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Abstract

This paper investigates the relationship between intergenerational asset transfers and the choice of the discount rate for use in cost-benefit analysis in a model of a competitive overlapping generations economy constrained by a socially managed exhaustible resource. Provided that there are no distortions in capital markets and that all agents hold perfect foresight, cost-benefit techniques will result in a Pareto efficient resource allocation if the discount rate is set equal to the market rate of interest. But since the path of the interest rate depends on the level of intergenerational transfers, cost-benefit techniques do not ensure a socially desirable distribution of welfare between generations; a social optimum will result only if intergenerational transfers are properly chosen and enforced. Decentralized private altruism may result in intergenerational transfers that both present and future individuals would agree are too small if members of the present generation attach positive weight to the general welfare of future generations, not simply their personal descendants. In a world where intergenerational transfers are non-optimal, second-best policy-making may imply a constrained optimum that is inefficient. Together, these findings suggest that cost-benefit analysis is at best a partial criterion to policy formulation that should be used only in conjunction with ethical principles that define the proper distribution of welfare between present and future generations.

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Introduction

Cost-benefit analysis plays an important role in the economic analysis of public projects and policies. Since programs yield benefits and costs that are realized over time, the results of program evaluations are highly dependent on the choice of the discount rate used to measure net willingness to pay in present-value units. Assuming that there are no distortions in capital markets, that there is no uncertainty with respect to future economic conditions, and that the distribution of wealth between individuals is socially desirable, the market rate of interest, equal to both the marginal return on investment and the marginal rate of substitution with respect to consumption in consecutive periods, constitutes the appropriate discount rate. In the real world, however, such "first-best" conditions generally do not hold, and their violation significantly complicates the choice of the discount rate and the application of cost-benefit techniques (Lind, 1982 and 1990).

A substantial body of research has focused on the implementation of cost-benefit procedures, including the choice of the discount rate, under second-best conditions. The taxation of personal and corporate income, for example, drives a wedge between the pre- and post-tax return on investment so that the marginal rate of substitution and the physical return on investment do not equilibrate. The literature has shown that given such distortions the discount rate is appropriately set equal to the after-tax rate of return, but the cost and benefit streams should be adjusted to reflect the higher pre-tax return of private investment (Lind, 1982; Stiglitz, 1982).

The problem of uncertainty has also received attention. Because risky investments generally must yield higher expected returns than less risky alternatives if they are to attract investors in competitive markets, some analysts have argued that the expected net benefit streams of risky projects and policies should be assessed using a special risk-adjusted discount rate. From a theoretical perspective, however, both the nature and distribution of risk are relevant to the identification of the willingness to pay for uncertain net benefit streams, so issues related to uncertainty may not be satisfactorily resolved through the mere choice of the discount rate (Wilson, 1982).

In this paper, we focus on a third concern — the implications of the distribution of welfare between present and future generations for the choice of the social discount rate and, more broadly, the use of cost-benefit procedures. Many have noted the apparent perversity of disounting costs and benefits accruing to members of future generations. Since the use of a positive discount rate implies that virtually no weight is attached to impacts a generation or more into the future, a growing number of philosophers and resource policy analysts have called for the rejection or extension of the cost-benefit approach to make way for criteria that explicitly reflect society's presumed obligation to provide for the welfare of future generations (Partridge, 1981; Weiss, 1984; WCED, 1987; Howarth, 1992). Within the cost-benefit framework, economists have debated the conditions under which second-best concerns over intergenerational equity justify the rejection of discounting procedures or at least the use of a social discount rate below the private rate used in private decision-making (Marglin, 1963; Markandya and Pearce, 1988; Batie, 1989; Daly and Cobb, 1989).

Marglin (1963) provided the best recognized argument that investments may yield social returns that are not captured by private investors and hence are not reflected by the market rate of interest. If each member of the present generation is broadly concerned about the welfare of future generations, not just her own offspring, she will benefit from the actions of others to benefit future persons whether or not she takes such actions herself. Alternatively, investments made by selfish individuals may yield spillover benefits to others that are not reflected by the prevailing interest rate (Sen, 1982). In either case, future welfare takes on the characteristics of a public good, and private individuals underinvest in productive assets. This argument has been used to support the position that the appropriate social discount rate should be lower than the market interest rate.

We argue below that attempts to achieve intergenerational equity through the choice of the discount rate are based in part on a misinterpretation of the role of cost-benefit procedures in the overall framework of welfare economics. Cost-benefit analysis is properly concerned with allocative efficiency, not distributional equity, and concerns for the distribution of welfare between generations should be addressed through the identification and enforcement of appropriate intergenerational asset transfers rather than through manipulation of the discount rate. Given a desirable distribution of assets between generations and ignoring potential uncertainties and distortions in capital markets, the market interest rate constitutes an appropriate indicator of the social discount rate, and cost-benefit procedures may be used to improve allocative efficiency to the benefit of both present and future generations. But where the distribution of assets is undesirable, cost-benefit procedures may fail to support even allocative efficiency. Our analysis therefore implies that cost-benefit analysis is at best a partial criterion to applied policy analysis that should be used only in conjunction with ethical principles that define the proper distribution of welfare between present and future generations.

These issues are investigated using a set of highly simplified models of natural resource allocation in competitive intertemporal economies. While one might challenge our models as literal descriptions of the many complexities of economic reality, we believe that they shed light on important conceptual relationships that are directly relevant to real-world concerns. What matters is not the particular assumptions of the models but rather what their underlying structure implies for the process of optimal resource planning. In this sense, the models are much more general than their apparent simplicity might suggest.

We believe that the concepts illustrated below may find application in a broad array of policy contexts. The problem of intergenerational equity looms large in natural resource and environmental planning, and the criterion of sustainable development, which holds that policy makers should seek to meet the needs of the present generation without compromising the ability of future generations to meet their own needs (WCED, 1987), has won wide acceptance national governments and the world community. The response of economists to the sustainability criterion has been mixed. While some have embraced the criterion as a reflection of social values that should be incorporated into the decision-making process (Page, 1977; Tietenberg, 1984; Pearce and Turner, 1990), others have argued that sustainability contradicts established principles of allocative efficiency as embodied in standard cost-benefit techniques. We would argue that there is in fact no such contradiction and that the apparent contradiction is due to the misframing of the normative issues at stake. Sustainability is a criterion defining the just distribution of resources between generations; cost-benefit analysis is intended to achieve society's objectives — whatever they may be — as efficiently as possible (Howarth and Norgaard, 1992).

Whether or not the sustainability criterion captures social preferences regarding the proper distribution of welfare between generations, the problem of intergenerational equity implies that policies must be coordinated with proper regard to such preferences, however they are defined (Howarth and Norgaard, 1990; Howarth, 1991a and 1991b). If all decisions were made using cost-benefit techniques on the grounds that their marginal impacts on the distribution of welfare were small, the resulting state of affairs might be "intertemporally efficient and yet be perfectly ghastly", as Dasgupta and Heal (1979, p. 257) framed the issue. The question of intergenerational equity is not a technocratic problem of selecting the appropriate rate at which future costs and benefits are to be discounted. It is rather a broader question of identifying the kind of world we wish to leave behind to members of future generations and imposing the social institutions required to bring that future into being.

Intertemporal Equilibrium and the Social Discount Rate

To facilitate the analysis of the issues raised above in a parsimonious and conceptually straightforward manner, we consider the allocation of a socially managed nonrenewable resource in a simple three-period economy. There are n identical firms that produce a composite consumption/investment good in sequential periods $t = 1,2,3$ using inputs of labor (L_t), capital (K_t), and an exhaustible resource (R_t) according to the net production function $f_t = (L_t K_t R_t)^{1/3}$. (The assumptions regarding the functional forms and parameter values used in the model are made strictly for illustrative purposes; for a more general analysis, see Howarth, 1991a). It is assumed that firms hold no endowments and are unable to store goods between periods and must therefore purchase inputs during the period in which they are used. The consumption/investment good is taken as numeraire, and the spot prices of labor, capital services, and resource inputs are w_t, r_t, and p_t respectively.

There are two overlapping generations of consumers $t = 1,2$, each of which consists of n identical individuals. A representative individual from generation t lives in periods t and $t+1$, enjoying the sequential consumption levels C_{tt} and C_{tt+1}. Her preferences are defined by the utility function $U_t = 4 + \ln(C_{tt}) + \ln(C_{tt+1})$. Each individual holds an endowment of one unit of labor in each period of her life that she supplies inelastically to the production sector. Individuals of generation 1 each hold an initial capital endowment $K_1 = 1$. While individuals in generation 2 hold no capital endowments, each receives an income transfer T during period 2 from members of generation 1 denominated in units of the consumption/investment good. Each individual of generation t invests part of her period t income in her period $t+1$ capital stock (K_{t+1}), and consumers rent the capital under their control to the production sector. For the time being, we shall assume that the transfer level T is chosen and enforced by an independent social institution — the government — on the basis of some criterion defining the proper distribution of welfare between generations. Individuals therefore take the income transfers they give and receive as fixed, although we shall later generalize the model to consider the implications of private income transfers rendered on the basis of explicit intergenerational altruism.

The initial resource stock ($S = 4n$) is controlled by a public resource management agency that sells R_t units of the resource to each firm in period t so that the total rate of extraction is nR_t. Extraction costs are assumed equal to zero, and the proceeds from resource sales are distributed equally to the consumers alive at each date. Markets are assumed to be perfectly competitive, and each agent has perfect foresight regarding future prices and economic conditions. While the number of firms and individuals in each generation is not especially important, it is convenient to assume that n is large so that the assumption of perfect competition is reasonable. Competitive equilibrium is established through the simultaneous satisfaction of the maximization problems confronting each agent, and it is to those problems that we now turn.

Natural Resource Planning

We assume that the resource management agency seeks to maximize the net present value of resource utilization over time in accordance with the partial equilibrium approach of cost-benefit analysis. As the problem is typically formulated (Hotelling, 1931; Fisher, 1981, ch. 2), the current-period benefit from resource utilization is $\int_0^{nR_t} p_t(x)dx$ where $p_t(nR_t)$ is the inverse market demand function for resource inputs. The criterion function thus takes the form $\sum_{t=1}^{3}\delta_t \int_0^{nR_t} p_t(x)dx$ where the discount factor δ_t is equal to one for date 1 and $\prod_{\tau=1}^{t}\frac{1}{1+\rho_\tau}$ for dates 2 and 3 where $\rho_t \geq 0$ is the social discount rate at time t. Maximization of this expression subject to the constraints that resource sales are nonnegative and that cumulative resource extraction does not exceed the initial resource stock yields the following first-order conditions for the achievement of an interior solution:

$$\frac{p_{t+1}}{p_t} = 1 + \rho_{t+1} \qquad (1)$$

$$\sum_{t=1}^{3} nR_t = S. \qquad (2)$$

These conditions hold that the resource price should rise at the social discount rate and that resource utilization should fully exhaust the initial resource stock over time. Together, they imply that the marginal social value of resource use, evaluated in present-value units, should be constant from period to period and that none of the resource should be wasted through disuse.

The application of this approach to the case under consideration raises certain technical difficulties. Because the production functions of the various firms are linearly homogeneous, resource demand is not a well-defined function of prevailing market prices. We may sidestep this issue, however, by assuming that the agency makes use of eqs. (1)-(2) in deciding its plan of action on the basis of marginalist arguments that are not contingent on the social surplus approach.

Profit Maximization

As noted above, we assume that firms are unable to store inputs from period to period and instead purchase inputs during the period in which they are used. This assumption implies that a representative firm will seek to maximize its period t profit level $\pi_t = f_t(L_t, K_t, R_t) - w_t L_t - r_t K_t - p_t R_t$ independently in each period subject to the constraint that input quantities are nonnegative. Differentiation of this function with respect to labor, capital, and resource inputs yields the following first-order conditions that characterize interior solutions:

$$w_t = \frac{\partial f_t}{\partial L_t} \tag{3}$$

$$r_t = \frac{\partial f_t}{\partial K_t} \tag{4}$$

$$p_t = \frac{\partial f_t}{\partial R_t}. \tag{5}$$

Because the production function is linearly homogeneous, profits are zero in each period.

Utility Maximization

To derive the conditions generated by utility maximization, we must first outline the budget constraints faced by representative members of each generation. In period 1, each member of generation 1 receives a total income of $w_1 + r_1K_1 + p_1R_1$ from sales of labor and capital services and her share of period 1 resource revenues. Her expenditure on purchases of consumption and net capital investment is $C_{11} + K_2 - K_1$. In period 2, she receives the net income level $w_2 + (1 + r_2)K_2 + \frac{1}{2}p_2R_2 - T$, the entirety of which is spent on consumption. (Because the total period 2 resource revenue nR_2 is divided equally between the $2n$ individuals alive at the time, each individual's share is given by $\frac{1}{2}R_2$.) This holds because each individual consumes the capital stock remaining at the end of her life or sells it to members of the next generation. Accordingly, a representative member of generation 1 faces the period 1 and 2 budget constraints:

$$C_{11} + K_2 = w_1 + (1 + r_1)K_1 + p_1R_1 \tag{6}$$

$$C_{12} = w_2 + (1 + r_2)K_2 + \frac{1}{2}p_2R_2 - T. \tag{7}$$

The budget constraints for members of generation 2 are somewhat different in form because these individuals hold no initial capital endowments but instead receive income transfers during the first period of their lives. A representative member of generation 2 receives the period 2 income $w_2 + \frac{1}{2}p_2R_2 + T$ while her expenditure on consumption and capital investment is $C_{22} + K_3$. In period 3, her income is $w_3 + (1 + r_3)K_3 + p_3R_3$ while her expenditure is C_{23}. Her period 2 and 3 budget constraints thus take the form:

$$C_{22} + K_3 = w_2 + \frac{1}{2}p_2R_2 + T \tag{8}$$

$$C_{23} = w_3 + (1 + r_3)K_3 + p_3R_3. \tag{9}$$

The problem confronting a representative member of each generation is to maximize her intertemporal utility subject to her budget constraints and nonnegativity constraints on her consumption levels and the capital stock under her control. Since markets are competitive, individuals take prevailing prices as given along with the income transfer level and the revenues they receive from the resource management agency. This problem generates the first-order condition:

$$\frac{\partial U_t / \partial C_{tt}}{\partial U_t / \partial C_{tt+1}} = 1 + r_{t+1} \tag{10}$$

that holds in the case of an interior solution.

Competitive Equilibrium

A competitive equilibrium is defined as a set of values for the variables in the model such that the resource planning, profit maximization, and utility maximization conditions specified by eqs. (1)-(10) are simultaneously satisfied subject to the restriction that markets for labor, the consumption/investment good, and resource inputs clear in each period. Provided that members of generation 1 are technically able to achieve the income transfer level mandated by the government, it may be shown that an equilibrium exists for the economy in question. Before examining the equilibria that arise under alternative income transfer levels, however, we shall examine the efficiency properties of the economy and the relationship between allocative efficiency and the choice of the social discount rate. An allocation is intergenerationally efficient if it would be impossible to increase the welfare or utility of any individual in any generation without decreasing the welfare of some other individual. For the case at hand, it may be shown that efficient allocations satisfy the condition:

$$\frac{\partial U_{ti} / \partial C_{tti}}{\partial U_{ti} / \partial C_{tt+1i}} = \frac{\partial U_{tj} / \partial C_{ttj}}{\partial U_{tj} / \partial C_{tt+1j}} = \frac{\partial f_{t+1} / \partial R_{t+1}}{\partial f_t / \partial R_t} = 1 + \frac{\partial f_{t+1}}{\partial K_{t+1}} \tag{11}$$

where the subscripts i and j denote the utility and consumption levels of any two individuals of generation t. Allocative efficiency requires that the marginal rate of substitution with respect to consumption in consecutive periods is identical across the members of a particular generation and is equal to the marginal returns on investments in capital and resources. Will competitive equilibria satisfy these conditions? Suppose that the social discount rate ρ_t applied to benefits acrruing at dates 2 and 3 is set equal to the market interest rate or price of capital services. Eqs. (1), (4), (5), and (10) then imply that the condition is indeed satisfied. But if the discount rate differs from the interest rate, eq. (11) *is not* satisfied. These facts illustrate the conclusion that *competitive equilibria will be efficient if and only if the social discount rate is set equal to the market rate of interest.*

How do the intergenerational welfare distribution and the path followed by the discount rate depend on intergenerational transfers? We assume that the discount rate is set equal to the market interest rate and investigate the consequences of three income transfer regimes:

(1) the *laissez faire* policy, where the income transfer level is set equal to zero;

(2) the *maximin* policy, where the income transfer level is chosen to support the social optimum defined by the social welfare function $W_1 = \min\{U_{ti} : t = 1,2; i = 1,2,\ldots,n\}$ as a competitive equilibrium;

(3) the *utilitarian* policy, where the income transfer level is chosen to support the social optimum defined by the social welfare function $W_2 = \sum_{t=1}^{2}\sum_{i=1}^{n} U_{ti}$ as an equilibrium.

Here, as above, U_{ti} denotes the utility of the ith individual of generation t. The equilibria that result under each of these distributional policies are outlined in Table 1.

The results indicate that the utility and consumption levels achieved by members of the future generation are low in comparison with those of the present in the absence of intergenerational transfers. The maximin optimum provides equivalent utility levels to members of each generation, and the utility of future individuals exceeds that of their predecessors under the utilitarian optimum.

As the income transfer level is increased from 0 to 1.35, the welfare of future individuals increases while the period 2 and 3 interest rates fall. Since in this model the social discount rate is set equal to the market rate of interest, comparatively low discount rates are associated with the redistribution of welfare from present to future. It is important to note, however, that intergenerational equity (however defined) may be achieved through the enforcement of appropriate intergenerational transfers, not through manipulation of the discount rate *per se*. The rule for selecting the discount rate remains unaltered regardless of social objectives regarding the distribution of welfare between generations.

For the cases considered, transfers of assets from present to future reduce the rate of resource extraction in periods 1 and 2 and accelerate the rate of capital accumulation. Intergenerational transfers thus advance conservationist principles in the sense that stocks of productive assets — including natural resources — are reserved for future utilization.

Equilibrium with Intergenerational Altruism

The model developed in the preceding sections embodies an interesting paradox: The model as it stands assumes a world of selfish individuals concerned only with their own well-being. The distribution of welfare between generations is relegated to an independent agency — the government — with no explicit foundations in social reality. But the problem of intergenerational equity is significant from a policy perspective precisely because members of the present generation — or at least a substantial number of them — are interested in the welfare of future generations out of concern for their grandchildren or perhaps the general future of our species. Should not this inherent altruism lead private individuals to transfer sufficient assets to future generations to assure them of a reasonable standard of living, resulting perhaps in a socially optimal welfare distribution?

Much of the literature on intergenerational transfers assumes that transfers are motivated strictly by the concern of parents for their immediate offspring, and it is generally known that parent-offspring altruism may lead to intergenerational transfers that support a welfare distribution that might be considered socially optimal under certain distributional criteria (Barro, 1974). But as Marglin (1963) has suggested, an individual's concern for the welfare of future generations may not be limited to her children or grandchildren, but may extend to *all* members of future generations. Under this assumption, the welfare of future generations may be viewed as a public good, and individuals of the present generation will have an insufficient incentive to make transfers large enough to support an optimal intergenerational welfare distribution even when there is unanimity concerning distributional criteria.

To facilitate the analysis and discussion of this issue, we modify our treatment of the utility maximization problem confronting representative members of each generation to allow for explicit intergenerational altruism. Under this setting, income transfers are not assumed to be institutionally mandated but rather are rendered voluntarily based on each individual's ethical preferences. The behavior of firms and the resource management agency remains unchanged; we assume as before that firms maximize their profits and that the agency maximizes the present value of resource utilization over time. Conditions (1)-(5) thus extend directly to the revised model we shall now consider.

Suppose that $U_{ti} = 4 + \ln(C_{tti}) + \ln(C_{tt+1i})$ is interpreted as the ***hedonistic utility*** or consumptive pleasure of the ith individual of generation t. Individuals, however, care not only about their own utility but also about the utility of others. To be specific, we shall assume that each member of the present generation seeks to maximize the ethical valuation function:

$$V_{1i} = U_{1i}(C_{11i}, C_{12i}) + \alpha U_{2i}(C_{22i}, C_{23i}) + \beta \sum_{j \neq i} U_{1j}(C_{11j}, C_{12j}) \qquad (12)$$

$$+ \gamma \sum_{j \neq i} U_{2j}(C_{22j}, C_{23j})$$

where α, β, and γ are constants with values between zero and unity. Under this framework, individual i of generation 1 is the *parent* of individual i in generation 2, and each individual attaches unit weight to her own utility, weighting the utility of her offspring, her contemporaries, and other members of the future generation by the constants α, β, and γ.

Individuals of generation 2 are not concerned about the welfare of their parents, but weight their own utility against the utility of their contemporaries according to the function:

$$V_{2i} = U_{2i}(C_{22i}, C_{23i}) + \theta \sum_{j \neq i} U_{2j}(C_{22j}, C_{23j}) \tag{13}$$

for some $0 \leq \theta \leq 1$.

To proceed further in the discussion, it is necessary to modify the budget constraints faced by each individual. Suppose that T_{ijkl} is the income transfer from the jth individual of generation i to the lth individual of generation k. Without loss of generality, we may assume that all income transfers are effected during period 2. The ith member of generation 1 receives the net transfer income $\sum_{j \neq i}(T_{1j1i} - T_{1i1j}) - \sum_{j=1}^{n} T_{1i2j}$, and her budget constraints take the form:

$$C_{11i} + K_{2i} = w_1 + (1 + r_1)K_1 + p_1 R_1 \tag{14}$$

$$C_{12i} = w_2 + (1 + r_2)K_{2i} + \frac{1}{2}p_2 R_2 + \sum_{j \neq i}(T_{1j1i} - T_{1i1j}) - \sum_{j=1}^{n} T_{1i2j} \tag{15}$$

where K_{t+1i} is the period $t+1$ capital stock commanded by the ith individual of generation t. Similarly, the ith member of generation 2 receives the transfer income $\sum_{j=1}^{n} T_{1j2i} + \sum_{j \neq i}(T_{2j2i} - T_{2i2j})$, and her budget constraints are thus:

$$C_{22i} + K_{3i} = w_2 + \frac{1}{2}p_2 R_2 + \sum_{j=1}^{n} T_{1j2i} + \sum_{j \neq i}(T_{2j2i} - T_{2i2j}) \tag{16}$$

$$C_{23i} = w_3 + (1 + r_3)K_{3i} + p_3 R_3. \tag{17}$$

Using the budget constraints, the consumption levels of each individual may be eliminated from eqs. (12) and (13) so that the ethical valuation functions may be rewritten in terms of equilibrium prices, the rate of resource extraction, and the capital stocks and income transfers selected by each individual (Kimball, 1987; Blanchard and Fischer, 1989, pp. 107-110). Each individual seeks to maximize her valuation function through the choice of the variables under her control subject to the appropriate nonnegativity constraints and taking prices and the behavior of other individuals as given. Assuming the capital stock is positive in each period, the first order conditions generated by these problems may be written in the form:

$$\frac{\partial U_{ti}/\partial C_{tti}}{\partial U_{ti}/\partial C_{tt+1i}} = 1 + r_{t+1} \tag{18}$$

for $t = 1,2$ and:

$$-\frac{\partial U_{1i}}{\partial C_{12i}} + \alpha\frac{\partial U_{2i}}{\partial C_{22i}} \leq 0 \quad (= \text{if } T_{1i2i} > 0) \tag{19}$$

$$-\frac{\partial U_{1i}}{\partial C_{12i}} + \beta\frac{\partial U_{1j}}{\partial C_{12j}} \leq 0 \quad (= \text{if } T_{1i1j} > 0) \tag{20}$$

$$-\frac{\partial U_{1i}}{\partial C_{12i}} + \gamma\frac{\partial U_{2j}}{\partial C_{22j}} \leq 0 \quad (= \text{if } T_{1i2j} > 0) \tag{21}$$

$$-\frac{\partial U_{2i}}{\partial C_{22i}} + \theta\frac{\partial U_{2j}}{\partial C_{22j}} \leq 0 \quad (= \text{if } T_{2i2j} > 0) \tag{22}$$

for $j \neq i$. If we assume that individuals weight their own utility more heavily than that of their contemporaries and that there is a symmetric equilibrium so that the consumption levels of contemporaries are identical, the left-hand sides of relations (20) and (22) will be negative so that there will be no intragenerational transfers. Furthermore, income transfers will occur only between parents and their own children in symmetric equilibria if members of the present generation weight their children's utility more heavily than the utility of other future individuals.

It may be shown that relations (1)-(5) and (18)-(22) define a competitive equilibrium once the various parameters in the model are specified. What are the welfare properties of these equilibria? If the social discount rate is set equal to the market rate of interest, the equilibrium will satisfy eq. (11) and thus be *weakly efficient* in the sense that it is impossible to increase the hedonistic utility of any individual without decreasing the utility of some other individual. As we shall see, however, the preference structure embodied in the model suggests that equilibria may fail to be fully efficient since cases exist where all individuals, both present and future, would prefer larger transfers from present to future than those achieved under *laissez faire* equilibria.

To demonstrate this point, we illustrate the equilibria that arise under three alternative sets of assumptions regarding the parameters specified in the model:

(1) *parent-offspring altruism* — individuals of the present generation care only about themselves and their children, attaching zero weight to the utility of other individuals; future individuals care only for themselves; $\alpha = 0.75$, $\beta = \gamma = \theta = 0$.

(2) *intermediate case* — individuals attach positive weight to the utility of their contemporaries and non-filial future individuals, but weight the utility of their children more heavily; $\alpha = 1/2$, $\beta = \gamma = \theta = 1/(n-1) \to 0$ as $n \to \infty$.

(3) *future welfare as a pure public good* — individuals attach equal weight to the utility of their children and all other present and future members of society; $\alpha = \beta = \gamma = \theta = 3/(n+3) \to 0$ as $n \to \infty$.

The equilibria that arise for each of these cases are outlined in Table 2. Each equilibrium is symmetric, and income transfers occur only between parents and their immediate offspring. As one would expect, the income transferred from present to future rises as the weight parents attach to their children's utility increases. In case 3, the weight attached to future welfare by private individuals is so small that no intergenerational transfers occur.

What are the welfare properties of these equilibria? Suppose, for the moment, that the social welfare function takes the form $W_3 = \sum_{i=1}^{n} V_{1i}$; that is, social preferences are determined by the algebraic sum of the ethical valuation functions of each member of the present generation. The striking result is that the social optimum defined by this criterion is the same for each of the three cases considered and may be supported as a competitive equilibrium given an institutionally enforced transfer level $T = 1.07$ between present and future individuals. This corresponds exactly to the *laissez faire* equilibrium achieved under parent-offspring altruism, so we may conclude that unfettered private behavior may, in at least some cases, generate an optimal distribution of welfare between generations.

For cases 2 and 3, this optimum is not achieved as an equilibrium, although it would be preferred by all individuals, both present and future, over the *laissez faire* outcome as judged by their own ethical preference functions. The interpretation of this result is intuitively apparent. Because each member of the present generation attaches positive weight to the utility of each future individual, income transfers effected by private individuals give rise to social benefits that are not captured by their own distributional preferences. In other words, members of the present generation reap psychic satisfaction from the aggregate transfer of assets from present to future whether or not they contribute to it themselves. Future welfare may therefore be construed as a public good, and private income transfers rendered by altruistic members of the present generation will be insufficient to support a welfare distribution that all individuals would agree is desirable. The present generation would therefore be willing to support public institutions that ensured appropriate transfers of assets from one generation to the next, justifying the "exogenous transfers" approach taken in the first section of this paper.

Even the optimality of the equilibria established under pure parent-offspring altruism breaks down given a richer and more realistic model specification. In reality, most people live in households where assets are shared between members. Parents' efforts to benefit their offspring will thus benefit their offspring's spouses as well, much to the satisfaction of the spouses' parents. Given such interconnections between families, the welfare of children becomes a public good; acting individually, parents will underinvest in their children's futures relative to the outcome that could be achieved through collective action. As Daly and Cobb (1989, , p. 39) point out,

"Your great-great grandchild will also be the great-great grandchild of fifteen other people in the current generation... Presumably your great-great grandchild's well-being will be as much an inheritance from each of these fifteen others as from yourself... The farther in the future is the hypothetical descendant, the greater the number of co-progenitors in the present generation, and consequently the more in the nature of a public good is any provision made for the distant future."

Of course, the presumed optimality of equilibria would also break down if positive weight were attached to the distributional preferences of the future generation. While the rationale for counting only the preferences of the present generation is unclear from an ethical perspective, its political foundations are perfectly obvious. The definition of the presumed social welfare function involves far-reaching questions that are beyond the scope of this paper. Nonetheless, such issues must be addressed by those who would claim that a particular policy is "socially optimal" in a real-world policy environment.

We have shown that if individuals care not only about the well-being of their children but also about the welfare of future persons to whom they are not personally related, the welfare of future generations may take on the characteristics of a public good. This raises the question of whether such an assumption is an appropriate reflection of actual intergenerational preferences. A casual assessment leads us to the conclusion that this issue ought to be taken quite seriously. A great many individuals who neither have nor plan to have children profess a concern for future generations, and participants in debates over such diverse issues as the environment, the national debt, and education often argue that members of the present generation are obligated to provide for future generations *in general*, not simply for their own lineal descendants. Moreover, public intergenerational transfers are readily observed in today's world in the forms of government expenditures on education and support services for the young and the preservation of natural environments for the enjoyment of future generations.

Constrained-Optimal Resource Planning

In a world of optimal intergenerational transfers, the problem of resource planning is clear-cut: the resource management agency should set the social discount rate equal to the market rate of interest and apply cost-benefit procedures to arrive at the socially optimal resource allocation. But in a world where institutional barriers prevent the achievement of distributional objectives via appropriate intergenerational transfers, what criteria should be used in the analysis of proposed resource policies?

Consider the social welfare functions specified by the maximin and utilitarian forms $W_1 = \min\{U_{ti} : t = 1,2; i = 1,2,\ldots,n\}$ and $W_2 = \sum_{t=1}^{2}\sum_{i=1}^{n} U_{ti}$. The unconstrained social optima defined by these criteria are shown in Table 1 and may be supported as competitive equilibria given the income transfer levels $T = 1.03$ and 1.35 respectively. Suppose, however, that there are no institutions to transfer assets from present to future so that the income transfer level is fixed at zero. As before, the proceeds from resource sales are divided equally amongst the individuals alive in each period. Taking the transfer level and the behavioral relations (3)-(10) as given, the resource management agency chooses the rate of resource extraction to maximize social welfare. The equilibria that arise under these assumptions are shown in Table 3.

Several conclusions may be drawn from this exercise. First, a cost-benefit analyst applying the criterion specified by eq. (1) to the equilibria in question and setting the social discount rate equal to the market rate of interest would conclude that resource allocation was inefficient and that the welfare of both present and future individuals could be increased if resources were reallocated and *it were feasible to effect compensatory transfers between generations.* But such transfers are explicitly ruled out under the present assumptions, and the allocations in question, although inefficient, are nonetheless distributionally superior to all other allocations that may be supported as competitive equilibria with zero intergenerational transfers.

A second point is also of direct interest. In the cases at hand, the resource price falls over time in contradiction to the Hotelling rule. On the one hand, this is consistent the use of distributional weights in cost-benefit analysis (Little and Mirlees, 1968; Harberger, 1978). In a world of non-optimal intergenerational transfers, the government acts as if it were discounting marginal benefits accruing to future generations at a *negative* discount rate. But because the appropriate distributional weights are determined by social preferences regarding the distribution of welfare across generations, the rationale for using cost-benefit techniques in the evaluation of resource policy is unclear. We might as well focus directly on the social welfare function. In this sense, it is the application of cost-benefit procedures — not the choice of the discount rate *per se* — that should be called into question. While cost-benefit procedures may be used to identify an efficient allocation of resources subject to the prevailing set of intergenerational transfers, Pareto efficiency and thus cost-benefit analysis may be inappropriate guides to policy in an environment characterized by second-best income distribution.

Conclusions

The principal findings and conclusions of this paper may be summarized as follows. If there is no uncertainty regarding future prices and economic conditions and there are no distortions in capital markets, cost-benefit procedures may be applied to identify an efficient allocation of resources if the discount rate is set equal to the prevailing rate of interest. The efficient allocation of resources so obtained and the discount rate itself depend upon the distribution of assets between generations (Howarth and Norgaard, 1992). Increasing the level of intergenerational transfers lowers interest rates and thus the discount rate appropriate for cost-benefit analysis, at least for the cases considered.

Cost-benefit analysis does not ensure a socially desirable distribution of welfare across generations, and a social optimum will result only if intergenerational transfers are chosen with social objectives regarding the proper distribution of welfare in mind. Furthermore, decentralized private altruism may yield intergenerational transfers that both present and future individuals would agree are too small if members of the present generation attach positive weight to the general welfare of future generations, not simply their personal descendants. This fact suggests a potential role for collective institutions in the provision of intergenerational transfers.

In a world where intergenerational transfers are non-optimal and policy makers are unable to alter them, second-best policy-making may imply a constrained optimum that is inefficient. In such cases, cost-benefit procedures would indicate an opportunity to improve social welfare through the reallocation of resources accompanied by appropriate intergenerational transfers. In the absence of such transfers, however, the resource allocation suggested by cost-benefit techniques might lead to an allocation that was judged to be socially less desirable than the constrained-optimal policy.

Table 1

Competitive equilibria under alternative transfer policies

	laissez faire	Maximin Optimum	Utilitarian Optimum
T	0.00	1.03	1.35
U_1	4.94	4.22	3.93
U_2	2.19	4.22	4.56
C_{11}	1.31	0.94	0.82
C_{12}	1.96	1.33	1.15
C_{22}	0.32	0.95	1.15
C_{23}	0.52	1.31	1.53
L_1	1.00	1.00	1.00
L_2	2.00	2.00	2.00
L_3	1.00	1.00	1.00
K_1	1.00	1.00	1.00
K_2	0.98	1.28	1.38
K_3	0.18	0.62	0.76
R_1	2.14	1.79	1.71
R_2	1.63	1.69	1.71
R_3	0.23	0.58	0.52
w_1	0.43	0.40	0.40
w_2	0.25	0.27	0.28
w_3	0.12	0.23	0.26
r_1	0.43	0.41	0.40
r_2	0.50	0.42	0.40
r_3	0.65	0.37	0.33
p_1	0.20	0.23	0.23
p_2	0.30	0.32	0.33
p_3	0.50	0.44	0.44

Table 2

Competitive equilibria with intergenerational altruism

	Parent-Offspring Altruism	Intermediate Case	Future Welfare as a Pure Public Good
T	1.07	0.71	0.00
U_1	4.18	4.47	4.94
U_2	4.27	3.80	2.19
C_{11}	0.92	1.05	1.31
C_{12}	1.31	1.52	1.96
C_{22}	0.98	0.76	0.32
C_{23}	1.34	1.08	0.52
L_1	1.00	1.00	1.00
L_2	2.00	2.00	2.00
L_3	1.00	1.00	1.00
K_1	1.00	1.00	1.00
K_2	1.29	1.18	0.98
K_3	0.64	0.48	0.18
R_1	1.78	1.89	2.14
R_2	1.69	1.67	1.63
R_3	0.53	0.45	0.23
w_1	0.40	0.41	0.43
w_2	0.27	0.26	0.25
w_3	0.23	0.20	0.12
r_1	0.40	0.41	0.43
r_2	0.42	0.44	0.50
r_3	0.36	0.42	0.65
p_1	0.23	0.22	0.20
p_2	0.32	0.32	0.30
p_3	0.44	0.45	0.50

Table 3

Constrained social optima with zero income transfers

	Constrained Maximin Optimum	Constrained Utilitarian Optimum
T	0.00	0.00
U_1	4.54	4.80
U_2	2.63	2.53
C_{11}	1.00	1.18
C_{12}	1.70	1.88
C_{22}	0.34	0.34
C_{23}	0.75	0.68
L_1	1.00	1.00
L_2	2.00	2.00
L_3	1.00	1.00
K_1	1.00	1.00
K_2	0.71	0.86
K_3	0.16	0.17
R_1	0.36	1.15
R_2	2.34	2.07
R_3	1.30	0.78
w_1	0.24	0.35
w_2	0.25	0.25
w_3	0.20	0.17
r_1	0.24	0.35
r_2	0.70	0.59
r_3	1.23	1.00
p_1	0.66	0.30
p_2	0.21	0.25
p_3	0.15	0.22

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