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Ethical preferences in the presence of resource constraints

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The interest in the concept of a *sustainable development* arises from a concern that natural and environmental resources may not be managed in a manner that secures the well-being of future generations. By letting each generation's capital and resource management be made according to its *subjective preferences* and by assuming that each generation through these subjective preferences exhibits altruism for its descendants, then this issue translates into a concern that the altruism may not be sufficient to secure the well-being of future generations.

An example where these concerns are well-founded is constructed by letting the subjective preferences of each generation t be represented by

$$w_t = u_t + bw_{t+1} = \sum_{s=t}^{\infty} b^{s-t} u_s, \quad 0 < b < 1.$$

Here the *subjective welfare* of generation t (w_t) depends on its own *utility* (u_t) and the subjective welfare of its immediate descendents. The utility of generation t is assumed to be an unquestionable indicator of the well-being that is generated from the situation in which it lives. Due to its recursive form these sub-jective preferences are equivalent to *discounted utilitarianism*. The fact that the utility discount factor (b) is smaller than 1 means that future utility is discounted. There is a two-fold justification for these subjective preferences: (1) They are consistent with the observation that parents care for the welfare of their children. (2) They are consistent with an objective function that is very commonly applied and for which Koopmans (1960) has provided an axiomatic foundation.

It is not hard to construct economic models where discounted utilitarianism leads to ethically unacceptable results due to the presence of resource constraints. The most well-known such example is the Dasgupta-Heal-Solow (D-H-S) model of capital accumulation and resource depletion (Dasgupta & Heal (1974; 1979, Ch. 10) and Solow (1974)). In the simple version that will be considered here, it is a model with non-overlapping generations of constant size and no technological progress. A stock of reproducible capital and a flow of resource extraction enters a production function. Production is split into consumption (c) and capital accumulation.
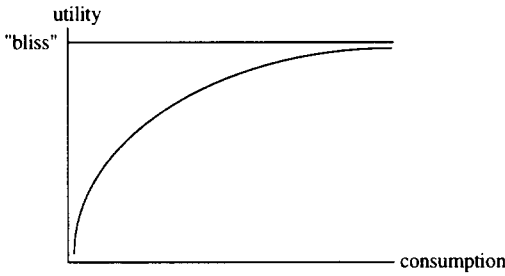
Figure 1

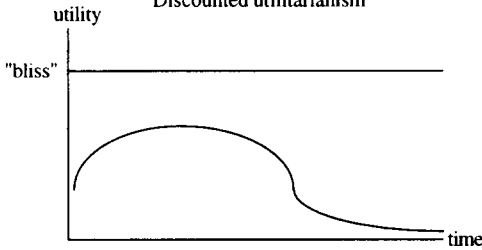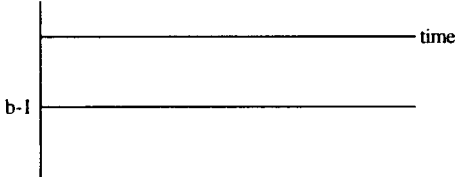## Figure 2a
Discounted utilitarianism

Figure 2b

cost of utility transfer from the present to the future

No production is feasible without resource extraction, while total resource extraction is constrained by the availability of a finite stock since the resource is assumed to be non-renewable. However, with positive initial stocks of capital and resource, positive and constant consumption is feasible.[1] This is achieved by having an increased stock of reproducible capital make up for a diminishing flow of resource extraction. Let utility depend on consumption: $u_t = u(c_t)$. I will assume that $u(\bullet)$ is strictly increasing, strictly concave and bounded above, as illustrated by Figure 1.[2] The upper bound on utility values will be called 'bliss'. Under these assumptions, if the subjective preferences are represented by $w_t = u_t + bw_{t+1}$, then consumption is forced to approach zero as time goes to infinity. This manifestly unjust outcome is obtained no matter how small the discounting is, i.e., no matter how close the discount factor b is to 1. Any constant discounting of the future leads to the same qualitative result. The optimal utility path according to discounted utilitarianism is illustrated in Figure 2a.

Ethical preferences
In order to achieve an ethically acceptable outcome in the D-H-S model, *ethical preferences* need to be introduced. The terminology, 'ethical' vs 'subjective' preferences is taken from Harsanyi (1955). While the term 'subjective preferences' is here meant to capture 'selfish' altruism – in the sense that a generation is motivated to contribute to the welfare of its children because it leads to increased welfare of the contributor – the term 'ethical preferences' is meant to capture preferences which are costly to abide by and which, as a consequence, will not be accepted unless they are imposed as a moral obligation.

Harsanyi (1953) and Rawls (1971)[3] argue that ethical preferences on intergenerational

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1. This holds in continuous time if the stock of capital and the flow of resource extraction enter into a Cobb-Douglas aggregate production function where the factor elasticity of the capital stock exceeds the factor elasticity of the resource flow. In the present discussion of the D-H-S model, I assume that the model has the same properties as in continuous time with such a Cobb-Douglas function. For an analysis of the D-H-S model in discrete time, see Dasgupta & Mitra (1983). For a general analysis of the feasibility of positive and constant consumption despite a resource constraint, see Cass & Mitra (1991).
2. The assumption that $u(\bullet)$ is bounded above is needed for the Chichilnisky and Ramsey criteria considered later.
3. Due to the influence of Rawls' (1971) *A Theory of Justice*, also on questions of intergenerational justice, I will relate much of my discussion to his book.

distributions should stem from principles of justice that generations would agree on in the original position. Moreover, Rawls (1971: 4) supports the view that ethical preferences should be evaluated by their implications in specific economic environments by posing the question: Are the distributional consequences acceptable given our moral intuitions?[4] This is in line with his concept of a *reflective equilibrium*.

Based on Rawls' (1971) view, I will here evaluate different forms of ethical preferences by showing their implications in the D-H-S model. That a specific form of ethical preferences yields ethically acceptable implications in the D-H-S model does not, of course, mean that it is universally applicable. However, since the D-H-S model is very often used to show that discounted utilitarianism produces ethically unacceptable outcomes, it seems natural to subject alternative criteria to the same test.

Before undertaking this exercise, it is useful to present a taxonomy which can be applied for classifying the different forms of ethical preferences that will be considered. On the one hand, ethical preferences may differ with respect to the object on which they are defined:

- The ethical preferences may be defined on the flow of subjective welfares: (w_1, w_2, w_3,...). This is in accordance with what Sen (1977) calls *welfarism*: «The general approach of making no use of any information about the social states other than that of personal welfares generated in them ... .» I will assume that w_t is interpersonally level comparable.

- The ethical preferences may be defined on the flow of utilities: (u_1, u_2, u_3, ...). I will assume that u_t is interpersonally level and unit comparable.

On the other hand, ethical preferences may differ with respect to what kind of ordering they yield:

- The ethical preferences may yield a complete preordering, implying that if an intergenerational distribution is *maximal* [5] with respect to the preordering, then it is weakly preferred to all feasible distributions.

- The ethical preferences may yield a partial preordering,[6] allowing for the possibility that maximal intergenerational distributions may not be comparable. Intergenerational distributions that are not maximal with respect to the preordering are deemed ethically unacceptable.

It must be required that the ethical preferences do not depend on the stocks of capital and resource. This is especially important in a model (like the D-H-S model) where positive consumption entails depletion of a non-renewable resource. Because otherwise, any feasible flow of utilities (or welfares) with positive consumption at any time can be realized by conditioning in a particular way the capital and resource management on the remaining stock of the resource.[7] Moreover, it must be

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4. This approach is in principle supported also by e.g. Koopmans (1967), Mishan (1977), and Dasgupta & Heal (1979, pp. 308–311).
5. A distribution is *maximal* if there is no alternative distribution that is strictly preferred to it.
6. A partial preordering is reflexive and transitive, but not complete.
7. This restriction seems to preclude that the ethical preferences at time t are endogenous in the sense of being dependent on the history up to time t. Note, however, that for each of the Ramsey, Solow, Dalton, and Calvo criteria considered later, it is possible to express each generation's optimal capital and resource management as a function of its inherited stocks of capital and resource. This can be done even though the ethical preferences do not depend on stocks.

required that generations have identical ethical preferences. Because otherwise, any feasible flow of utilities (or welfares) can be realized by letting the preferences change. This means that the ethical preferences must not depend on *absolute* time. Finally, generations must perform consistent planning in the sense of taking into account that the same ethical preferences will be applied by future generations.

The Chichilnisky criterion

Chichilnisky (1996) has suggested a class of ethical preferences that are based on the axioms that neither 'the present' nor 'the future' should be dictated. Ethical preferences in this class are defined on $(u_1, u_2, u_3, \dots)$ and depend both on the flow of utilities over time and the long-run behavior of utility values. Following Beltratti, Chichilnisky & Heal (1995), I here consider the following representation (where the discount factor δ need not coincide with the discount factor b of the subjective preferences):[8]

$$\theta \sum_{t=1}^{\infty} \delta^{t-1} u_t + (1-\theta) \liminf_{T \to \infty} {}_{t \geq T} u_t, \quad 0 < \theta < 1, \ 0 < \delta < 1.$$

Hence, the ethical preferences are represented by a weighted sum of the sum of discounted utilities and the level of utilities that is approached when time goes to infinity.

Beltratti, Chichilnisky & Heal (1995, p. 149) «... feel that this formulation is in tune with the concerns of those who write about sustainability and our responsibilities to future generations.» However, any of the future generations that such writers have concern for will live in *finite* time. Hence, the Chichilnisky criterion is in tune with these concerns only if the weight on the limiting pro-

perties of the utility flow is instrumental in securing the well-being of future generations. Therefore, it seems interesting to pose the question: What are the implications of imposing the Chichilnisky criterion as ethical preferences in the D-H-S model? Note that Alistair Ulph in his discussion of Beltratti, Chichilnisky & Heal (1995) argues that this is an important exercise: «I would like to see the implications of the proposed new welfare criterion worked out in a wider class of models, and in particular models of the type ... involving non-renewable resources and for which we know that the discounted utilitarian criterion with high utility discount rates gives unpalatable outcomes» (Ulph (1995, p. 171).

In the D-H-S model, 'bliss' can be approached in the limit as time goes to infinity as long as there are positive stocks of capital and resource at any finite time. Hence, the second term of the objective function representing the Chichilnisky criterion is not precluded from attaining its maximum value as long as the stocks are positive. If both stocks are not positive, consumption must converge to zero as time goes to infinity. This means that the second term of the objective function works as an instrument for keeping stocks positive. Now, the program that maximizes the sum of discounted utilities – i.e., the first term of the objective function representing the Chichilnisky criterion – implies that stocks are positive at any finite time. Hence, 'bliss' can be approached as time goes to infinity even if the concern for future generations is postponed. Therefore, such a postponement is desirable according to the Chichilnisky criterion since it does not affect the second term of the objective function, while it allows for an increase of the first term. On the other hand, ethi-

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8. If u_t is a convergent sequence, then $\liminf u_t = \lim u_t$. Note that $\liminf u_t$ is defined even if u_t is not convergent.

cal welfare is decreased if the concern for future generations is postponed indefinitely since then 'bliss' is not approached as time goes to infinity. The conclusion is that *no optimal distribution exists.*[9]

It is important to note that this non-existence problem does not arise due to technical issues of a mathematical nature. It arises because the limiting properties of the utility flow as time goes to infinity cannot be used as a proxy for the well-being of future generations that live in finite time. In fact, in the D-H-S model a utility path that is 'nearly' optimal according to the Chichilnisky criterion will be close to the utility path that is optimal according to discounted utilitarianism.[10] Beltratti, Chichilnisky & Heal's (1995, p. 150) claim – that their «approach is fully consistent with earlier discussions of sustainability» – is therefore puzzling.

The Ramsey criterion – Classical utilitarianism

Ramsey (1928) suggests to apply classical utilitarianism to intertemporal distributions. This means that the ethical preferences are defined on $(u_1, u_2, u_3, \dots)$ and are represented by

$$\sum_{t=1}^{\infty} (u_t - u),$$

where u is the 'bliss' utility level. Dasgupta & Heal (1979, Ch. 10) consider the Ramsey criterion and show that an optimal utility path

exists under given assumptions on the utility function. When it exists, the optimal utility path is always increasing and approaches 'bliss' as time goes to infinity. These properties of the optimal utility path – which are caused by the fact that investment in capital is always productive in the D-H-S model in the sense of yielding a positive net return – are illustrated in Figure 3a.

It will prove useful to describe criteria in terms of their relation to the cost of intergenerational transfers. Therefore, say that a transfer of utility from one generation to another has *negative cost* if the provider loses less utility than the receiver gains. Due to positive productivity of capital investments, a given sacrifice of *consumption* can be turned into a greater gain of consumption for the next generation. Hence, along a path with constant consumption (so that total and marginal utility is constant), a given sacrifice of *utility* can be turned into a greater gain of utility for the next generation. In this case, there is a negative cost of utility transfer from one generation to the next. Note that the cost of utility transfer is related to capital productivity, growth in consumption, and the concavity of the utility function; not to incentive constraints as in the case of intragenerational redistribution.

A utility path that is optimal according to discounted utilitarianism has a negative cost of utility transfer from one generation to the next since a loss of b (<1) for the provider

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9. Existence may be ensured if δ is time variant and the utility discount *rate* $((-d\delta/dt)/\delta)$ goes sufficiently fast to zero as time goes to infinity. However, in such a case the second term of the objective function is not needed since maximization of the first term ensures that 'bliss' is approached as time goes to infinity. Furthermore, given our requirements, δ can only depend on *relative* time, not *absolute* time. When δ is not time invariant, this in turn creates a time inconsistency problem in the sense that some generation $t > 1$ will not want to continue the optimal path at time 1. Whether existence can be restored when generations plan consistently appears to be an open question.

10. The following is precise statement of this result. The supremum of the Chichilnisky objective function is the weighted sum of the value of the path optimal according to discounted utilitarianism and the value of a path approaching 'bliss' as time goes to infinity. Consider for any n a path with a value according to the Chichilnisky objective function less than $1/n$ from the supremum. As n goes to infinity, this sequence of paths approaches in the topology of pointwise convergence the path that is optimal according to discounted utilitarianism.

yields a gain of 1 for the receiver. If this was not the case, the utility path would not be optimal since a transfer increasing the value of the objective function of discounted utilitarianism would have been feasible. This observation, which reflects that the future is discounted, is illustrated by Figure 2b.

The Ramsey criterion is characterized by the requirement that any feasible utility transfer with negative cost should be undertaken.

Hence, the Ramsey optimal utility path satisfies that the cost of utility transfer from one generation to another is zero.[11] Again, if this was not the case, the utility path would not be optimal since a transfer increasing the value of the objective function of the Ramsey criterion would have been feasible. This is illustrated by Figure 3b.

It is sometimes claimed that Rawls (1971) argues against discounting the future; there are quotes from Rawls (1971:45) that seem to support this claim: «There is no reason for the parties to give any weight to mere position in time.» However, it is absolutely clear that Rawls (1971) does not support the Ramsey criterion. He writes the following on the use of classical utilitarianism in the context of intergenerational justice:

> « ... [I]t seems evident ... that the classical principle of utility leads in the wrong direction for questions of justice between generations. ... [T]he utilitarian doctrine may direct us to demand heavy sacrifices of the poor generations for the sake of greater advantages for later ones that are far better off.» Rawls (1971:44)

Figure 3a
The Ramsey criterion

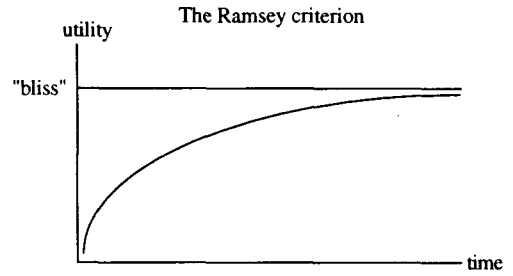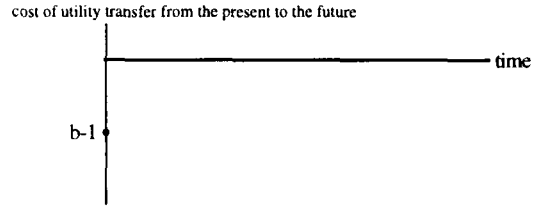### Figure 3b
cost of utility transfer from the present to the future

Dasgupta (1995) refers to Mirrlees (1967) and Chakravarty (1969) who showed in plausible economic models that the present generation would be asked to save and invest around 50 percent of GNP if the Ramsey criterion were imposed. One may argue – as Rawls do – that this implication undermines the ethical appeal of the Ramsey criterion.

The Solow criterion – Rawlsian maximin on utility
Rawls (1971) does not support the use of maximin (or the *difference principle*) in the context of intergenerational justice. He writes:

> «We can do something for posterity, but it can do nothing for us. ... It is now clear why the difference principle does not apply to the savings problem. There is no way for later generations to improve the situation of the least fortunate first generation.» Rawls (1971:44)

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11. An earlier generation has a greater marginal utility of consumption since its consumption level is lower. Hence, a given change in utility corresponds to a smaller change in consumption for an earlier generation. When a transfer is made from an earlier to a later generation, this difference in marginal utility is canceled out by the positive capital productivity. This explains how the earlier generation's sacrifice of utility equals the later generation's gain of utility.

However, Rawls (1971) does not seem to take into account that, if we can increase our immediate well-being by depleting natural resources and reducing the long-term quality of environmental resources, then, in effect, posterior can do something for us. Therefore, with resource constraints it seems right for Solow (1974) to be « ... *plus Rawlsien que le Rawls*» by applying maximin also in the context of intergenerational justice. This means that the ethical preferences are defined on $(u_1, u_2, u_3, ...)$ and are concerned with the worst-off generation in terms of utility; hence, the preferences are represented by[12]

$$\inf_{t \geq 1} u_t$$

In the D-H-S model, the Solow criterion yields a completely egalitarian utility path, as showed by Solow (1974) and illustrated in Figure 4a.

The Solow criterion is characterized by the requirement that any utility transfer from a richer to a poorer generation should be undertaken,

no matter the cost of transfer (as long as the cost is finite). As illustrated by Figure 4b, this implies that the cost of utility transfer from one generation to the next can initially be quite negative, reflecting the positive and decreasing productivity of capital investment.

Solow (1974, p. 41) notes an important drawback with the use of the maximin principle in the context of intergenerational justice: «... [I]t requires an initial capital stock big enough to support a decent standard of living, else it perpetuates poverty, but it can not
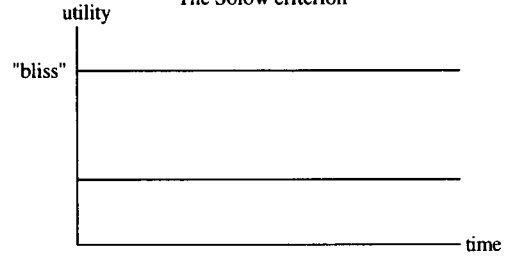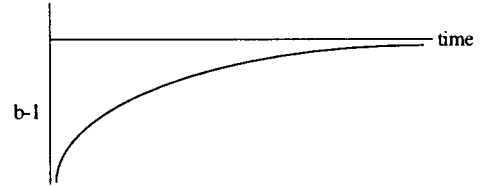
Figure 4a

The Solow criterion

Figure 4b

cost of utility transfer from the present to the future

tell us why the initial capital stock should ever have been accumulated.» A second problem can be added: If each generation has an altruistic concern for its immediate descendants, parents may wish to save for the benefit of their children over and beyond the level of saving that is implied by the Solow criterion. Why should such additional saving be disallowed when it contributes to increased subjective welfare for both the parents and their children?[13] For the remainder of this paper, two alternative ways to overcome these problems will be discussed.

The Dalton criterion – The modified principle of transfers

Are there ethical preferences that produce acceptable outcomes in the D-H-S model? In order to provide a different perspective on this problem, let us go back to a seminal con-

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12. Since there is an infinite number of generations, there may not exist a worst-off generation. If a worst-off generation exists, then inf u_t = min u_t. Note that inf u_t is defined even if there is no worst-off generation.
13. Roemer (1996) discusses this issue and concludes that «[e]galitarians should, indeed, prefer the maximin solution to its altruistic deviation». Rather than arguing pro and contra this view, the purpose of the remainder of my paper is to show how ethical preferences can be amended so that they allow for the «altruistic deviation».

tribution to the literature on inequality, namely Dalton (1920). He writes:

« ... [I]nequality ... may be conveniently defined as the ratio of total economic welfare attainable under an equal distribution to the total economic welfare attained under a given distribution. ... [I]f ... a transfer of income takes place from the richer to the poorer, inequality is diminished.» Dalton (1920, pp. 349 & 351)

Hence, he argues that when income is transferred from a richer to a poorer and the transfer is not so large that their relative positions are reversed, then a preferred social state is achieved. Dalton (1920) calls this the *principle of transfers*. I will here apply this principle in the context of transfers between generations. Moreover, in order to relate this principle to the other criteria of this paper, I choose to strengthen the principle so that transfers of *utility* are considered, not transfers of consumption. This *modified principle of transfers* can be stated as follows:

Any utility transfer with zero cost from a richer to a poorer generation should be undertaken.

Note that the Dalton criterion yields a partial preordering, deeming an intergenerational distributions $(u_1, u_2, u_3, ...)$ ethically unacceptable if there exists a feasible transfer of utility with zero cost from a richer to a poorer generation.

Since capital investments are productive in the D-H-S model, the Dalton criterion applied to the D-H-S model implies that the utility path $(u_1, u_2, u_3, ...)$ is an acceptable social choice only if it is non-decreasing. To see this,

assume to the contrary that one generation has a higher utility than the immediately succeeding generation. Since capital investment is productive, it is possible to transfer *consumption* with negative cost from the earlier (i.e. richer) generation to the later (i.e. poorer) generation. Since the utility function is a strictly increasing and strictly concave function, it is thus possible to transfer *utility* with negative cost from the richer generation to the poorer generation. With the additional assumption that there is free disposal of investment flows,[14] this means that it is possible to transfer utility with zero cost from the richer generation to the poorer generation. In fact, the only utility paths in the D-H-S model that are consistent with the Dalton criterion are

• completely egalitarian paths, and
• efficient and non-decreasing paths with a non-positive cost of utility transfer from an earlier to a later generation.

Figure 5 illustrates the intuition behind this result in the case with only two generations. Here, the curve depicts the set of efficient utility paths. The Ramsey optimal path (R) maximizes the sum of utilities. The Solow optimal path (S) is efficient and completely egalitarian. The cost of utility transfer from generation 1 to generation 2 is negative for utility paths on the efficient curve to the right of R. Notice that, among the efficient utility paths satisfying the Dalton criterion, the Ramsey optimal path is at the one extreme having barely non-positive cost of utility transfer, while the Solow optimal path is at the other extreme being barely non-decreasing.

The term sustainable development has by many writers been associated with non-decreasing utility.[15] Above I have argued that the

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14. Note that an assumption of free disposal of investment flows, in a model with environmental capital, means that negatively valued waste products can freely be generated, not freely be disposed off.

Dalton criterion in the context of the D-H-S model admits only outcomes that are consistent with this idea of sustainability. It is, however, important to note that the asymmetry in outcomes – namely that only non-decreasing paths are compatible with the Dalton criterion – does *not* arise because the Dalton criterion is asymmetric with respect to time. The Dalton criterion is perfectly symmetric with respect to time. The asymmetry in outcomes is caused by the positive capital productivity of the D-H-S model: Along a path with constant utility, transfers from earlier to later generations are less costly than transfers from later to earlier generations. Hence, sustainability is not adopted as a primitive assumption. Rather, it is the result of a primitive assumption, namely, the Dalton criterion, that does *not* assign any inherit value on making future generations better off than the current generation.[16] In this way, the Dalton criterion offers a foundation for sustainability in technologies with positive capital productivity.

Since the Dalton criterion is a partial preordering, it causes no conflict between the ethical preferences on the one hand, and the altruistic concern expressed through the subjective preferences on the other hand. Generations may therefore choose according to their subjective preferences, but subject to the constraint that the resulting utility path satisfies the Dalton criterion. This entails that the

Figure 5
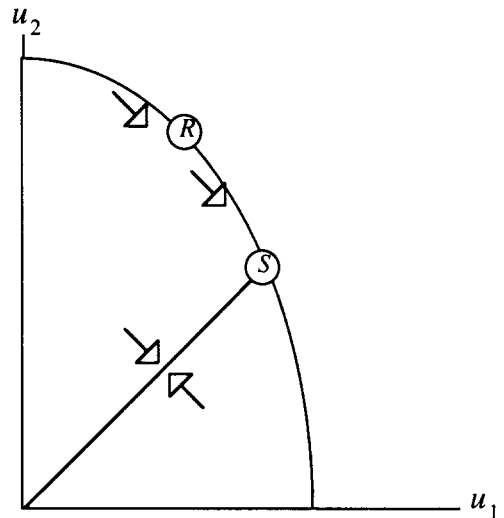
generations consider it a moral obligation to choose a distribution that is acceptable given the Dalton criterion, but that they may – within these bounds – maximize their 'selfish', but altruistic, subjective welfare as specified in the introduction. If generations maximize their subjective welfare subject to the Dalton criterion, the resulting distribution is nondecreasing with an eventual stationary phase. With a small capital stock and a large resource stock, this eventual phase is preceded by an initial phase with increasing utility.[17] In the latter case, all generations are better off measured in subjective welfare than

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15. The idea defining sustainability in this way dates at least back to Tietenberg (1984) and seems to have been fairly widely accepted; see, e.g. Repetto (1986), Pezzey (1989), and Mäler (1989). A critical assessment of this interpretation of sustainability is given by Pearce et al. (1989, pp. 32 & 49). Hammond (1994) gives an interesting review of references relating to the notion of sustainability. See also Solow (1993).

16. Hence, the Dalton criterion is not subject to a critique proposed by Roemer (1996): « ... that we value progress because it will make everyone in the future better off than today, does not stand up to analysis». See Bucholz (1996) for a related foundation of sustainability that is also symmetric with respect to time.

17. These results are established in Asheim (1991, Proposition 7). The ethical preferences in Asheim (1991, Definition 3) differs from the Dalton criterion as specified here. In particular, only the *un*modified principle of transfers (hence, in terms of consumption) is satisfied (Lemma 2(ii)). Still, Proposition 7 applies since the optimal utility path is efficient and non-decreasing, it maximizes subjective welfare over all non-decreasing paths, and it has a negative cost of transfer from an earlier to a later generation (Asheim (1988, Proposition 2 & Lemma 4)).
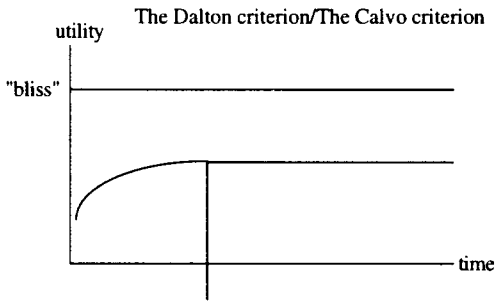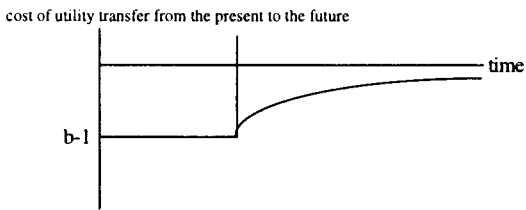
Figure 6a

The Dalton criterion/The Calvo criterion

Figure 6b

cost of utility transfer from the present to the future

with the Solow optimal path.[18] In any case, the least fortunate first generation is better off measured in subjective welfare than with the Ramsey optimal path.[19] The Dalton optimal path is illustrated in Figure 6a. As illustrated by Figure 6b, the cost of utility transfer from one generation to the next is negative. It is equal to $b - 1$ initially if there is a phase with increasing utility, and decreasing to zero in the eventual phase with constant utility.[20]

The Dalton criterion therefore provides a solution to the problem of finding ethical preferences that yield acceptable implications in the D-H-S model.

The Calvo criterion – Rawlsian maximin on subjective welfare

Some scholars – notably Arrow (1973), Dasgupta (1974), and Calvo (1978) – have interpreted Rawls (1971) as promoting the view that one should take into account the altruism of the generations when finding a just savings principle for intergenerational justice. Here are some quotes that supports this interpretation:

« ... [S]ince it is assumed that a generation cares for its immediate descendants, as father say care for their sons, ... certain limits on [a just savings principle] would be acknowledged. ... They try to piece together a just savings schedule by balancing how much at each stage they would be willing to save for their immediate descendants against what they would feel entitled to claim of their immediate predecessors.» Rawls (1971:44)

Calvo's (1978) suggestion is to apply Rawlsian maximin on the subjective welfare, which amounts to ethical preferences that are in accordance with welfarism. This means that the ethical preferences are defined on $(w_1, w_2, w_3, ...)$ and are concerned with the worst-off generation in terms of subjective welfare; hence, the preferences are represented by

$$\inf_{t \geq 1} w_t$$

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18. The Dalton optimal path uniquely maximizes the first generation's subjective welfare over all non-decreasing paths. If the Dalton optimal path differs from the Solow optimal path, then the former must yield higher subjective welfare for the first generation than the latter, since the latter is also non-decreasing. Since the Dalton optimal path yields a non-decreasing path of subjective welfares, while the Solow optimal path yields a constant path of subjective welfares, the result follows.

19. The Dalton optimal path uniquely maximizes the first generation's subjective welfare over all non-decreasing utility paths. Since the Dalton optimal path differs from the Ramsey optimal path and the latter is also non-decreasing, the result follows.

20. Figure 5b measures at time t the average cost, per unit time, of a marginal utility transfer from generation t to its descendants in all generations, given that all later generations receive an equal utility gain. Formally, the measure is equal to $a - 1$, where a is defined in Asheim (1988, p. 474).

Table 1

	Complete preordering			Partial preordering
Flow of utilities (excl. altruism)	Chichilnisky Neither the present nor the future should be dictated	Ramsey Classical utilitarianism	Solow Rawlsian maximin	Dalton Modified principle of transfers
Flow of welfares (incl. altruism)			Calvo Rawlsian maximin	

If the generations perform consistent planning, the Calvo criterion yields the same distribution as maximizing subjective welfare subject to the Dalton criterion.[21] In particular, the Rawlsian maximin principle may allow for growth so that poverty is not perpetuated. Furthermore, the least fortunate first generation is allowed to transfer utility to later generations if it considers this to be in its own interest. The Calvo criterion therefore resolves the two drawbacks that were associated with the Solow criterion.

The Calvo criterion provides an alternative solution to the problem of finding ethical preferences that yield acceptable implications in the D-H-S model. In contrast to the other criteria that are considered here, the Calvo criterion is in accordance with welfarism.

Concluding remarks

Table 1 gives an overview of the criteria of intergenerational justice that I have evaluated in the D-H-S model. The Chichilnisky criterion fails by not yielding existence. The remaining four criteria lead to non-decreasing consumption and thus solve the fundamental problem associated with discounted utilitarianism in the D-H-S model. However, one may claim – as Rawls (1971:44) does – that the Ramsey criterion is unfair to the least fortunate first generation. Furthermore, the Solow criterion tends to perpetuate poverty and do not respect the altruistic concern that parents may have for their children. Therefore, of the criteria considered, only the Dalton and Calvo criteria remain. These two criteria have identical implications in the D-H-S model, and they are not subject to any of the problems mentioned above:

• existence is ensured, and consumption is non-decreasing,
• the first generation has a strictly lower consumption than later generations only if it – according to the altruistic concern of its subjective preferences – chooses to let the next generation consume on its behalf,
• poverty need not be perpetuated if parents thus let children consume on their behalf, and,
• the altruistic concern that parents may have for their children is thereby respected.

The present paper does not address how the Dalton and Calvo criteria would result from principles of justice agreed upon by the generations in the original position. Some remarks will be offered, though.

The Calvo criterion relies on the assumpti-

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21. This result is established in Asheim (1988, Theorem 2).

on that the generations know in the original position to what extent they will have an altruistic concern for their immediate descendants. Rawls (1971) can be interpreted as supporting the view that altruism should *not* enter into the conception of justice:

«There is no inconsistency, then, in supposing that once the veil of ignorance is removed, the parties find that they have ties of sentiment and affection, and want to advance the interests of others and to see their ends attained. But the postulate of mutual disinterest in the original position is made to insure that the principles of justice do not depend upon strong assumptions. Recall that the original position is meant to incorporate widely shared and yet weak conditions. A conception of justice should not presuppose, then, extensive ties of natural sentiment.» Rawls (1971:22)

Moreover, it appears unresolved how the Calvo criterion follows from primitive axioms of intergenerational justice. This may, however, be an interesting topic for future research.

The Dalton criterion does *not* assume that the generations know in the original position to what extent they will have an altruistic concern for their immediate descendants. Hence, it does «not presuppose ... extensive ties of natural sentiment». Moreover, its statement is in the form of a primitive axiom of intergenerational justice. It seems natural to claim that this axiom is a «widely shared and ... weak» condition. Finally, in models with positive capital productivity it yields implications that are consistent with a concept of sustainability that many writers have suggested. Thus, in such models, the Dalton criterion yields an unquestionable foundation for a concept of sustainability that would, in the absence of such a foundation, appear *ad hoc*.

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