Discounting and Intergenerational Ethics

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The question of social discounting is central in intertemporal cost-benefit analysis that often shapes economists' recommendations regarding climate policy. The practice of discounting has been the object of heated debates among economists and philosophers, revolving around the issue of intergenerational ethics. In this chapter, we review the different arguments for and against specific values of social discounting. We show that there are actually two different ethical issues at stake: 1) the question of impartiality (or equal treatment of all generations); 2) the question of priority to the worse-off (aversion to inequality in resources, capabilities or welfare). These questions have emerged in the utilitarian approach and can be neatly separated in that case. They also have very different consequences for climate policy. We then argue that the question of social discounting is not confined to the utilitarian framework as it more generally describes the social value of income (or capability or welfare) transfers to future generations. Lastly, we discuss the many limitations of social discounting as a tool for policy analysis.

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Introduction

The social discount rate is an important tool in intertemporal cost-benefit analyses used by economists to inform long-term policy choices, for instance mitigation policies aiming at reducing greenhouse gas emissions. The social discount rate is used to convert future monetary costs and benefits in present value. For instance, a rate of 2 % (=0,02) means that a project whose cost is $1,000,000 in 50 years has a present value of $1,000,000 / $(1+0,02)^{50} \approx$ $371,528 today. As illustrated by this simple example, even low discount rates can significantly reduce the value of future costs and benefits. Moreover, if the social discount rate is 3% the present value of the same project would be about $228,107, that is, two thirds of a the present value using the 2% rate. Hence, apparently small changes in the social discount rate have huge implications in terms of how we value future economic impacts.

As acknowledged in the last report of Working Group 3 of the IPCC (Intergovernmental Panel on Climate Change), "the use of a temporal discount rate has a crucial impact on the evaluation of mitigation policies and measures" (Kolstad et al. 2014, p. 211). The Working Group asserts that the appropriate risk-free social discount rate should be between one and three times the anticipated growth rate in real per capita GDP, but also underscores that these values are based on the so-called Ramsey rule and that ultimately there are normative choices to be made. In this chapter, we aim at presenting some of these normative choices. We also argue that one does not need to restrict attention to the Ramsey rule and that the discount rate is a general tool that can be applied in many ethical frameworks.

Heated discussions around specific values of the social discount rate have aroused after the publication of the Stern review's recommending strong action to reduce greenhouse gas emissions (Stern 2006). A key principle that was discussed was intergenerational equity and the discussion mostly relied on the Ramsey rule. In Section 1 of this chapter, we present the Ramsey rule and explain how it encompasses two different dimensions of equity: impartiality (the equal treatment of all generations) and preference for more equal distributions of resources. We explain why these two aspects can go in opposite directions. We also present the different positions in the debate that followed the Stern review.

The Ramsey rule emerged in the Utilitarian moral framework. In his seminal paper, Ramsey (1928) explicitly assumed that "enjoyments and sacrifices at different times can be calculated independently and added" (Ramsey, 1928, p. 543) and used a criterion that explicitly adds utilities across periods. An important question then could be whether social discounting is tied to an excessively narrow (e.g., utilitarian, economistic) ethical approach, or whether it can accommodate a variety of relevant principles and values. One thesis defended in this chapter is that,

while usual practice of discounting is indeed restricted to an unduly narrow ethical framework, the methodology itself is rather flexible. Still, it is part of a cost-benefit approach, which relies on a consequentialist axiology. Section 2 provides a general ethical framework in which discount rates may be obtained and we argue that this framework can encompass many moral views about who matters, how claims should be balanced, how advantages should be distributed, and how to measure individual advantage.

Despite its salience, the issue of discounting cannot be considered as the only important one in the evaluation of policies that affect future people (for instance, climate policies). We briefly recall why discount rates are theoretically relevant only for the analysis of marginal changes and can therefore not be used to assess abrupt regime shifts or existential risks. They are also not the right tool to use for choice that may affect the size or composition of the future population. Last, the discounting issue should also not obscure other important equity issues like the distribution of cost and benefits within generations. We present these limitations of social discounting in Section 3.

1 Discounting: definition in the utilitarian framework and equity issues

As explained in the introduction, the standard approach to determining the social discount rate is based on the *Ramsey equation*. The perspective adopted to derive this equation is that of a benevolent social planner (or sometimes a representative agent) that seeks to maximize a value function. Such a value function assigns a real number to each possible state of affairs, with better states of affairs being assigned a greater number. The standard approach typically describes states of affairs as streams of consumption for all future generations, with c_t the consumption of generation t (where $t = 0$ denotes the current generation), and the value function is given by[3]

$$V(c) = \sum_{t=0}^{\infty} e^{-\delta t}\, u(c_t)\,, \qquad (1)$$

where function u is the utility function (transforming consumption levels into utility numbers) and δ is the so-called `*utility discount rate*' or `rate of pure time

[3] We do not account for population size in this formula to simplify the exposition. We could more generally write utility as $u(N_t, c_t)$, with N_t the population size in period t. Typically, the total utilitarian approach takes $u(N_t, c_t) = N_t v\left({}^{c_t}/_{N_t}\right)$.

preference'. The term $e^{-\delta t}$ can be seen as a decreasing weight put on the utility of future generations.

Equation (1) is often further simplified by assuming that $u(c) = c^{1-\eta}/(1-\eta)$. 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).

The idea of social discounting consists in measuring the value of a small increase in consumption in period *t* as equal to the value of a small increase in consumption today, discounted by a factor $1/(1+\rho_t)^t$. The ρ_t parameter is the social discount rate. From the value function described in Equation (1), it can be derived from the Ramsey equation:

$$\rho_t = \delta + \eta g_t, \tag{2}$$

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

The Ramsey Equation (2) clearly distinguishes two reasons for discounting. One is pure time discounting expressed by parameter δ: we discount future consumption or future damages because we discount the welfare of future people. This first reason has given rise to a debate about intergenerational equity that could better be expressed as a debate about impartiality. The second part of the Ramsey equation combines the elasticity parameter η and the growth rate of consumption. This is "discounting for growth": given that future generations are richer when g_t is positive, their consumption has less priority. The rate of decrease in the value of future consumption is proportional to growth, and the proportionality parameter η represents the strength of the redistributive motive. A higher η represents a higher willingness to reduce consumption inequalities.

We now separately discuss these two rationales for discounting.

1.1 Discounting and intergenerational impartiality: "normative" and "positive" approaches

The main controversy in the economics of climate change was probably the Nordhaus-Stern debate that arose after the publication of the Stern review (Stern, 2006). The Stern review promoted a strong action to reduce greenhouse gas emissions, while Nordhaus promoted a gradual response (Nordhaus, 2008). As explained by Nordhaus himself (Nordhaus, 2007), a big part of the difference lies in using different values of the social discount rate: the Stern review is based on a 1.4% discount rate, while Nordhaus preferred a 5.5% discount rate. Part of the difference

is due to using a different value of the utility discount rate: Stern argued in favor of $\delta = 0.1\%$ while Nordhaus chose $\delta = 1.5\%$.

The line of argument used by Stern to justify his low value of the utility discount rate 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). Ramsey himself used the idea of impartiality to justify a zero-utility discount rate. In the end, Stern does not use a zero-utility discount rate but a very low rate to account for a small probability that future generations may not exist.[4] The impartiality argument is the main argument in favor of a zero or near-zero utility discount rate.[5]

Despite this strong impartiality argument, several authors have insisted that several reasons may explain a positive pure time discount rate. A first line of argument in favor 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 rationality and parsimony principles of 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; Zame, 2007; Lauwers, 2010).

One possible conclusion from this strand of literature would be that we cannot maintain the impartiality requirement in the intergenerational context because the Pareto principle is deemed to have more normative appeal. There are however several objections. A first objection is that it does not seem plausible that there will be infinitely many future generations, at least if we only consider generations of humans on Earth (there may exist other living species in other galaxies or worlds, but one may dispute whether they are morally relevant for us). A key problem then is that we do not know how many future generations there will be: we cannot plausibly specify a number of years until humans disappear. A well-known remedy has been proposed: to introduce an extinction (or existential) risk (Dasgupta and Heal, 1979; Stern, 2006). In the utilitarian case, this risk provides a foundation for a utility discount rate δ equal to the hazard rate of extinction as explained in footnote

[4] With this interpretation, the utility discount factor $e^{-\delta t}$ is the probability that the future generation of period t exists.

[5] Greaves (2017, p. 405) mentions another argument based on an extended Pareto principle. We believe that this argument, which involves a choice made an individual between existing today with some consumption level or living tomorrow with this same level, is not real realistic unless we consider a veil of ignorance context that actually serves to promote the impartiality principle.

2 (for a more general treatment, beyond the utilitarian case, see Fleurbaey and Zuber, 2015b).

Another objection is that violations of impartiality occur only because we want to have a value function that is able to rank and compare all situations. We may consider a less demanding moral theory based on *incomplete* criteria (that may not always say which situation is morally better). Several incomplete versions of utilitarianism – without utility discounting – have been proposed, in particular the overtaking criterion (Von Weizsäcker, 1965) and the Gale criterion (Gale, 1967). Last, let us underline that Koopmans' (1960) argument in favor of a positive value of δ does not provide any guidance about the exact value of this parameter. In principle, it could be as low as one wishes so that, for any practical purpose, we may just neglect this part of the Ramsey equation.

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 a large enough utility discount rate is that it is not morally acceptable to demand excessively high savings rates of any one generation: simple growth models with a value of δ close to zero typically imply a very large savings rate (see Mirrlees, 1967). This drawback of undiscounted utilitarianism was already 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). He went on to say that "these consequences can be to some degree corrected by discounting the welfare of those living in the future" (Rawls, 1971, p. 262). However, Rawls never argued in favor of discounted utilitarianism but simply wanted to point out a flaw of utilitarianism in the intergenerational context. The concern that utilitarianism may demand too large sacrifices from the current generation may also 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).

While the two previous lines of arguments against the zero-utility discount rate may be related to normative considerations, many economists have preferred to offer reasons that are not directly stated as ethical reasons. Some scholars have labelled approaches relying on these reasons as "descriptive" approaches (see Arrow et al., 1996) or "positivist" approaches (Posner and Weisbach, 2000). These

approaches mainly use a revealed preference argument.[6] Most people do in fact discount their future utility, as revealed for instance in 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. In particular, Nordhaus (2007) famously declared Stern's approach as undemocratic and depicted it as a situation where a utilitarian elite (epitomizing "the dying embers of the British empire") makes decisions based on its own rather than the population's belief. Several objections can be made to the revealed preference argument. First, even if markets do aggregate preferences in some way (provided markets are well-functioning) 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 and on their initial wealth, 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 stance on how advantages should be distributed across generations, they do implicitly rely on ethical assumptions. These assumptions are broadly that only current generations, and among them mostly the wealthier people or at least those who are active on markets, may have a say on how to allocate goods between periods, even in the long term.

The many objections to arguments in favor 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).

1.2 Discounting and aversion to intergenerational inequalities

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 clearly 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:

[6] Posner and Weisbach (2000) have a different "positivist" line of argument to choose the social discount rate (without reference to the Ramsey equation): an opportunity cost argument. We should never choose projects with returns lower than the market interest rate because otherwise we would incur a loss – we could have invested in a market fund and get a larger benefit in the future. But the identity between the social discount rate and the market rate is justified only in the very specific case where we are already at the economic optimum (so that no more investments are required). It also assumes that the maturity of the market investment is the same as that of the proposed policy, which is unlikely for very long term policies like climate policy. We have discussed this line of arguments in more details in Fleurbaey and Zuber (2013).

- Individuals' relative risk aversion;
- Individuals' inverse elasticity of intertemporal substitution;
- 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 value 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 rather than appealing to normative reasons to choose one of them. We would like to argue that they correspond to specific interpretations of the utilitarian formula (1), including non-utilitarian ones.

The two first interpretations (in terms of individuals' risk or temporal preferences) correspond to a specific view on utility, namely utility as preference satisfaction. Although this is the standard interpretation of utility in economic theory, this is not uncontroversial for utilitarians that may prefer a hedonistic interpretation, or definitions appealing to people' judgement on their own life. But even if one accepts the preference satisfaction definition of utility, it appears that one has to choose what preferences are relevant: risk preferences or instantaneous temporal preferences.

The use of risk preferences to measure utility has a long history in economics. Harsanyi (1953, 1953) famously provided two frameworks to justify a representation of utility by risk preferences. Harsanyi's (1953) *impartial observer theorem* assumes that, behind a veil of ignorance, individuals have extended preferences on prospects of outcomes and identities, so that they can compare welfare across outcomes and preferences. Harsanyi assumed that all deliberators behind the veil of ignorance will have the same extended preferences that are revealed by choices under uncertainty. Harsanyi's (1955) *aggregation theorem*, which involves the Pareto principle applied to risky situations, characterizes utilitarianism as a sum of Von Neumann-Morgenstern individual utilities.[7] Although they have attracted less attention, time preferences can give a foundation for individual utility by arguments similar to those in Harsanyi's (1955). Zuber (2011, Prop. 1) showed that when individual preference are time separable, social aggregation satisfying the Pareto principle must a sum of these utilities.

[7] Sen (1976) and Weymark (1991) argued that, while Harsanyi's theorem establishes that social welfare is a sum of VNM utilities, it does not follow that it is the sum of individuals' welfare levels. But this is beside the point of the theorem, whose potent message is that social evaluation must rely on a (weighted) sum of VNM utilities. See Fleurbaey and Mongin (2016) for further discussion.

Interestingly, both time and risk preferences have been used to construct welfare-like measures for the case of health. Indeed, QALYs (Quality Adjusted Life Years) that are widely used health measures are often calibrated using two methods (Drummond, Stoddart and Torrance, 1987): the standard gamble methodology (using risk preferences) and the time trade-off methodology (using time preferences).

The other prominent interpretation of the elasticity parameter η is that it controls social attitudes towards inequality (it is the coefficient of relative inequality aversion in the terminology used in economics). The foundation here may not be in terms of decreasing marginal utility of consumption, as in the standard utilitarian approach, but in terms of social priority for consumption of poorer people. Most empirical approaches to estimate this inequality aversion parameter are based on individuals' attitudes towards redistribution in stated-preference experiments (see, e.g., Atkinson et al. 2009) or on actual redistribution policies (see, e.g., Tol 2010). A method providing intuition about the inequality aversion parameter is the leaky bucket thought experiment (Okun 1975), where one has to declare how much one is willing to lose in a transfer of money from richer to poorer people. But some authors argue that in the intergenerational context, we should rather ground our moral intuitions in experiments concerning the saving rate (Dasgupta 2008).

In all cases, the parameter will control the marginal social value of consumption for any individual, depending on her initial consumption level. A larger value of η implies a greater priority for poorer people or poorer generations. Thus, a value function exhibiting "greater concerns for intergenerational inequality" (in the specific sense of inequality aversion with respect to consumption) typically exhibits a larger social discount rate.

We then end up with two similarly opposite effects of ethical principles of justice on the social discount rate. The principle of impartiality, discussed in 1.1, would require a very low level of δ (actually $\delta = 0$ if we do not account for a risk of extinction) and thus a low level of the discount rate. A principle of equality (or aversion to inequality), as applied to consumption levels in the discussion above, would require a high level of η and thus a high level of the discount rate, at least in the standard case where the consumption growth rate g_t is positive.[8] Of course, there is no direct logical connection between the principles of impartiality and

[8] See Equation (2). Of course, if $g_t < 0$, i.e., when future generations are poorer than current generations, more aversion to consumption inequality will decrease the social discount rate, possibly yielding a negative discount rate. This will also happen in a framework with uncertainty about future growth, provided that it is sufficiently likely that situations where $g_t < 0$ may happen (see Fleurbaey and Zuber, 2013).

equality, but one may expect that foundations of the social discount rate that are based on the idea of intergenerational justice will promote both a low value of δ and a high value of η.[9] All in all, one can conclude that there is no clear reason why intergenerational justice in general would promote high or low values of the social discount rate.

2 Discounting beyond utilitarianism

Discounting is not restricted to Utilitarianism. However, it still entails making strong ethical assumptions. Indeed, any notion of discounting is derived from the existence of a value function, whose general form can be as follows:

$$V = F(c_0, c_1, \dots, c_t, \dots), \tag{3}$$

where c_t is a vector of all "goods" that matter in period t and that can be discounted to compare with the value of good(s) in period 0.

The existence of a value function means that we are trying to assess and compare situations in terms of their goodness or, more accurately, their betterness. This is in contrast with ethical frameworks pertaining to the theory of the right or other approaches involving notions of harm, virtues or duties. Also, it means that we are primarily concerned with outcomes or consequences of actions. Therefore approaches for which discounting can be a relevant tool belongs to a broad class of maximizing consequentialist theories. Note however that some people who don't think that consequentialism is the only relevant ethical view may still think that consequences are part of the ethical considerations we should rely on. For instance, Broome (2012) argues public morality can focus on the pursuit of goodness while individuals can focus on avoiding actions that harm other (future) people, including by compensating potential harms through carbon offsetting. This division of labor can be debated but cost benefit analysis and thus discounting are important tool for coordinating the pursuit of the common good and thus pertain to axiological public morality. More generally, discounting may be relevant in an ethical theory that is not purely consequentialist: it is relevant only in so far as consequences are relevant.

Equation (3) is a very broad and general definition of the value function. It may include several "goods" or ethical dimensions that may range from human-centered individualistic and materialistic considerations (the amount and distribution of personal consumption goods in a population in a given period) to more holistic and

[9] And indeed, for instance, Dasgupta (2008) criticized the Stern report for using principles of intergenerational justice to justify a low value of δ without considering such principles when setting the value of η.

non-speciesist (we may include dimensions like the quality of social relations, the level of biodiversity and protection of other species in the list of goods). The key assumption made by Equation (3) is that these different goods are measurable as well as comparable: we can derive overall good from them (and thus implicitly trade-off the different dimensions).

With the general value function described in Equation (3), we cannot obtain a precise description of the main elements of the social discount rate. We will thus focus on a more specific value function encompassing many individualistic consequentialist ethical theories.

2.1 A general formula for individualistic consequentialist ethics

The more specific class of value functions we will focus on is described by the following formula:

$$V = W\left(\left(w(i,c_i)\right)_{i\in N_0}, \left(w(i,c_i)\right)_{i\in N_1}, \dots, \left(w(i,c_i)\right)_{i\in N_t}, \dots\right), \qquad (4)$$

where each c_i is a vector of "goods" available to person *i* and each person *i* belongs to a specific generation (N_t is the set of all individuals leaving in generation *t*; typically generation 0 is the current generation, but we may imagine that some past generation could be the "first" generation).[10] Function *w* is an individual advantage function that depends on the identity of each individual (therefore *w* depends on *i*) and on the consumption vector.

Formula (4) provides a very flexible framework to encompass many ethical theories. Different theories can be described as taking a stance on three different issues: the scope of justice (the population N_t of individuals included in each generation); the currency of justice (the individual advantage functions *w* and the goods included in the vectors c_i of personal goods); the shape of justice (the "aggregator function" *W* that combines and weighs the advantages of the different individuals).

The scope of justice: The question is to decide which entities are the legitimate recipients of burdens and benefits. Formally, in Equation (4) the question is to decide who is included in population N_t in each period. We may even ask whether population N_t should appear for $t > 0$. As suggested in "descriptive" approaches to

[10] There is an ambiguity in the economic literature with the notion of generation: usually economic models consider only time periods but name such periods a "generation". Most ethical theories would use indices of individual lifetime well-being to weigh the claims of different people, while in most applications only indices of momentary well-being appear. See Greaves (2017, p. 396) for a discussion of this matter.

social discounting, some may argue that only current generations can have legitimate claims and that future generations claim are taken into account only insofar as some people in current generation care about them. However, most approaches to climate ethics would include both current and future generations.

Within a period, one may then wonder whether we should include all persons irrespective of the country they belong to. Schelling (1995) famously suggested distance in space might justify different treatment of individuals and that we may care less about people in the far away countries. Again, the impartiality principle seems to prevent us for making a difference between individuals on the basis of where and when they live. But the literature about global justice and cosmopolitanism has produced (controversial) arguments to justify some bias against aliens in defining social priorities (Rawls 1999; Nagel 2005).

Then we could also argue that the scope of justice includes not only humans but also nonhuman animals or even other nonhuman species. For instance, climate change is an important stressor for biodiversity so that it may overwhelm species that are slow to move or adapt. Of course, the instrumental value for humans of the environment may be included in the vector of goods c_i that is available to a person. But this completely ignores any possible intrinsic value. The literature on animal ethics and climate change is developing quickly (see Hsiung and Sunstein 2007, McShane forthcoming, Sebo forthcoming) and emphasizes the need to broaden the scope of justice. One of the key difficulties remains to identify principles of cross-species comparisons: how can we trade off human against non-human interests? Even within a hedonistic utilitarian approach, the question is not easy to settle: it is not at all obvious how to compare emotions across differently structured brains, or neural systems more generally.

In principle formula (4) could cover any scope discussed above. As highlighted by the problem of nonhuman species, it is however not simple in practice to extend the scope of justice as far as one would like and most applications restrict attention to the human population in all countries and all present and future periods.

The currency of justice: The question is to define what should be distributed and how the situation of the different people composing the population should be assessed and compared. In the philosophical and economic literature on social justice, many answers have been provided. Of course, one classical answer that we have already discussed before is that the function w in Equation (4) is an individual advantage function, as used in Utilitarianism. But even then, as emphasized before, there are several approaches to such an individual advantage function, including preference-satisfaction, extended-preferences, hedonistic or other mental-state approaches. One can give the generic label of welfarism to approaches relying on such individual advantage functions.

Several alternatives to welfarism have been proposed at least since the seminal book by Rawls (1971). Rawls proposed to replace welfare metrics with indices of primary goods: in that case, the vector c_i would be a vector of primary goods and $w(i, c_i)$ the corresponding index. Sen (1985) proposed the concept of capabilities reflecting the freedom or ability to achieve valuable functionings (i.e. "beings and doings"). In that case, the vector c_i should be not thought of as a vector of commodities but as access to functionings and the function w becomes an index of capabilities as developed in the economic literature (see Alkire 2016 for a recent review). Roemer (1996) proposed to develop indices of opportunities that should be equalized to achieve social justice. Opportunities are distributions of outcomes or advantages that people may choose or achieve through effort. Fleurbaey and Maniquet (2011) and Fleurbaey and Blanchet (2013) recently revived theories of equivalent-income to combine multiple dimensions of human achievement and welfare into a single index formally similar to function $w(i, c_i)$. There are many other possible views on the appropriate currency, including objective goods approaches (see Adler and Fleurbaey 2016 for presentations and comparisons of many different approaches).

Formally, any of these approaches could give rise to a specific application of the social discounting methodologies. There are however practical restrictions depending on the specific case. First, only goods that are included in the vector c_i can be discounted and converted into some corresponding present value. Some of the approaches we have discussed may include non-material goods (or even no material goods at all), which raises the question of how such non-material goods should be measured. Some of the approaches also consider opportunities described as menus or distributions of outcomes or achievements. What we should be discounting, then, are changes in those distributions, which is not mathematically as straightforward as discounting changes in simple quantities. But distributions can be seen as risky outcomes and a whole methodology has been developed to discount risky outcomes.[11]

The shape of justice: The question concerns the criteria to use to determine how to weigh the benefits accruing to different people. Beside the additive formula of Utilitarianism exhibited in Equation (2), where (weighted) welfare numbers are simple added, many other forms for the "aggregator function" *W* have been proposed and studied. A prominent alternative defended by Parfit (1997) and Broome (2004) is an additively separable formula that yields Prioritarianism. A general formula would be:

[11] We cannot extensively cover the case of risky outcomes in that chapter. The question has been discussed in depth in other papers, for instance Fleurbaey and Zuber (2015a), Greaves (2017) and Fleurbaey et al. (2019).

$$V = \sum_{t=0}^{\infty} \sum_{i \in N_t} \phi\big(w(i, c_i)\big), \quad (5)$$

With Prioritarianism, welfare numbers are transformed using a concave function ϕ that grants more priority to welfare that accrues to worse-off people compared to that accruing to better-off people. Such a formula has been applied to social discounting and climate policy (Fleurbaey and Zuber 2015b, Adler et al. 2017).

Another prominent option is Egalitarianism either in its strict form proposed by Temkin (1993) or in the modified form of maximin or leximin as suggested by Rawls (1971). They have usually been considered too extreme (including by Rawls himself, as recalled earlier) for application to intergenerational equity. Strict egalitarianism faces the levelling-down objection that we may prefer to reduce the welfare of everyone in society to promote equality and therefore has not been used by economists who seek efficient allocations. The maximin approach has counter-intuitive implications in the case of climate change policy: given that it only focuses on the worst-off, it completely discount impacts or outcome changes of all other individuals and thus, in all existing models, of all future generations. Given that the current worst-off generation pays for the cost of climate policy, we do not want to make any sacrifice for the sake of the future.

Sufficientarianism is the doctrine that the notion of sufficiency, understood as having a decent (or good enough) life, should be the key consideration for distributive justice. A version of sufficientarianism holds that as many people as possible should enjoy conditions of life that place them above a sufficiency threshold (Frankfurt 1987, 2000). Another version holds that we should give greater priority to helping worst-off persons up to the point at which these persons attain a good enough quality of life, but otherwise we should only maximize total welfare (Crisp 2003).

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. Asheim, Mitra and Tuggoden (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. Zuber and Asheim (2012) have introduced a rank-dependent model that implies a relative priority (in contrast to the absolute priority of prioritarian criteria) to worst-off people. The model shares some similarities with discounted utilitarianism except that the pure-time discount rate is conceived as a social weight prioritizing the interests of least-advantaged people.

The W function is therefore very flexible, so that the discounting technique can be applied to many views regarding how interests should be balanced. Most consequentialist approaches would fit into the model proposed by Equation (4).

2.2 The main elements of the discounting formula

In Fleurbaey and Zuber (2015a), we developed a general methodology to compute a social discount rate for the general value function described in Equation (4). The social discount rate then generally represents the rate of change in the value of a specific (or composite) good in the future period t compared to a reference (composite) good in the current period.[12] This rate will depend on two key elements: the rate of change in marginal advantage derived from the consumption of the good; the rate of change in the social priority of individual advantage. The "marginal advantage derived from the consumption of the good" is similar to the concept of marginal utility of consumption. The only difference is that the individual advantage function $w(i, c_i)$ is not necessarily a utility function that measures changes in pleasure or happiness, but may measure changes in opportunities, capacities or other concepts.

What we call the "social priority of individual advantage" is a generalized notion of priority that does not necessarily correspond to the concept developed in the prioritarian theory.[13] It simply measures the social or ethical marginal value of advantage for a specific person. This makes it possible to compare and balance the distributive claims or needs of different people: is such or such increase in the advantage of the current generation more or less valuable than such or such increase in the advantage of a generation living in one thousand years?

In a utilitarian formula, social priority of utility would be the same for all individuals in all generations. In a discounted utilitarian formula, this social priority would be $e^{-\delta t}$ for a person of generation t, and thus decreasing through time. In a prioritarian formula, this social priority would be lower the better-off a person is. In a sufficientarian formula, the social priority would be greater for badly-off individuals up to some level of advantage and then the same for all. In an egalitarian maximin formula, all individuals would have zero priority except the worst-off persons, implying an extreme discounting formula.[14]

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[12] The term "specific good" means that we consider a particular good in the vector c_i for a specific individual $i \in N_t$. The term "composite good" means that we consider an aggregate or equivalent quantity to represent the level of all goods either for an individual or the society at large in a given period. Typically, economic models focus on average consumption in a population.

[13] See Parfit (1997) for the introduction of this notion of priority and Broome (2015) for a defense of the concept.

[14] For instance, the maximin case with one person per generation and one good, the discount rate would be infinitely large if the current generation is the worst-off generation.

The simple decomposition in terms of marginal advantage and social priority of individual advantage can actually become more complex in practice for three reasons: 1) there are multiple goods; 2) there are several people in a generation; 3) there may be some risk or uncertainty about future outcomes.

Contrary to the simple case of formula (1) and the associated Ramsey equation (2), the value function (4) allows the advantage measure for individuals to depend on several goods (or resources or attributes). These different goods will generally have different discount rates, reflecting future changes in their relative value or price. One way out of this complication is to construct an "aggregate" good that can be discounted with a single discount rate. But, as explained in Greaves (2017), we must then be careful not to forget the issue of changing relative prices: if some good (for instance environmental quality, the level of biodiversity, etc.) becomes less abundant in the future compared to another good (for instance material consumption), its relative price will increase making it more valuable. And more to the point: not only the relative market price may change, but the relative value for the ethical assessment may change (where these relative value is computed as a *shadow price* using the value function in Equation (4), which may not be reflected in market prices). Retaining good-specific discount rates (see for instance Gollier 2010), on the other hand, is more transparent and makes it possible to highlight the importance of certain goods when assessing policies affecting several generations: for instance, the "ecological discount rate" for future damages on the environment may become negative if we think that environmental quality will decrease in the future (Gollier 2010).

Future generations are composed of several individuals that may be affected by the decisions we take today. For ethical assessment, we do not want to assume that there exists a representative agent of these different individuals as is generally assumed when using the Ramsey equation. This raises the issue of the inequality within future generations. One standard methodology to take inequality into account relies on *equity weights* when we compute the future costs and benefits of a policy (see Anthoff, Hepbrun and Tol 2009 for an application to climate policy). In that case, we compute an "average" social discount rate for the future (that looks at the average level of a good enjoyed by the future generation) and transform the measure of impacts in the future to account for inequalities. An alternative consist in incorporating directly (intra-generational) inequality considerations in the measure of the social discount rate as suggested by Gollier (2015) and Fleurbaey and Zuber (2015a). The idea is that a less unequal future generation can be considered as better-off so that we may want to put less weight in increases in their consumption of goods and resources. In that case, the social discount rate can be viewed as an aggregation of individual or personalized discount rates (for person-to-person

transfers) and it also makes it possible to include the consideration of inequalities in the distribution of consequences (Fleurbaey and Zuber 2015a).

Risk is also a pervasive phenomenon in many problems involving intergenerational ethics and in particular for climate justice. There is a lot of uncertainty about the level of resources available to future uncertainty and also epistemic uncertainty about the models we can use to foresee the future consequences of our actions. Risk has attracted a lot of attention in the economic literature. Several attempts have been made to adjust the discounting formula in that case as well as providing alternative decision model that may disentangle attitudes towards risk and attitudes towards intergenerational distribution in the value function (see Greaves 2017 and Fleurbaey et al. 2019 for extensive surveys of this issue). Formally, the question of risk is very similar to the question of inequality. But there is one key difference: in the case of risk, the discounting formula may include an additional term that reflects the correlation between individual advantage and the aggregate advantage of people in all generations (Fleurbaey and Zuber 2015b). This involves a notion of correlated or aggregate risk, which is a risk on the overall value function.

3 Conclusion: Beyond social discounting

In this chapter, we have argued that social discounting is a flexible tool for policy evaluation for problems spanning several generations. Social discounting does not necessarily entail a violation of the principle of impartiality among generations: on the contrary, we have argued that ethically defensible versions of social discounting typically satisfy this principle. Social discounting may also involve different ethical positions regarding how resources, well-being or advantages should be distributed across people in different generations. We have actually argued that the social discounting methodology can be developed for a wide range of ethical views. The main restriction is that it remains within the scope of consequentialist axiology, and thus is not the appropriate tool to deal with considerations of right, harm, virtues or duties. But even people who do not view consequentialism as the only relevant moral theory may accept that consequentialist considerations are part of the overall moral picture: in that sense, the social discounting methodology may still be useful for them.

However, even within the scope of cost-benefit analysis, the social discounting approach (and the associated methodology of net present values) should not be considered an all-purpose tool that can serve for all evaluations and issues. We would like to conclude this chapter with some caveats.

First, we must emphasize a well-known point that is sometimes overlooked. As stressed for instance by the Stern review (Stern 2006 *§* 2A.2), the social discount

rate is useful to evaluate small transfers of consumption across individuals living at different times. It is not adapted to large-scale changes. For instance, there is evidence that climate change may affect future growth and therefore that a climate policy may alter the underlying consumption path (Dell et al. 2012, Moore and Diaz 2015). Similarly, climate change may worsen inequalities or hinter the development of some regions in the world, and such changes may alter our willingness to implement policies that reduce more greenhouse gas emissions in the near term (Hallegate et al. 2016, Budolfson et al. forth.).

Similarly, policy may change the size or the composition of the future population. For instance, climate change and climate policy could influence patterns of fertility and mortality thereby changing who will exist in the future. Thus, our value function should incorporate population sizes, thereby raising issues of population ethics (Broome 2012, Kolstad et al. 2014, p. 211). Population ethics is known to raise difficult puzzles and no single approach has emerged that is consistent with all attractive intuitions (Parfit 1984; Blackorby et al. 2005). 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). 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, Méjean et al. 2017).

Population ethics is particularly important in the case of catastrophic or existential risks that may drastically reduce future population size (or even lead to human extinction). Climate policy in general has focused on future impacts of climate on consumption or on the goods (in a broad sense) available to future generations. But climate change may not only alter future resources, it may alter the risk that future generations (not only human, but also for other species) do not exist. In economic cost-benefit analysis, the technique used to evaluate changes in probabilities of a risk on the existence (of an individual) consists in computing the 'value of a statistical life'. The methodology can be extended in the case of risks on the existence of future generations (the idea was suggested, but used in a very different way by Weitzman, 2009). In that case, the social discount rate is not any more the key parameter to value future consequences and alternative methods must be developed (Bommier, Lanz and Zuber 2015; Méjean et al. 2017).

For all three cases mentioned above (effects of the policy on growth, on population size or on large-scale risk), the computation of net present values using some social discount rate cannot provide the right guidance if the underlying ethical theory can be represented by a value function like the one exhibited in Formulas (1) or (4). For these cases (and other similar cases) policy evaluation has to rely directly

on the underlying value function. This reminds us that the social discounting methodology is only an approximation of our ethical assessment. And that the soundness or attractiveness of a discounting formula only derives from the soundness and attractiveness of the underlying ethical theory. Discounting is good only insofar as it relies on sound ethical principles.[15]

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