in a given country (or for a given period) according to the equity weight.

An alternative consists in directly using individual utilities and aggregate them to compute a measure of welfare at a given period in the future. The later approach actually encompasses the first one and give explicit formulas for equity weight in the case of marginal damages (Fleurbaey and Zuber 2015a). In the context of CHIPS project, we will prefer the later approach as already implemented in the NICE model (Dennig et al. 2015) or a modification of RICE by Anthof and Emmerling (2019).

Multiple goods

Both Eq. (1) and the Ramsey eq. (2) consider a single aggregate good, namely consumption. As explained by Greaves (2017), this is innocuous in principle. We can construct an aggregate consumption numbers that correspond to the indifference surfaces (determined by the individuals' utility function) of a specific bundle of goods. But this raises the issue of how such an aggregate number is constructed: basically, this is like constructing a comparable individual well-being metric and many approaches exist to do so (see Fleurbaey and Zuber forth).

There is a literature discussing the role of relative prices for discounting and the social cost of carbon, arguing that different commodities should be treated differently (Sterner and Persson 2008, Gollier 2010, Yamaguchi 2019). The focus on environmental commodities. Recent papers also include mortality to construct individual wellbeing functions (Fleurbaey et al. 2020). But other consideration may matter and be included in the list of goods, for instance relational aspects like relative consumption (Johansson-Stenman and Sterner 2015).

These multidimensional aspects will not be much explored in the CHIPS project.

The aggregation of utility

Beside the additive formula of utilitarianism exhibited in Equation (1), where individual numbers are simple added, many other forms for the social aggregation function have been proposed and studied. A prominent alternative defended is an additively separable formula that yields prioritarianism used by Adler and Treich (2015) and Adler et al. (2017).

Another prominent approach is Egalitarianism in its modified form of Maximin or Leximin as suggested by Rawls (1971). Tol (2013) proposed a social welfare function mixing the utilitarian approach with this egalitarian Rawlsian approach. In a similar vein, Zuber and Asheim (2012) have introduced a rank-dependent model that implies a relative priority to worst-off people, whose limits are utilitarianism on the one hand and Maximin on the other hand.

The economic literature has also provided several social criteria to aggregate individual welfare or advantage with the idea to promote a notion of sustainability. Chichilnisky (1996) proposed sustainable social preferences that combine a discounted sum of utilities and a long-run value. Dietz and Asheim (2012) introduced a sustainable discounted utilitarian criterion similar to discounted utilitarianism in the sustainable case where future generations are better-off than the current generation, but which is similar to Maximin case for unsustainable paths.

Last, Anthoff and Tol (2010) have explored different social welfare functions that regions (and not a social welfare planner) can use in climate models. Some of these functions can represent a bias towards people in its own region.

Some of these alternatives are difficult to implement in integrated assessment climate-economy models. But this review reveals a wide set of alternatives that could be explored for social welfare evaluation. They represent different ethical theories. They may be worth using in the CHIPS project.

Many social welfare approaches exist beyond the prominent utilitarian approach. They can represent different ethical theories.

Population size

Climate policy may change the size or the composition of the future population (it may influence patterns of fertility and mortality). Thus, social welfare function should incorporate population sizes, thereby raising issues of population ethics. Population ethics is known to raise difficult puzzles and no single approach has emerged that is consistent with all attractive intuitions (Millner 2012; Kolstad et al. 2014, p. 211). A broad divide is between theories that value population size even at the expense of average well-being (like Total Utilitarianism) and theories that regard average well-being as the most important aspect even if it implies reducing population size (like Average Utilitarianism).

A few papers a showed that population ethics can significantly modify our view on policy, especially in cases when we are not sure about the future population trajectory (Scovronick et al. 2017, Fleurbaey et al. 2020). Although this question is not central in the CHIPS project, it may be important to keep it in mind when designing welfare metrics in the context of climate change.).

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