Chapter 6 Public Goods and Bads

6.1 Introduction

A public good is a commodity for which use of a unit of the good by one agent does not preclude its use by other agents. In short, a *pure public good* is *nonrival*[1] in consumption. This means that once the good is provided, the additional resource cost of another person consuming the goods is zero. Knowledge provides a good illustration. The use of a piece of knowledge for one purpose does not preclude its use for others. In contrast, a *private good* is *rival* in consumption.

Several characteristics are noted.

(1) Even though everyone consumes the same quantity of the good, this consumption need not be valued equally by all.

(2) Classification as a public good is not an absolute (i.e. consumption of an impure public good is to some extent rival).

(3) The notion of *excludability*[2] is often linked to that of public goods.

(4) A number of things that are not conventionally thought of as commodities have public good characteristics (e.g. honesty, trust and fair distribution of income).

(5) Private goods are not necessarily provided exclusively by the private sector (e.g. medical services and housing).

(6) Public provision of a good does not necessarily mean that it is also produced by the public sector.

For a simple exposition, an increase of one unit in the consumption of *private goods* reduces the consumption available to others by one unit. An increase in the consumption of *public goods* leads to no reduction for others. Figure 1 illustrates these relationships.

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[1] Nonrival is defined as consumption of the public good by one household does not reduce the quantity available for consumption by any other.

[2] Non excludability is defined as follows: if the public good is supplied, no household can be excluded from consuming it except, possibly, at infinite cost.

Figure 1 Public and Private Goods.

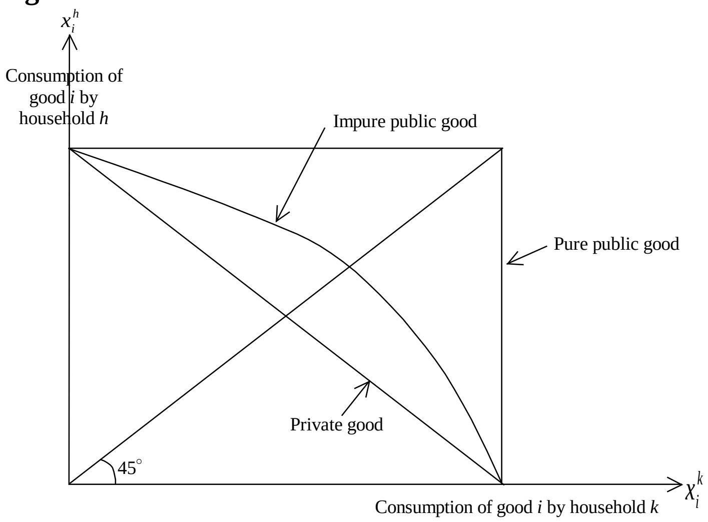

Table 1 provides the list of goods that are commonly, but not necessarily universally, publicly provided. In each case, one can ask whether exclusion is feasible (at reasonable cost), what are the properties of demand, what are the costs of supplying to the individual, and whether these are likely to be distributional arguments.

Table 1 Characteristics of Publicly Supplied Goods

	Costly exclusion	Demand irresponsive	Low cost of individual supply	Distributional arguments
National defense	Yes	Yes	Yes	---
Roads and Bridges	Yes	---	Yes?	---
TV, Radio, Internet	Yes?	---	Yes	---
Education	---	---	---	Yes
Water	---	Yes	---	Yes?
Police	Yes	---	Yes	Yes
Medical care	---	---	---	Yes
Fire protection	Yes	---	---	---
Legal system –Criminal cases	Yes	Yes	Yes	---
--Civil cases	Yes	Yes	Yes	---
Sewerage and Rubbish	---	---	Yes	---
National parks	Yes	---	Yes	---

6.2 The Optimality Condition of Samuelson[3]

Consider an economy where only two goods exists: a private good *x* and a public good *z*. The consumer $i = 1, \cdots, n$ has a utility function $U_i(x_i, z_i)$. The public good is produced from the private good according to a technology given by $z = f(x)$, where *f* is increasing and concave. The initial resources of the economy boil down to *X* units of the private good.

Assume that a quantity *x* of private good is set aside to produce a quantity *z* of public good. Then, the scarcity constraint for the private good expresses that the sum of consumptions must not exceed what remains of the private good, or

$$\sum_{i=1}^{n} x_i \leq \mathrm{X} - x \qquad (1)$$

The consumption of *i* in public good is limited only by the total disposable quantity since the public good is by definition *nonrival*. One gets,

$$z_i \leq z \qquad \forall i = 1, \cdots, n \qquad (2)$$

One obtains the Pareto optima by fixing the utility of the last *n*-1 consumers and by maximizing the utility of *i*=1 under the feasibility constraints, or

$$\begin{aligned} & \max U_1(x_1, z_1) \\ & \quad U_i(x_i, z_i) \geq \overline{U}_i \qquad \forall i = 2, \cdots, n \\ & \quad \sum_{i=1}^{n} x_i \leq \mathrm{X} - x \\ & \quad z_i \leq z \qquad \forall i = 1, \cdots, n \\ & \quad z \leq f(x) \end{aligned} \qquad (3)$$

Recall that in this program *x* represents the quantity of the private good set aside for the production of the public good and *z* the quantity of the public good produced. Since utility functions are increasing, one gets $z_i = z = f(x), \forall i = 1, \cdots, n$. Let us denote *g* the cost in the private good for the production of the public good:

$$z \leq f(x) \Leftrightarrow x = g(z) \qquad (4)$$

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[3] This part is drawn heavily from Salanié (2000), Chapter5.

g is an increasing and convex function. The program is simplified to,

$$\begin{aligned}&\max U_1(x_1, z_1)\\&\quad U_i(x_i, z_i) \geq \overline{U}_i \qquad \forall i = z, \cdots, n\\&\quad \sum_{i=1}^{n} x_i \leq \mathrm{X} - g(z)\end{aligned} \tag{5}$$

The Lagrangean can be written,

$$L = U_1(x_1, z) + \sum_{i-2}^{n} \lambda_i (U_i(x_i, z) - \overline{U}_i) + \mu(X - g(z) - \sum_{i=1}^{n} x_i) \tag{6}$$

normalizing $\lambda_1 = 1$ to make the formulas symmetrical, the first-order conditions are

$$\begin{aligned}&\sum_{i=1}^{n} \lambda_i \frac{\partial U_i}{\partial z} = g'(z)\\&\quad \lambda_i \frac{\partial U_i}{\partial x_i} = \mu, \qquad \forall_i = 1, \cdots, n\end{aligned} \tag{7}$$

From the second group of the above conditions,

$$\lambda_i = \frac{\mu}{\partial U_i / \partial x_i} \tag{8}$$

where, by substituting in the first condition the Pareto-optimality condition which sets the level of public good production,

$$\sum_{i=1}^{n} \frac{\partial U_i / \partial z}{\partial U_i / \partial x_i} = g'(z) = \frac{1}{f'(x)} \tag{9}$$

This is called the optimality condition of Samuelson (1954).

$$\frac{\partial U_i / \partial z}{\partial U_i / \partial x_i} = -\left.\frac{\partial x_i}{\partial z}\right|_{U_i} \tag{10}$$

Notice that is simply the marginal rate of substitution of consumer *i*, that is, his propensity for sacrificing his private good consumption to instigate growth is the level of his public good consumption. But as an increase of public good production by definition benefits all consumers, its marginal cost $g'(z)$ must be compared to the sum of all propensities for paying for a public good (Σ (marginal rates of substitution) = the marginal rate of transformation).

6.3 Public Goods and Market Failures

In order to isolate the role of *exludability* and *rivalronsuess* in consumption, we consider instances in which a good has one property but not the other. For some goods, consumption is non-rival but exclusion is possible (e.g. TV show via pay-TV). Charging a price for a non-rival good prevents some people from enjoying the good, even though their consumption of the good would have no marginal cost. Thus, charging for a non-rival good is inefficient because it results in *underconsumption*. The marginal benefit is positive, the marginal cost is zero. The *underconsumption* is a form of inefficiency.

But if there is no charge for a non-rival good, there will be no incentive for supplying the good (Is it true for free software without any compensation?). In this case, inefficiency takes the form of *undersupply*.

Thus, there are two basic forms of market failure associated with public good: *underconsumption* and *undersupply*. In the case of non-rival goods, exclusion is undesirable because it results in underconsumption. But without exclusion, there is the problem of undersupply.

1) Paying for Public Goods

If exclusion is possible, even if consumption is non-rival, governments often charge fees, called *user fees*, to those who benefit from a publicly provided good or service. Toll roads are financed by user fees. The airline ticket tax can be considered as a user fee. However, when consumption is non-rival, user fee introduces an inefficiency.

2) The Free Rider Problem

Many of the most important publicly provided goods have the property of non-excludability, making rationing by the price system unfeasible. For example, the international vaccine program against smallpox virtually wiped out the disease, to the benefit of all, whether they contributed to supporting the program or not.

The infeasibility of rationing by the price system implies that the competitive market will not generate a Pareto efficient amount of the public good. If every individual believe that he would benefit from the services provided regardless of whether he contributed to the service, he would have no incentive to pay for the services *voluntarily*.

That is why individuals must be forced to support these goods through taxation. The reluctance of individuals to contribute voluntarily to the support of public goods is referred to as the *free rider problem* (think of fire departments and lighthouses).

On the empirical ground, there are good reasons to doubt the importance of the free rider problem.

First, *honesty* is a social norm that models the behavior of individuals. Second, at least in a small group, where each consumer has a notable influence on the level of public good, it is difficult for each agent to calculate the best way to undervalue its demand. Moreover the majority of decisions of public goods production are made by elected representatives who may have less tendency to announce levels that are very low.

6.4 Optimal Provision of Public Goods and Its Finance[4]

To simplify notation in what follows, we will take the private good as the numéraire; that is, its price will be normalized to one.

1) The Subscription Equilibrium

The first solution to consider consists of asking consumers to subscribe part of their wealth to contribute to public good production (*z*). Assume that the wealth of consumer *i* is R_i. He can subscribe s_i to public good production, thus consuming $x_i = R_i - s_i$ private good units. The total quantity of public good produced will be simply $f\left(\sum_{i=1}^{n} s_i\right)$.

The choice of *i* of the quantity s_i is made according to the principles of the Nash equilibrium: *i* will take the quantity subscribed by other consumers s_i as given and will resolve the program.

$$\begin{aligned} \max_{x_i, S_i, z} \quad & U_i(x_i, z) \\ & x_i + s_i = R_i \\ & z = f\left(\textstyle\sum_{i=1}^{n} s_i\right) \end{aligned} \tag{11}$$

[4] This section is also drown heavily from Salanié (2000) Chapter5.

(6.11) can be simplified as

$$\max_{S_i} U_i\left[R_i - s_i, f\left(s_i + \sum_{j\neq i} s_j\right)\right] \tag{12}$$

This leads to the first order condition,

$$\frac{\partial U_i / \partial z}{\partial U_i / \partial x_i} = \frac{1}{f'\left(\sum_{j=1}^{h} s_j\right)} \tag{13}$$

which does not coincide with the optimality condition of Samuelson (10). In effect, when a consumer decides to subscribe to the public good, he takes into account only the increase of his own consumption of public good. He neglects the subsequent growth of the utility of all other consumers, so the equilibrium cannot be optimal. *Under reasonable conditions, subscription equilibrium leads to a subproduction of public good*.

2) Voting Equilibrium

An alternative procedure is to ask the agents to vote for their preferred level of public good. To simplify things, suppose that the public good is produced at a constant marginal cost, that is, $g'(z) = c$ for every *z*. Furthermore, suppose that each consumer believes it is his statement that will determine the level of public good production, and that the production cost will then be distributed equally among all consumers. Then each consumer chooses z_i in such a way as to maximize.

$$F_i(z_i) = U_i\left(R_i - \frac{cz_i}{n}, z_i\right) \tag{14}$$

The voting equilibrium consists of choosing the median agent's preferred level of production. With *m* as the median agent, the retained level of production is z_m such that $F'_m(Z_m) = 0$. So after these immediate substitutions we have

$$\frac{\partial U_m / \partial z}{\partial U_m / \partial x_m}\left(R_m - \frac{cz_m}{n}, Z_m\right) = \frac{c}{n} \tag{15}$$

This result again does not coincide with the optimal condition of Samuelson (6.10).

Contrary to the subscription equilibrium, the voting equilibrium does not necessarily lead to a subproduction of the public good: the direction of the comparison depends on fine characteristics of the distribution of the marginal rates of substitution.

3) The Lindahl Equilibrium

Assume that *personalized prices* for the public good can be established. Every consumer *i* must pay P_i per unit of public good that he consumes. The producer of the public good would perceive a price $P = \sum_{i=1}^{n} P_i$ and produce up to the level where his marginal cost equals *P*:

$$g'(z) = P \qquad (16)$$

Every consumer chooses to equate his marginal substitution rate to his personalized price:

$$\frac{\partial U_i / \partial z}{\partial U_i / \partial x_i} = P_i \qquad (17)$$

At equilibrium the amount of public good in demand by each consumer must equal the amount produced, or

$$z_i(P_i^*) = z(P^*) \qquad \forall i = 1, \cdots, n \qquad (18)$$

From this, the first order condition will be

$$\sum_{i=1}^{n} \frac{\partial U_i / \partial z}{\partial U_i / \partial x_i} = \sum_{i=1}^{n} P_i = P = g'(z) \qquad (19)$$

This time, the optimal condition of Samuelson (10) is verified. The disadvantage to this process is that it assumes as a matter of fact the existence of *n* “micromarkets” upon which a sole consumer buys the public good at *his personalized price*. In such circumstances it is difficult to maintain the competitive hypothesis unless one can assume that the consumers are divided in homogeneous groups from the point of view of their propensity to pay for the public good. In the opposite case, it is in every consumer’s interest to underestimate his demand, hoping that the others will be move honest and that the level of produced public good will then be high enough to meet his needs; this leads to *the free-rider problem*.

4) Personalized Taxation

Suppose that every consumer *i* is taxed by the state in terms of his consumption z_i of public good: the budgetary constraint of the consumer *i* then becomes

$$\frac{\partial U_i / \partial z}{\partial U_i / \partial x_i} = t'_i\,(z_i) \qquad (20)$$

If the state chooses taxes of the form $t_i(z_i) = P_i^* z_i$, where P_i^* is the personalized price of *i* in the Lindahl equilibrium, it is clear that the condition of optimality will hold.

This operation assumes that the state is *privy* to very detailed information about the tastes of all consumers, which is not realistic. In practice, the financing of a public good is accomplished by fiscal resources from taxes and bonds. Insofar as these taxes and bonds bring on economic distortions and affect agent's decisions, the optimality condition of Samuelson must be modified. This *second-best* problem reduces the optimum production level of the public good.

5) The Pivot Mechanism

Consider an indivisible public good of which 0 or 1 unit can be consumed and for which the unit costs *C*. The utilities of the agents are assumed to be quasi-linear: if x_i represents the consumption of the sole private good and *z* that of the public good, we get

$$U_i(x_i, z) = x_i + u_i z \qquad (21)$$

where u_i is a parameter of propensity to pay for the public good which is known only by consumer *i*, who has initial resources R_i in private good at his disposal.

The decision to build a bridge brings a benefit of $\sum_{i=1}^{n} u_i$ and a cost of *C*. In the Pareto optimum the bridge should be built if and only if the sum of propensities to pay exceeds the bridge's cost: $\sum_{i=1}^{n} u_i \geq C$.

A first mechanism consists of asking consumers to vote on the opportunity of building the bridge, knowing that each will contribute equally to its financing.

Then the consumer *i* will vote for the construction if and only if $u_i \geq C/n$. Let *F* be the cumulative distribution function of the characteristics u_i in the population. The bridge will be constructed if and only if $F\left(C/n\right) \geq 1/2$, that is if C/n does not exceed the median of *F*.

The comparison with the Pareto optimal decision rule immediately shows that this mechanism is only optimal if the median of *F* coincides with its average, which has no particular reason to be true.

A second revealing mechanism that implements the optimal decision rule can be considered as an application of the theory of auctions. Assume an indivisible object is proposed to buyers $i = 1, \cdots, n$ whose propensities to pay u_i are known only to themselves. First, consider a first price auction, where the winner (the one who bid the highest) pays the price he indicated. If any consumer *i* announces a price v_i, he will have a utility $u_i - v_i$ if he wins and zero if not. He can guarantee himself a positive utility in expectation by announcing a price v_i inferior to his true disposition to pay u_i, for he can win the bid if the other consumers are not very tempted by the object.

The second price auction suggested by Vickrey consists of making the winner (who is still the one who indicated the highest price) pay the price indicated by the person immediately after him. Consider still consumer *i*, and let $\overline{v_i}$ be the highest price announced by the other consumers. If *i* announces $v_i > \overline{v_i}$, he will win the bid and will have a utility $u_i - \overline{v_i}$; if he bids $v_i < \overline{v_i}$, he will lose and will have a zero utility.

Thus he will choose to bid some $v_i > \overline{v_i}$ if $u_i > \overline{v_i}$ and some $v_i < \overline{v_i}$ if $u_i < \overline{v_i}$. In both cases his utility is independent of his bid, and it is not in his interest to lie.

Interpretation of this result goes as follows. If *P* is the price at which the seller values the object, the social surplus is $u_i - P$. But if the other consumers tell the truth, the increase of utility of *i* in the second price auction when he raises his bid in order to win is $u_i - \overline{u_i}$, which coincides with the increase in the social surplus. The second price auction is a *revealing mechanism* because it leads consumers' objectives to align themselves on the social objective.

To simplify the notation, let us subtract from the u_i the per capita cost c/n, the new u_i can therefore be either positive or negative, and the Pareto-optimal decision rule amounts to constructing the bridge when $\sum_{i=1}^{n} u_i \geq 0$. Let *d*(*u*) be the indicator of that event.

Social surplus, with which the utility of each consumer must be identified, is $\sum_{i=1}^{n} u_i d(u)$. Let $v = (v_i, \cdots, v_n)$ be the statements of the agents. In equilibrium, all consumers must tell the truth; the consumer *i* evaluates the social surplus at

$$\left(\sum_{j\neq i} v_j + u_i\right) d(v) \tag{22}$$

If a transfer $t_i(v)$ is deducted from him, we then have

$$R_i - t_i + u_i d(v) = \left(\sum_{j\neq i} v_j + u_i\right) d(v) \tag{23}$$

which implies

$$t_i(v) = -\sum_{j\neq i} v_j d(v) \tag{24}$$

In fact, we can add to the transfers of every agent any quantity independent of his statement. This mechanism is characterized by

(1) $d(v) = 1$, the bridge is constructed if and only if

$$\sum_{i=1}^{n} v_i \geq 0$$

(2) the consumer *i* pays a transfer

$$t_i(v) = -\sum_{j\neq i} v_j d(v) + h_i(v_{-i})$$

where $h_i(v_{-i})$ is any sum depending only on statements of the other consumers.

This mechanism is revealing in dominant strategies. The utility of *i* under this mechanism is written,

$$R_i + \left(\sum_{j\neq i} v_j + u_i\right) d(v) - h_i(v_{-i}) \tag{25}$$

which depends on the statement v_i of *i* only through $d(v)$. The agent *i* must choose his statement in such a way as to maximize the second term, which gives

$$d(v) = 1 \qquad \text{if and only if } \sum_{j\neq i} v_j + u_i \geq 0$$

But by definition

$$d(v) = 1 \qquad \text{if and only if } \sum_{j\neq i} v_j \geq 0$$

and $v_i = u_i$ is one of the solutions of the program of agent *i*, whatever the statements of the other agents may be.

Since the agent *i* plays a decisive role in his statement, he is called a *pivot* agent and this mechanism is called *the pivot mechanism*.

6.5 Public Bads or Negative Externalities[5]

There are many public bads and negative externalities. When an agent's actions or harm the possibilities of other agents. For example, pollution constitutes a negative production externality, noise or cigarette smoke and negative consumption externalities[6].

1) The Pareto Optimum

Consider an example that comprises two goods (1 and 2), two firms and one consumer. good 1 is polluting and good 2 is nonpolluting.

Firm1 produces good 1 from good 2: $y_1 = f(x_2)$.

The consumer has a utility function: $U(x_1^c, x_2^c)$

Firm 2 produces good 2 from good 1, since it is downstream from firm 1 (which ejects its wastes into river A) and from consumer 1 (who pollutes river B), its production suffers from two negative externalities, so its production function is, $y_2 = g(x_1, y_1, x_1^c)$.

Denote (w_1, w_2) the initial resources of the economy the Pareto optima of this economy are given by the following program:

$$\text{Max} \quad U\left(x_1^c, x_2^c\right)$$

$$\text{subject to} \begin{cases} x_1^c + x_1 \le w_1 + y_1 & (\lambda_1) \\ x_2^c + x_2 \le w_2 + y_2 & (\lambda_2) \\ y_1 \le f(x_2) & (\mu_1) \\ y_2 \le g(x_1, y_1, x_1^c) & (\mu_2) \end{cases} \tag{26}$$

where $\lambda_1, \lambda_2, \mu_1$ and μ_2 are four multipliers.

From the first-order conditions, eliminating the multipliers,

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5 This section is drown heavily from Salanié (2000), Chapter 6.

6 Needless to say, there are many positive externalities. For example, the network effects tied to the extension of a telephone network are positive consumption externalities. Scientific research also constitutes a positive externality.

$$\frac{\left(dU/\partial x_1 + \left(\partial U/\partial x_2\right)\left(\partial g/\partial x_1^c\right)\right)}{\left(\partial U/\partial x_2\right)} = \frac{\partial g}{\partial x_1} = \frac{1}{\partial f/\partial x_2} - \frac{\partial g}{\partial y_1} \quad (27)$$

The left-hand member is the marginal rate of substitution of the consumer, corrected by the fact that his consumption of good 1 entails pollution downstream. This is called the social marginal rate of substitution of the consumer, and it takes into account all of the consequences of his consumption on social welfare. The right-hand member is the marginal rate of transformation of firm 1, corrected by the effect of its pollution on firm 2. The central term is the marginal rate of transformation of firm 2, which coincides its private marginal rate of transformation as firm2 does not pollute.

The principle is that, in the presence of external effects, the usual optimality condition of equality between the marginal rates of substitution of consumers and the marginal rates of transformation of firms bears on the *social* values of these quantities. The social values take into account the external effects of each agent's decisions on the rest of the economy.

At the optimum, firm 1 must produce less, and the consumer must consume less of good 1 than in the absence of externalities.

In 1972 the member countries of the Organization for Economic Cooperation and Development (OECD) adopted the Polluter-Pays Principle (PPP). According to this principle,

> "Public measure are necessary to reduce pollution and to reach a better allocation of resources by ensuring that prices of goods depending on the quality and/or quantity of environmental resources reflect more closely their relative scarcity and that economic agents concerned react accordingly・・・.
>
> The Principle means that the polluter should bear the expenses of carrying out the above mentioned measures decided by public authorities to ensure that the environment is in an acceptable state.
>
> In other words, the cost of these measures should be reflected in the cost of the goods and services which cause pollution in production and/or consumption",
>
> (OECD, 1975).

2) Implementing the Optimum

There are several ways to internalize externalities.

The Competitive Equilibrium

Assume that firm 2 takes the pollution factors y_1 and x_1^c as given. Then if the prices of goods are p_1 and p_2, the agent's choices will lead to the following relation which is inefficient.

$$\frac{\partial U/\partial x_1}{\partial U/\partial x_2} = \frac{p_1}{p_2} = \frac{\partial g}{\partial x_1} = \frac{1}{\partial f/\partial x_2} \qquad (28)$$

In competitive equilibrium the agents only take into account the consequences of their choices on their own welfare, in equating the private marginal rates of substitution and of transformation. Under usual conditions, one can show that there is too much of good 1 being produced and consumed.

Quotas

The simplest way to arrive at a Pareto optimum is of course for the government to set quotas specifying that the externality-inducing activities should be set at their optimal level. This is certainly *an author-itarian solution* and one that assumes a very fine knowledge of the characteristics of the economy. In the example studied here, it would amount to calculating the Pareto-optimal levels of y_1 and x_1^c, which we denote y_1^* and x_1^{c*}, and to forbid firm 1 from producing more than y_1^* and the consumer from consuming more than x_1^{c*} of good 1. It is nevertheless *an oft-adopted solution*, under a slightly less brutal form, that consists of limiting the quantity of a certain type of pollutants emitted by firms or even by consumers (as in carbon emissions of automobiles).

Subsidies for Depollution

It is sometimes possible to install dispositions to reduce pollution. Suppose that firm 1 can invest in depolluting a quantity *a* of good 2 which, without affecting its production, reduces its pollution as if y_1 were $y_1 - d(a)$.

First, let us look for the Pareto optimum. The scarcity constraint for good 2 becomes

$$x_c^2 + x_2 + a \leq \omega_2 + y_2 \qquad (29)$$

while the production constraint of firm 2 becomes

$$y_2 \leq g\left[x_1, y_1 - d(a), x_1^c\right] \qquad (30)$$

The quantity *a* also becomes a maxim and of the program. We easily see that the optimality conditions obtained above are unchanged, but that we must add to them a condition to determine the optimal depollution level a^*:

$$d'(a^*) = -\frac{1}{\partial g / \partial y_1} \tag{31}$$

What happens here with the competitive equilibrium? If firm 1 is not prompted to depollute, it will of course choose not to do so. It still seems reasonable for the government to subsidize such an expense by paying firm 1 a sum *s*(*a*). The profit maximization program of firm 1 then becomes

$$\max_{x_2, a}\left[p_1 f(x_2) - p_2 x_2 - p_2 a + s(a)\right] \tag{32}$$

while firm 2 maximizes in x_1

$$p_2 g\left[x_1, y_1 - d(a), x_1^c\right] - p_1 x_1 \tag{33}$$

The condition of profit maximization of firm 1 implies that

$$s'(a) = 1 \tag{34}$$

So choosing subsidy s(.) such that $s'(a^*) = 1$ induces the firm to realize the socially optimal expenditures of depollution. Unfortunately, the first-order conditions also entail

$$\frac{\partial g}{\partial x_1} = \frac{1}{\partial f / \partial x_2} \tag{35}$$

So the subsidized equilibrium is still not Pareto optimal.

The Rights to Pollute

Meade (1952) suggested a solution to the problem of external effects which has generally found favor with economists (and more rarely with decision makers). It rests on the finding that externalities contribute to inefficiency only because no other market exists upon which they may be exchanged. Therefore assume that the state (or any other institution) creates a “rights to pollute” market: a right to pollute gives the right to a certain number of pollution units. The polluters (firm 1 and the consumer) can then pollute with the proviso that they buy the corresponding rights to pollute. Thus

- firm 1 pays q to firm 2 for each unit of y_1
- the consumer pays r to firm 2 for each unit of x_1^c

The consumer's program gives

$$\frac{\partial U/\partial x_1}{\partial U/\partial x_2} = \frac{p_1 + r}{p_2} \tag{36}$$

while the profit maximization of firm 1 implies that

$$\frac{p_1 + q}{p_2} = \frac{1}{\partial f/\partial x_2} \tag{37}$$

As for firm 2, it must take into account payments it receives for determining the number of pollution rights it is ready to sell; it solves therefore

$$\max_{x_1, y_1, x_1^c} \left[p_2 g(x_1, y_1, x_1^c) - p_1 x_1 + r x_1^c + q y_1 \right] \tag{38}$$

whence

$$\begin{cases} \dfrac{p_1}{p_2} = \dfrac{\partial g}{\partial x_1} \\ \dfrac{q}{p_2} = -\dfrac{\partial g}{\partial y_1} \\ \dfrac{r}{p_2} = -\dfrac{\partial g}{\partial x_1^c} \end{cases} \tag{39}$$

All of these equalities amount to

$$\frac{(\partial U/\partial x_1) + (\partial U/\partial x_2)(\partial g/\partial x_1^c)}{\partial U/\partial x_2} = \frac{\partial g}{\partial x_1} = \frac{1}{\partial f/\partial x_2} - \frac{\partial g}{\partial y_1} \tag{40}$$

which is the condition of efficiency. The creation of markets for rights to pollute thus implements a Pareto optimum[7]. In other respects, it is a system far less demanding than the imposition of pollution quotas, since the calculation of such quotas implies that the state knows the preferences and technologies of all agents. It is enough here for the state to open pollution rights markets and let equilibrium establish itself[8].

This result merits some comments. First, note that the consumer and firm 1 do not necessarily pay the same price to pollute at equilibrium. We would get q=r only if the pollution was impersonal in the sense that $g(x_1, y_1, x_1^c) = G(x_1, y_1 + x_1^c)$. Second, there is one sole applicant and one sole supplier on each open pollution rights market in this example, which raises the problem of strategic behaviors. This solution is therefore better adapted to situations where the pollution is of collective origin – we can imagine similarly disposed polluters around the same lake[9].

Taxation

It is conceivable to tax the production of the good 1 at the rate τ and its consumption at the rate t. It is easy to see that if one chooses $\tau = q$ and t=r, where q and r are the equilibrium prices on virtual markets of pollution rights, we again find a Pareto optimum. These tax levels are often called *Pigovian taxes*, in honor of Pigou (1928). The disadvantage to this remedy is that like the imposition on the pollution quotas, one needs extraordinarily detailed information on the primitive data of the economy, since the government must be able to calculate the equilibrium prices on pollution rights markets.

The Integration of Firms

For simplicity's sake assume that the consumer does not pollute, so $\partial g / \partial x_1^c = 0$. In this case one can envision the two firms as merging (in economic terms, we speak of "intergrating"). The new firm thus formed will maximize the joint profit as

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[7] Neglected here are second-order conditions, which Starrett (1972) has shown are problematic. In effect, function g cannot be concave in y_1 or x_1^c on all of IR[+], since it is decreasing and positive. The program of firm 2 is therefore nonconvex, and this can cause difficulties for equilibrium.

[8] We assume that the pollutees are authorized to sell pollution rights, which results in an optimal pollution level. In practice, these markets are often reserved to the polluters. The pollution level attained depends then on the number of rights put into circulation, which poses the problem of the government's capacity to calculate the optimal pollution level, to issue the correct number of rights to pollute, and to resist the pressure of agents who would like to see that number modified.

[9] One of the most spectacular applications of the pollution rights market functions in the San Francisco bay area (see Henry 1989). The regulation of thermal power stations and of sulfur dioxide emissions in the United States offers other examples. More recently the summit on global warming held in Kyoto in 1997 decided to study the use of rights markets at the world level.

$$\begin{cases} \max_{x_1,x_2,y_1} \left[p_1 f(x_2) + p_2 g(x_1, y_1) - p_2 x_2 - p_1 x_1\right] \\ \qquad\qquad y \leq f(x_2) \end{cases} \tag{41}$$

which gives

$$\frac{p_1}{p_2} = \frac{\partial g}{\partial x_1} = \frac{1}{\partial f / \partial x_2} - \frac{\partial g}{\partial y_1} \tag{42}$$

Again we have the Pareto optimum. The solution is obviously radical, and it shows little regard for property rights. We often see in industrial economics that the market power conferred upon mastodons is not without inconveniences. Nevertheless, the integration of firms is not to be discarded entirely.

Must Prices or Quantities Be Regulated?

We have seen that regulation by quantities (e.g., in the form of emission quotas) and regulation by prices (e.g., by taxation) both permit the restoration of Pareto-optimality of the equilibrium and are therefore equivalent. Let us follow Weitzman (1974) and consider a pollutant production q. The firm has costs $C(q)$ and its profit is then $\left(pq - C(q)\right)$ if the price is p. The production entails "benefits" $B(q)$ and a consumer surplus $B(q) - pq$.

This modeling suggests two comments. The first is of a semantic nature: many times students are amazed that pollutant production can be beneficial. In reality there is often joint production of a useful good and of pollution; what we call "benefits" of the pollutant production is the value of useful production minus the cost inflicted by pollution. The difference between benefits and costs is generally maximal for a positive level of pollution.

The reader will note that in this interpretation[10], the social production cost at once comprises the production cost $C(q)$ and the pollution cost, which was deducted from the value of production to get $B(q)$.

The second comment is more technical. In the example we have studied so far q would be y_1, the production of firm 1. This production permits the consumer to raise his consumption of good 1, but it reduces the production possibilities of firm 2. The sum of these two effects constitutes the "benefits" of y_1, which has moreover a cost given by the technology of firm 1. Unfortunately, it is not possible to describe the result in the form of a benefit minus a cost.

[10] We could resort to a dual interpretation where q represents the nonpolluted good, like air quality.

Such a breakdown is in fact more reasonable when the pollution injures consumers. In the interest of not straying too far from our needs, we will disregard this consideration here. We will also make the usual hypotheses that $B(q)$ is increasing and concave and $C(q)$ increasing and convex.

When information is perfect, the optimal emission quota is calculated by maximizing the social surplus $\left(B(q)-C(q)\right)$. We then get

$$B'(q^*) = C'(q^*) \tag{43}$$

As for the optimal tax rate, it is fixed in such a way that the prices verify

$$p^* = B'(q^*) = C'(q^*) \tag{44}$$

Then the firm effectively produces the optimal pollution level q^*.

At this stage the two modes of regulation are perfectly equivalent. Still, opinions on their respective advantages are generally quite clear-cut. As noted by Weitzman (1974, p.477):

> I think it is a fair generation to say that the average economist in the Western marginal tradition has at least a vague preference toward indirect control by prices, just as the typical noneconomist leans toward the direct regulation of quantities.

The introduction of an imperfection of government information on the costs and benefits will let us compare the two modes of regulation. Thus suppose that either because the agents benefit from private information or because the future is uncertain, the cost and benefit functions are affected by independent shocks θ and η so that they become $C(q,\theta)$ and $B(q,\eta)$.

Ideally price or quantity would be fixed conditionally to realizations of shocks in such a way as to verify

$$p^*(\theta,\eta) = \frac{\partial B}{\partial q}\left[q^*(\theta,\eta),\eta\right] = \frac{\partial C}{\partial q}\left[q^*(\theta,\eta),\theta\right] \tag{45}$$

and regulations by prices and by quantities would remain strictly equivalent.

In practice, this *first-best* solution is beyond reach, since the government must make decisions knowing only the distributions of η and θ and not their realizations. In this *second-best* situation, the government chooses the emissions quota $\hat{q}$ so as to maximize the expected social surplus

$$E\big(B(q,\eta) - C(q,\theta)\big) \qquad (46)$$

Things are only slightly more complicated for regulation by price. If the government fixes a price *p*, the firm will choose a production $Q(p,\theta)$ such that

$$p = \frac{\partial C}{\partial q}\left[Q(p,\theta),\theta\right] \qquad (47)$$

The government must then fix the price at the level $\hat{p}$ that maximizes

$$E\left\{B\left[Q(p,\theta),\eta\right] - C\left[Q(p,\theta),\theta\right]\right\} \qquad (48)$$

This time there is no more reason that the two modes of regulation be equivalent. In fact it is easily checked (using second-order calculations for small uncertainties) that the advantage (in terms of expected social surplus) of regulation by prices on regulation by quantities is

$$\Delta \simeq \frac{\sigma^2}{2(c'')^2}\left(\frac{\partial^2 B}{\partial q^2} + \frac{\partial^2 C}{\partial q^2}\right) \qquad (49)$$

where σ^2 is the variance of the marginal cost $\partial C/\partial q$. Since *B* is concave and *C* convex, the sign of Δ is ambiguous a priori. Note that if marginal costs are almost constant, then regulation by quantities will dominate regulation by prices. In effect a small error in price setting can lead to a large error in the level of pollution attained.

6.6 Coase's Theorem

In a famous article Coase (1960) doubted the necessity of any governmental intervention in the presence of externalities. His reasoning is very simple: let $b(q)$ be the benefit that the polluter draws from a level of pollutant production *q* and $c(q)$ the cost thus imposed on the pollutee[11]. When *b* is concave and *c* increasing and convex, the optimal pollution level is given by

$$b'(q^*) = c'(q^*) \qquad (50)$$

[11] Be careful not to identify this notation with that of the preceding section.

Suppose that the status quo q_0 corresponds to a situation where $b'(q_0) < c'(q_0)$, and thus the pollution level is too high. Then the polluter and the pollutee have an interest in negotiating. Let ε be a small positive number, and assume that the polluter proposes to lower the pollution level to $(q_0 - \varepsilon)$ against a payment of $t\varepsilon$, where *t* is comprised between $b'(q_0)$ and $c'(q_0)$. Since $t > c'(q_0)$, this offer raises the polluter's profits; and it is equally beneficial for the pollutee, since $t < b'(q_0)$. Therefore the two parties will agree to move to a slightly lower pollution level. The reasoning does not stop here: so long as $b' < c'$, it is possible to lower the pollution level against a well-chosen transfer from pollutee to polluter. The end result is the optimal pollution level. A very similar argument applies in the case where $b'(q_0) > c'(q_0)$. The "Coase theorem" can thus be set forth as follows:

If property rights are clearly defined and transaction costs are zero the parties affected by an externality succeed in eliminating any inefficiency through the simple recourse of negotiation.

Stated in this way, the theorem becomes more a tautology: if nothing keeps the parties from negotiating in an optimal manner, they will arrive at a Pareto optimum. In fact Coase (1988) explained in a collection of his articles that above all he wanted at the time to bring attention to the importance of property rights and of transaction costs. Unfortunately, it is more than anything his "theorem" that has passed into posterity.

What happens if the hypotheses of the theorem do not hold? First of all note that in many industrial pollution cases, property rights are not defined. For a common resource like ocean fish, for example, it is impossible to identify the polluters and the pollutees and then put a negotiation into place; Coase's theorem is therefore of no great help to us in attacking overfishing. Even if property rights are clearly defined, transaction costs are rarely negligible. For example, these costs include expenses incurred during negotiation (lost time, necessary recourse to lawyers, etc.). In the argument above, an elementary negotiation improves the social surplus by $\left(c'(q_0) - b'(q_0)\right)\varepsilon$. If the salary of the retained lawyer is higher, the parties will renounce this stage of the negotiation and will stop before having attained the optimal level.

Recent literature has above all insisted on the transaction costs due to asymmetrical information[12]. If the polluter has private information on $b'(q_0)$ and the pollutee has private information on $c'(q_0)$, each will try to "hog the blanket", thereby manipulating the transfer *t*. Myerson-Satterthwaite (1983) show that under these conditions the parties will not be able to

[12] Farrell (1987) offers a good discussion of this topic.

achieve a Pareto optimum. When the concerned parties become more numerous, it is of course much more difficult for each to them to manipulate this "prices" *t*. In fact the negotiation becomes again asymptotically efficient when the number of agents tends toward infinity (Gresik-Satterthwaite 1989). One can still wonder about the capacity of a large number of polluters and pollutees to negotiate together, since other transaction costs then risk coming out.

These critiques do not reduce the interest in the Coase theorem to nothing. In fact Cheung (1973) shows that in the case of the beekeeper-orchard crossexternality made popular by Meade, there exist in the United States contracts between two parties that seek to internalize the externality. It is therefore reasonable to think that under certain conditions the private agents, left to themselves, can effectively negotiate to arrive at a level of externality that, if not optimal, is at least more satisfying. The imperfections of such a solution to the externality problem must in any case be compared to those of the Pigovian solutions in a world where governmental information is quite imperfect.

6.7 Intergenerational Equity: How to discount the future? [13]

A. The Basic Problem

The argument thus far has not explored the question of intergenerational equity. Of course the amounts spent by future generations involve money, and at first glance that money must be discounted, simply because it is money. But critics are correct to say that discounting might contribute to serious problems involving intergenerational equity[14]. The reason is that with discounting, a cost-benefit analysis can lead the current generation to impose extremely high burdens and costs on future generations – leading to a net welfare loss, a serious distributional problem, rights violations, or all three[15]. To be sure, people might well have a pure time preference for money, choosing $100 today over the financially equivalent sum in a year[16]. But a pure time preference on the part of those now living cannot justify a discount rate with respect to harms faced by people not yet born[17].

It is possible, of course, that even without much worrying about its obligations to posterity, current generations will contribute a great deal to their welfare. The course of human history,

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[13] This section is drawn from Sunstein and Rowell (2007) pp.188-203.

[14] See Revesz, 99 Columbia L Rev at 996-1002 (cited in note 8) (suggesting that intergenerational discounting is unethical because pure time preferences mean that the current generation will use the majority of the available resources for its own welfare).

[15] See Portney and Weyant, *Introduction* at 6(cited in note 13) (emphasizing the distributional problem and noting that "efficiency is hardly the only criterion that matters in policy analysis").

[16] As noted, a pure time preference is challenged as irrational in Cowen and Parfit, *Against the Social Discount Rate* at 155 (cited in note 14). See also note 38 and accompanying text.

[17] Id ("Pure time preference within a single life does not imply pure time preference across different lives.").

with astounding improvements in wealth, health, and longevity, makes it more than plausible to suggest that such contributions do occur over time[18]. But there is no assurance that they will continue to occur, in general or for particular risks[19]. Consider, for example, the problems of ozone depletion and climate change. The former problem once threatened, and the latter now threatens, to impose catastrophic risks on those who will come later[20]. When the costs will be faced immediately, and the benefits enjoyed in the distant future, a cost-benefit analysis, based on discounting, can create genuine risks of both net welfare losses and distributional inequity[21].

It is not at all clear, however, that a refusal to discount is the best way of reducing those risks. On the contrary, any such refusal might well injure members of future generations. When the costs of regulations will be incurred in the distant future, and the benefits enjoyed immediately, discounting can be actually quite helpful to future generations, because it ensures current investments that redound to their benefit[22]. And if present benefits will ultimately produce welfare gains for future generations, a refusal to discount can be quite harmful; most of the time, the future gains from the increased wealth of the present[23].

It follows that the question of discounting should be separated from the question of obligations to future generations. It is not productive to collapse those two questions. If cost-benefit analysis with discounting imposes a serious loss on members of future generations, the current generation should be asked to fulfill whatever moral obligations it has. A refusal

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[18] See Vernon Smith, *Expert Panel Ranking*, in Bjørn Lomborg, ed, *Global Crises, Global Solutions* 630, 635 (Cambridge 2004) (stating that delay on global warming makes sense because of future gains in wealth, science, and knowledge); Thomas Schelling, *Expert Panel Ranking*, in Lomborg, ed, *Global Crises* 627, 627 (arguing that it makes no sense for current generations to pay to combat global warming because future generations will be "much richer" than current ones).

[19] See Posner, *Catastrophe* at 151-53 (cited in note 9) (arguing that inaction is not the right course of action just because of uncertainty as to future capabilities and events); Robert C. Lind, *Analysis for Intergenerational Decisionmaking*, in Portney and Weyant, *Discounting and Intergenerational Equity* at 173, 176 (cited in note 2) (arguing that there is no guarantee that current generations will contribute to future generations).

[20] See Cass R. Sunstein, *Montreal vs. Kyoto: A Tale of Two Protocols* 30 Harv Envir L Rev (forthcoming 2007) (emphasizing intergenerational inequities that both problems yield because the chemicals and gases produced "stay in the atmosphere for an extremely longtime").

[21] William Baumol suggests that a low discount rate, or even a zero discount rate, might make sense in narrow circumstances, such as those in which the goal is to prevent environmental damage that is both irreversible and potentially catastrophic. See Baumol, 58 Am Econ Rev at 801 (cited in note 9) (asserting that a high discount rate is appropriate in most situations, as "the future can be left to take care of itself", but reserving low discount rates for "irreversiblities"). In our view, this suggestion is best taken as an effort to protect future generations against unjustificable losses as a result of the actions of the current generation. On this particular problem, see Cass R. Sunstein, Irreversible and Catastrophic, 91 Cornell l Rev 841, 894-96 (2006) (discussing how law and policy should handle potentially irreversible and catastrophic events – in particular how cost-benefit analyses should be adjusted in order to account for such events).

[22] See Viscusi, *Fatal Tradeoffs* at 145 (cited in note 53) (noting that a high discount rate means a high level of expected future productivity, and therefore a higher future income level; if benefit values are adjusted appropriately, high discount rates should not dramatically reduce the attractiveness of policies that benefit the future).

[23] We are putting to one side debates about the (perhaps doubtful) contributions of economic growth to individual well-being. For a readable overview, see Robert H. Frank, *Luxury Fever: Money and Happiness in an Era of Excess* 146-58 (Princeton 1999) ("[T]he conflict between individual and group [interests] is the single most important explanation of current consumption patterns.").

to discount is a crude and possibly een perverse way of doing that.

B. Methuselah, Paretoville, and Beyond

To see the relevant considerations, consider five problems. Of these, the fourth and fifth are most important, but they are best understood in light of those that precede them.

1. Methuselah

Suppose that society consists of only one person, who, it turns out, will live for a great many years, even centuries. Let us call him methuselah. Suppose that Methuselah will face a set of health risks (by hypothesis, none of them fatal) over time. Suppose that each risk of concern – those that involve a significant malady – is in the vicinity of 1/100, and that Methuselah is willing to pay $30,000 to eliminate each of these risks. It Methuselah is paying to reduce those risks now, there is no need to worry about discounting; the question is how much he is willing to pay to reduce risks that will be faced imminently or sometime in the future. If Methuselah is assessing the present value of his future expenditures, it is fully appropriate for him to discount those expenditures, even if they will be for risk reductions. If a 1/100 risk will be faced in 20 years, it is worth not $30,000, but $30,000 discounted to present value. Methuselah can invest that discounted amount and watch it grow[24]. Money is being discounted, not health – a restatement of our conclusion in Part II.

This conclusion might be questioned if Methuselah is seen as a series of selves extending over time and if an early self does ot act as an appropriate agent for the later one[25]. It is possible that Methuselah should be required to take steps to insure against serious harms in old age, especially if bounded rationality, including self-control problems, looms large. But if we indulge the not implausible assumption that Methuselah, of all people (!), is a good agent for his later self, discounting is fully appropriate.

2. Paretoville

Suppose that everyone in a small town, Paretoville, faces a current risk of 1/100,000, and that every resident of Paretoville, having the same tastes and the same amount of income and wealth, is willing to pay $50, but no more, to eliminate that risk (Suppose, too, that such residents have been adequately informed and are not suffering from any kind of bounded

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[24] By itself, this argument rejects Revesz's claims about the appropriate treatment of latent harms. See Revesz, 99 Colum L Rev at 984 (cited in note 8):

> The reason for discounting in the case of latent harms is not htat a regulator … determines that life in the future is less than life in the present. Instead, discounting simply reflects the fact that the individual who is valuing he own life derives less utility from living a year in the future than in the present.

[25] See Parfit, Reasons and Persons at 302-06 (cited in note 14) (suggesting that imagining different people throughout time as a series of "successive selves" helps in thinking about connectedness between generations).

rationality). The mayor of Paretoville takes this figure very seriously, and decides not to eliminate risks of 1/100,000 if the cost of doing so is greater than $50. Under the assumptions of adequate information and sufficient rationality[26], the mayor is reasonably using cost benefit analysis in deciding how to proceed, and there is no objection from the standpoint of equity. The reason is that every member of Paretoville pays, in full, for risk reduction, and people should not be required to pay more than they wish unless there is a problem of inadequate information, bounded rationality, or harms to third parties[27]. In some regulatory contexts all three problems introduce serious complications[28], but we are assuming that they are absent in Paretoville.

For the citizens of Paretoville, the analysis of discounting is straightforward. If expenditures must be made now to reduce risks that will impose harm in the future, the mayor of Paretoville must ask about current willingness to pay to avoid such risks; in all likelihood, the figure will be less than $50. If the expenditures must be made in the future, the relevant amounts should be discounted.

3. Dirtyville and Cleanville in Kaldorhicksiana

Two towns, Dirtyville and Cleanville, are adjacent to one another in the large and somewhat messy state of Kaldorhicksiana. Dirtyville engages in polluting activity that produces $60 in benefits to each of its 100,000 citizens. That activity creates a risk of 1/100,000, faced by each of the 100,000 citizens of Cleanville. Each citizen of Cleanville is willing to pay $50, but no more to eliminate the risk of 1/100,000 caused by Dirtyville's polluting activity. On cost-benefit grounds, the polluting activity should be allowed; its value is $6 million, which is higher than its $5 million cost.

But this problem is different from Problem 2 because there is a distributional issue: the citizens of Cleanville are uncompensated losers. If we were committed to economic efficiency, we would want the polluting activity to continue, but the distributional problem complicates matters. And the problem may be worse still. Because monetized figures rather than direct measurements of welfare are involved, it is possible that the activity actually creates a net welfare loss, with the citizens of Cleanville losing more, in welfare terms, than the citizens of Dirtyville gain[29]. Suppose, for instance, that the citizens of Cleanville are relatively poor, and

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26 See Sunstein, 54 Duke L J at 422-25 (cited in note 57) (arguing against forced exchanges of money for risk reduction by the government, as individuals should be permitted to make their own decisions regarding their welfare).

27 Id (highlighting the difference between this situation of equality and a situation where the poor would be made worse off by being forced to use their limited resources on an unwanted reduction in risk).

28 Id (providing examples of such complications, including workers' compensation programs, where "nonunionized workers faced a dollar-for-dollar wage reduction, corresponding almost perfectly to the expected value of the benefits that they received").

29 See Matthew Adler and Eric A. Posner, *Implementing Cost-Benefit Analysis When Preferences Are Distorted*, 29

hence their willingness to pay only $50 to eliminate a risk of 1/100,000 is consistent with the conclusion that they are facing a huge welfare loss from their subjection to that risk. The relatively small amount each citizen is willing to pay – $50 – reflects the relative poverty of Cleanville, not a relatively small welfare loss. On plausible assumptions, the state of Kaldorhicksiana, containing these two towns, is not living up to its name, because the losers are not, in welfare terms, losing less than the winners gain.

The welfare question could be tested, and the problem could be made analytically equivalent to Problem 2, if the citizens of Dirtyville could be forced to compensate those of Cleanville through low or some process of bargaining. But let us suppose that this is not feasible. In that event, we cannot be sure whether the efficient solution is also the solution that promotes social welfare. An additional question, a familiar one in regulatory policy, is whether there should be some kind of equitable or distributional barrier to the use of cost-benefit balancing[30]. If the citizens of Dirtyville are wealthy, and those of Cleanville are poor, the barrier might well be justified, at least if there is no mechanism by which the citizens of Cleanville can capture some of the benefits of the activity.

Does this example seem fanciful? In fact many air pollution problems correspond to the tale of Dirtyville and Cleanville. As we shall see, the problem of climate change has a similar feature insofar as wealthy nations are imposing risks on poor ones – risks for whose prevention poor citizens in poor nations are not willing to pay all that much, even when they are gravely threatened.

4. Presentville and Futureville

Presentville engages in polluting activity that produces $60 in benefits to each of its 100,000 citizens. But the polluting activity does not harm citizens of Presentville or any other current place. Instead, it harms members of future generations. More particularly, the activity creates a risk that will materialize in 100 years, in the town of Futureville – which, as it happens, is Presentville, a century from now and much more populous. In that time, the one million citizens of Futureville will face a death risk of 1/100,000 – meaning that 100 people are expected to die. If the lives of the people of Futureville are valued at $8 million each, it is clear that the polluting activity should stop, because $800 million is far greater than 6 million. But if money is discounted at an annual rate of 7 percent, each of their lives is worth only $581, and hence the polluting activity should continue, because $6 million is far greater than $58,100.

J Legal Stud 1105, 1122-24 (2000) (discussing how measurement in money, rather than direct welfare, points to a problem with the use of cost-benefit analysis).

30 See Portney and Weyant, *Introduction* at 6 (cited in note 13) (arguing that even if a program passes a cost-benefit analysis it may nonetheless be objected to on distributional grounds, as it may be efficient, yet still benefit only "the five richest families in the country").

But on what premises does it make sense to refuse a $6 million (current) expenditure to save 100 future lives? If all the people of Presentville and Futureville were treated as a single person extending over time, then the case would be similar to Methuselah's, and discounting would be appropriate. In that case, the various people would amount to just one person who could invest the relevant resources and use them later (Also, no one would die, because we're talking about Methuselah). It is tempting to suppose that if there were an intergenerational negotiation between the people of Presentille and the people of Futureville, discounting would be part of a mutually beneficial trade[31]. Here is the reason: the people of Presentville could agree not to squander or to consume the benefits they receive, but instead to invest a relevant sum and offer that amount to the people of Futureville, making them better off on balance. Those who emphasize the opportunity costs of investments as a reason for discounting, including OMB, implicitly appeal to the idea that future generations will in fact benefit from the investments that current generations make[32]. Hence discounting might be seen as a part of a (hypothetical) mutually beneficial intergenerational negotiation.

But there are two problems with relying on that idea. The first is conceptual: what is the set of background entitlements against which this purely hypothetical negotiation is occurring? At first glance, the people of Presentville are literally dictators. They can decide to consume all existing resources, to ruin the environment, to impoverish posterity, even to remain childless and not create later generations at all. In the (hypothetical) negotiating process, are the people of Presentville permitted to threaten the (hypothetical) people of Futureville with nonexistence? If so, how much will Futureville be able to extract? If not, is this because hypothetical people have some entitlement to be permitted to exist? (How many of them?) And if Presentville merely threatens Futureville with impoverishment and desperation, the people of Futureville will be in a singularly weak position to extract protection against (say) individual risks of death of 1/100,000.

In short, the idea of a mutually beneficial deal raises serious conceptual difficulties. At the very least, it is necessary to identify some entitlements on the part of both Presentville and Futureville, setting the background against which they might bargain. To be plausible, any such specification will inevitably have to depend on an independent normative account of some

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31 See Dexter Samida and David A. Weisbach, *Paretian Intergenerational Discounting*, 74 U Chi L Rev 145, 153 (2007):

> An alternative version of equality would give the first generation approximately 80 units [out of 100 total] and the rest to the second generation (giving each one an endowment of that amount in the first year of its life). When the second generation's endowment of 20 is invested at 3 percent for the first 50 years, it will grow to about 80 units in year 51, generating an equal division of the resources.

See also Lind, *Analysis for Intergenerational Decisionmaking* at 176-77 (cited in note 75) ("In theory, this could be done in a world with overlapping generations. In practice, this is virtually impossible, in part because of the problem of getting and enforcing the commitment of intervening generations to carry out this intergenerational transfer").

32 See, for example, Lind, *Analysis for Intergenerational Decisionmaking* at 176-77 (cited in note 75).

kind, and that independent account, rather than a notion of intergenerational bargaining as such, will be doing the crucial work[33].

The second problem is pragmatic. Suppose, as is plausible, that there is no mechanism to ensure that any mutually beneficial bargain will be enforceable; the citizens of Presentville might simply consume their resources instead[34]. To be sure the problem could be solved with compensation, and the discounted value of the 100 future deaths should be used if Futureville will sufficiently benefit from the investment of that sum (by, for example, producing significant decreases in premature deaths). If so the case would be quite similar to Problem 2 (back to Paretoville). But as we have noted, there is no assurance that this will be the case[35].

It should be clear that Presentville is neither Methuselah nor Paretoville. But with cost-benefit analysis with discounting, the problem of Presentville and Futureville has many features in common with that of Cleanville and Dirtyville. In the case of Kaldorhicksiana, the use of cost-benefit analysis can create distributional problems, and it can even lead to an aggregate welfare loss; in the case of Presentville and Futureville, cost-benefit analysis with discounting may create those same problems. But the case of Presentville and Futureville nonetheless raises distinct questions: What does the present owe the future? Is the present obliged to compensate the future for the injuries it causes? What does the idea of "compensation" mean in this context? We will shortly return to these questions and their connection to the practice of discounting.

5. Reality

Turn now to a more realistic example, involving climate change[36]. Suppose, as is plausible, that the primary victims of climate change will include poor people in India and Africa[37].

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33 Hence John Rawls rejects the idea of intergenerational bargaining in favor of a just saving principle. See John Rawls, *Political Liberalism* 287-88 (Columbia 1993) (asserting that social contracts "are bound to be substantially affected by contingencies and accidents"). For further discussion see note 103.

34 See Portney and Weyant, *Introduction* at 6 (cited in note 13) ("Even if it is efficient to reject a climate protection program, … one might reasonably objet to this decision on distributional grounds, especially if one is dubious that [ ] compensation will actually be available to future generations."); Lind, *Analysis for Intergenerational Decisionmaking* at 176-77 (cited in note 75) ("We are so used to assuming the ability to transfer resources over time we sometimes forget that if we can't, then it's not appropriate to convert all flows to a present value".); Cowen and Parfit, *Against the Social Discount Rate* at 151-52 (cited in note 14) (arguing that it is a mistake to think benefits will be reinvested rather than simply consumed). Donohue defends discounting on the ground that it "is appropriate in that, if invested, our resources are expected to grow at [the stated] rate, so that if we forego spending and invest the money instead, we can save more lives in the future with the amount foregone today." Donohue, 108 Yale L J at 1905 (cited in note 13) (rejecting the notion that discounting reflects a lower valuation of future lives in a moral or ethical sense). The problem with this argument is that is assumes that Problem 4 is the same as Problem 1 – that society is a kind of giant Methuselah, which it clearly is not.

35 See Lind, *Analysis for Intergenerational Decisionmaking* at 176-77 (cited in note 75).

36 See Posner, *Catastrophe* at 151-52 (cited in note 9) (considering how, through discounting, an investment in climate protection may not seem efficient, and countering that there is no other realistic alternative because creating and maintaining a fund for the compensation of future global warming victims is highly unlikely).

37 See William D. Nordhaus and Joseph Boyer, *Warming the World: Economic Models of Global Warming* 91 (MIT 2000) (showing especially large losses in India and Africa). See also generally J. Timmons Roberts and

Suppose that the planners concerned with climate change decide what to do by engaging in cost-benefit analysis and discounting the victims' costs to present value. If so, such victims will not be much helped, because no one is planning to invest the discounted sum to create a fund to compensate them in the future. The result of relying solely on cost-benefit analysis with discounting may be serious welfare losses, distributional unfairness, or both. To be sure, technological innovations might mean that what we see as likely deaths, or many of them, will end up as mere illnesses (and perhaps minor illnesses at that). But this possibility does not justify discounting. It is instead an effort to deny that the anticipated harms will be as large as we project. I that number is inflated, then of course the analysis must change.

It is also true that future generations are likely to be wealthier than our own, and hence it might not make much sense for the relatively poor present to transfer resources to the relatively rich future[38]. This would be a perverse form of redistribution. If future generations can be expected to be richer, that point must be part of the analysis of what equity requires. And if future generations can be expected to be richer, their anticipated wealth is procduced by some combination of the efforts, investments, and altruism of their predecessors – a point that compounds the concern about perverse redistribution.

But even here, there are complications. Suppose, for example, that a relatively poor community is gaining $6 million as a result of activity that will cause 100 deaths in a relatively wealthy community. Is the activity justified merely because poorer people are obtaining the benefit, which by hypothesis is much smaller than the cost? That claim would be exceedingly difficult to defend. The most general point – suggested by the problem of Presentville and Futureville – is that cost-benefit analysis with discounting can indeed produce serious problems across generations, including a net welfare loss and distributional unfairness. In the case of climate change, these problems need to be considered, and they suggest that we might well reject the path suggested by cost-benefit analysis with a standard discount rate.

Responding to concerns of this sort, Thomas Schelling argues that "[g]reenhouse gas abatement is a foreign aid program, not a saving investment problem of the familiar kind" [39]. For long-term problems, it might be thought that the question is whether the current generation should provide "foreign aid" to posterity. And to the extent that posterity is likely to be wealthier than we are[40], there is a serious question whether such aid should be provided. As

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Bradley C. Parks, *Climate of Injustice: Global Inequality, North-South Politics, and Climate Policy* (MIT 2006) (exploring normative and empirical issues raised by the distributional effects of climate change, with its severe impact on poor nations); *Stern Review* at 104-05 (cited in note 29).

38 See Schelling, *Expert Panel Ranking* at 627 (cited in note 74) ("One must deduct the growth rate from the discount rate, since it is essential to assume overall growth in *per capita* income (global GDP).").

39 Thomas Schelling, *Intergenerational Discounting*, in Portney and Weyant, *Discounting and Intergenerational Equity* 99, 100 (cited in note 2).

40 Id at 100-01 (asserting that discounting is appropriate because it represents a choice to help those who are relatively poorer ,the current generation, rather than those who will be relatively richer, future generations).

Schelling suggests, citizens of the developed world are not now willing to make especially significant sacrifices to help people in poor nations; it would seem extremely unlikely that in the context of clime change, such citizens would be willing to make significant sacrifices to assist people in those same nations in the distant and probably less-poor future[41].

But Schelling's analogy has serious problems. In our example, Futureville is not merely a foreign country. It consists to a large extent of Presentville's own descendents, and the risks they face are a direct result of Presentville's own actions – both plausible reasons to think that Futureville might have special obligations towards Presentville. The problem of climate change is closely analogous. The idea of "foreign aid" is a singularly poor fit for that problem, in which environmental and health risks in some Futurevilles are a product of actions undertaken knowingly (and perhaps negligently) by some Presentvilles. In that event, the present might well be seen to have committed a kind of tort, and the claim for compensation is hardly a claim for some kind of subsidy, or "aid" [42].

To give a stark example, imagine that present generations plant a bomb that will explode in two centuries. Is this a violation of the obligation to provide "foreign aid"? Environmental problems are rarely bombs, for they are usually not created with malice or with destructive goals; but if they result from activities that are projected to create risks, they must be analyzed in the general terms of tort law. This point has important implications for climate change, because the risks, faced above all by poor nations, are a result of actions from which wealthier nations have benefited.

C. Not Discounting as a Crude Response to the Intergenerational Problem

1. Discounting and moral obligations to posterity

Suppose that the present generation believes that it has moral obligations to its successors, either because those successors will be our children's children, or because whoever they are, they will be injured by our actions. The point that we seek to emphasize here is that refusing to discount is not a good way of fulfilling these obligations[43]. Indeed, any such refusal might

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41 Id at 101 (maintaining that it is inappropriate to consider investments in environmental protection as an issue of "investing now to reap future benefits", as those who will benefit will likely live in a different part of the world and be relatively richer than those doing the investing).

42 See Roberts and Parks, *Climate of Injustice* at 1-2 (cited in note 93).

43 See Samida and Weisbach, 74 U Chi L Rev at 154 (cited in note 87) ("[W]e care about equality of well-being while those arguing against discounting are arguing for an equal division of current resources, which will inevitably lead to an inequality in well-being."). See also Cowen and Parfit, *Against the Social Discount Rate* at 158-59 (cited in note 14) (suggesting that while remoteness in time is not a reason to care less about social harms, it might make sense to take account of the possibility that "it would be cheaper now to ensure compensation"). William Nordhaus provides a powerful argument against responding to the ethically unacceptable consequences of cost-benefit analysis by altering discount rates, on the view that "[a]d hoc manipulation of discount rates is a very poor substitute for policies that focus directly on the ultimate objective." William D. Nordhaus, *Discounting and Public Policies That Affect the Distant Future* at 158 (cited in note 50) (contending that "there

well hurt posterity. The moral obligation is best discharged not by a zero discount rate, but by asking the current generation to do what it is morally obliged to do.

A refusal to discount, often justified as a way of assisting the future[44], is a singularly crude way of attempting to fulfill our obligations to future generations. There are two problems. The first is that if the refusal to discount will result in the postponement of protective programs, environmental and otherwise, the future is to that extent hurt rather than helped[45]. The second is that if the consequence of discounting is to reduce investments, economic and otherwise, that will lead to long-term prosperity, then discounting is hardly helpful to future generations, which greatly benefit from economic growth[46]. It follows that the moral obligations of current generations should be uncoupled from the question of discounting because neither discounting nor refusing to discount is an effective way of ensuring that those obligations are fulfilled. The moral issues should be investigated directly, and they should be disentangled from the practice of discounting.

2. Theory

We have argued that future generations might well have a legitimate complaint if current generations follow the path indicated by cost-benefit analysis with discounting. But what kind of complaint do they have? To answer that question, it is necessary to say something about the nature of intergenerational equity.

As we have suggested, it is tempting to think of ethical obligations in compensatory terms, as in the idea that ethical obligations are satisfied if the present can make it worthwhile for future generations to run the risks to which it subjects them. But this idea turns out to be a false start because it is hard to know what the idea of compensation means in this context. Must the present compensate the future for each particular risk? That conclusion would be implausible. Surely it would be acceptable to impose a risk of 1/100,000 on 10 million future people if the very step that imposes that risk also eliminates a 1/1,000 risk that would be faced by 800 million future people (including the 10 million future people subjected to a new 1/100,000 risk of death). At first glance, then, the goal should be to produce an overall "risk package" for which adequate compensation has been paid. But to what, exactly, is this overall risk package

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is no simple formula for modifying discount rates that incorporates long-term objectives in an efficient manner").

44 See Ackerman and Heinzerling, 150 U Pa L Rev at 1570-71 (cited in note 15) (asserting that discounting does not make sense in environmental law, an area of law that is distinctive because of its focus on the future); Revesz, 99 Colum L Rev at 987-1007 (cited in note 8) (arguing against intergenerational discounting as it could produce a world where "practically no current expenditure for the benefit of relatively distant generations could be justified within a cost-benefit framework").

45 See Keeler and Cretin, 29 Mgmt Sci at 303-04 (cited in note 24) ("For any attractive program, there is always a superior delayed program that should be funded first. The result is that no program with a finite starting date can be selected.").

46 Complications are outlined in Frank, *Luxury Fever* at 72-73 (cited in note 79) (noting that economic growth does not increase self-reported life satisfaction).

being compared? To a situation in which future generations face extreme poverty and catastrophic climate change? To a situation in which future generations do not exist at all? Do members of future generations have rights to exist? These questions are closely connected with the difficulty of specifying the background entitlements against which any hypothetical bargaining occurs[47].

In short, it is necessary to identify the baseline against which any "compensation" must be paid, and the real work is being done by that baseline, not by the idea of compensation. The baseline must come from a more general account of the ethical obligations owed by the present to the future[48] -- and hence we are not speaking of compensation at all. What might that account require? Some people believe that current generations are obliged not to make the environment worse than it is today.[49] On this view, current generations are environmental trustees. As such, they must follow a kind of environmental nondegradation principle. But there is a problem with this position, which is its selective focus on environmental quality. Suppose that the current generation sacrifices a remote island, but that as a direct result of that action, it is able to confer significant economic, medical, and other benefits on posterity, giving them healthier, longer, and better lives. Is it so clear that the sacrifice is morally unacceptable?

John Rawls emphasizes a more promising approach, embodied in a "just savings" principle, to be chosen by people behind a veil of ignorance in which "they do not know to which

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47 Note too that Rawls's "just saving" principle would be satisfied by less than full compensation. The reason is that it is possible to imagine, without full compensation for risks, a system of savings that will bring "about the full realization of just institutions and the equal liberties", with particular reference to the "standpoint of the least advantaged of each generation". Rawls, Political Liberalism at 287-88 (cited in note 89) ("[A]ny benchmark of comparison between the relative advantages of citizens must be founded on their present relationships and the way in which social institutions work now, and not on how the actual … historical sequence of transactions extending backward over generations has improved (or would improve) everyone's circumstances".). Indeed, it is possible to imagine situations in which full compensation might well be too demanding. Suppose, for example, that the result of full compensation would be to impoverish the most disadvantaged embers of the current generation, in order to ensure compensation to the already-wealthy members of future generations. Current generations might, in principle, be able to claim that full compensation is not necessary when the distributive consequences are perverse. In fact, this claim raises some causal and even conceptual difficulties: If future generations are significantly wealthier than past generations, their wealth is partly attributable to the actions and omissions of their predecessors. Once the causal chains have been sorted out we might well conclude that adequate compensation has been paid for any risks, taken not separately but as a whole.

48 For an influential view, see John Rawls, *A Theory of Justice* 284-93 (Belknap revised ed 1999) ("The present generation cannot do as it pleases but is bound by the principles that would be chosen in the original position to define justice between persons at different moments of time."). For a helpful overview, see Lukas Meyer, *International Justice*, in Edward N. Zalta, ed, *The Stanford Encyclopedia of Philosophy*, online at http://plato.stanford.edu/archives/sum2003/entries/justice-intergenerational/ (visited Jan 23,2007) ("The special features of our relations to (remote) future people – especially the lack of particular knowledge, the impossibility of cooperation, and the permanent asymmetry of influence – do not stand in the way of attributing rights to them that ground corresponding duties owed by us.").

49 See Edith Brown Weiss, *Intergenerational Equity: A Legal Framework for Global Environmental Change*, in Edith Brown Weiss, ed, *Environmental Change and International Law: New Challenges an Dimensions* 385, 390-93 (United Nations University 1991) (discussing several international agreements that "have contained language indicating either a concern for sustainable use of the environment or a concern for future generations").

generation they belong or, what comes to the same thing, the stage of civilization of their society."[50] The key point, for Rawls, is the extension of the device of the veil of ignorance to the intergenerational question. Rawls also contends that his conception of justice as fairness ought to inform choices behind the veil. What is required, on his view, is a system of savings that will bring about "the full realization of just institutions and the equal liberties,"[51] with close attention to the "standpoint of the least advantaged of each generation."[52] Under this approach, cost-benefit analysis with discounting will create serious problems from the standpoint of justice if it leads to decisions that (for example) impose especially grave hardships on the most disadvantaged members of future societies. The proper response would be to take steps to conform to the just savings principle.

On this view, for example, it would be unacceptable to refuse to take steps to protect against climate change *if* the refusal would lead to a violation of equal liberties, or if it meant that the least advantaged members of future generations would suffer extreme hardship, well beyond that of the least advantaged members of the current generation. On the other hand, the current generation would not be required to take protective measures that would produce hardship for its least advantaged members, if those least advantaged members are more disadvantaged than would be any other group in any future generation, even in the absence of those protective measures. (Suppose, for example, that serious efforts to reduce greenhouse gases would be extremely expensive, and that the expense would have to be borne in part by the most disadvantaged members of current generations.) And indeed, some debates over climate change devote attention to issues of exactly this sort.[53]

In a later treatment, Rawls suggests that it is unhelpful to "imagine a (hypothetical and nonhistorical) direct agreement between all generations."[54] Instead the parties, behind the veil of ignorance, might be "required to agree to a savings principle subject to the further condition that they must want all *previous* generations t

o have followed it."[55] This savings principle has the advantage of treating all generations the same, through a form of intergenerational neutrality that protects against the dual problems of impoverishing the present and impoverishing the future. On Rawls's approach, policies that harmed the most disadvantaged members of current generations for the sake of the future would

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50 Rawls, *A Theory of Justice* at 254 (cite in note 104) (contending that a veil of ignorance is the only way to truly consider what a fair exchange would look like).

51 Id at 257 (declining to extend this to the proposition that justice requires that "early generations save so that later ones are simply more wealthy").

52 Id at 258.

53 See, for example, Indur Goklany, *The Precautionary Principle* 85-87 (Cato Institute 2002) (discussing how the "precautionary principle" counsels against assuming an overly aggressive strategy in combating greenhouse gases, as this could harm the current generation and thereby "retard increases in global wealth").

54 Rawls, *Political Liberalism* at 274 (cited in note 89) (discussing the need for "just savings" between generations, as "society is a system of cooperation between generations over time").

55 Id.

likely be disfavored, and the question would be whether those policies were necessary to protect the most disadvantaged members of future generations from still greater harm (as, on one view, is the case for emissions of greenhouse gases[56]).

Rawls's own approach is not utilitarian or welfarist, but it would be easy to adapt the idea of a veil of ignorance, and the notion of intergenerational neutrality,[57] for welfarist purpose. From the welfarist point of view, the goal should be to maximize welfare over time; welfarists would require current generations to give members of future generations the same moral weight that they give to existing people. Hence the current generation violates its ethical responsibilities if it engages in projects that lead to net welfare losses, measured after including the interests of all generations (where interests themselves are given equal weight). Of course this approach raises many puzzles; for example, do we focus on the *average* welfare of those in future generations, or do we focus on *aggregate* welfare, in which case large populations are better by virtue of their size?

However such puzzles are resolve, we believe that the idea of a veil of ignorance is appealing, and that it points in the right directions. But the aim here is to sketch rather than to solve the problem of intergenerational equity. Behind the veil, discounting would often be chosen because it would help future generations as well as the present one. When discounting would not be chosen, it is because it would have a harmful effect on the most disadvantaged people (on Rawls's difference principle), or because it would reduce overall welfare (on a welfarist approach). But it would be much better to focus directly on intergenerational equity, and to explore how present generations should fulfill their obligations independently of the question of discounting. While cost-benefit analysis with discounting can violate principles of intergenerational equity, refusing to discount is not the right way to satisfy those principles. Whateverthe proper approach to intergenerational equity, the debate over that issue should be separated from the debate over discounting, and the former debate should be engaged directly.

3. Conclusions

Some simple conclusions follow from this analysis. Cost-benefit analysis with discounting can produce serious distributional problems and can easily lead to a net welfare loss. The proper response it to take steps to ensure that present generations do not violate their obligations to posterity. On an optimistic view, no special steps are necessary. Some combination of market forces and ordinary altruism tends to ensure that those who come later

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[56] See Posner, *Catastrophe* at 151-53 (cited in note 9) (highlighting the example of greenhouse gases, which has an increased annual cost over time).

[57] On intergenerational neutrality, see *Stern Review* at 31 (cited in note 29) ("[I]f a future generation will be present, we suppose that it has the same claim on our ethical attention as the current one."). See also generally Cass R. Sunstein, *Worst-Case Scenarios* (forthcoming Harvard 2007).

are, in all relevant respects, significantly better off than those who came before. [58]

But perhaps the optimistic view is unrealistic for some problems, such as climate change. Suppose that climate change imposes truly catastrophic losses on the world as a whole, or at least on the most vulnerable members of the most vulnerable nations.[59] And even if the losses from climate change are not catastrophic, it would be surprising if the gains from refusing to spend money on greenhouse gas emissions will turn out to be used for the protection of those who are most likely to suffer from greenhouse gas emissions. Under plausible assumptions, the current generation should take self-conscious steps to protect its successors from the effects of climate change, no less than from the effects of ozone depletion. Our goal is not to specify the mechanisms by which the current generation fulfills that obligations, but suggest that whether or not the optimistic view is right, a refusal to discount is not the appropriate response to the risk of intergenerational inequity.

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[58] See Shelling, *Expert Panel Ranking* at 627 (cited in note 74) ("Future generations will be much richer than current ones, and it thus makes no sense to make current generations 'pay' for the problems of future generations."); Schelling, *Intergenerational Discounting* at 101 (cited in note 95) (arguing that, for this reason, investments for the benefit of the future must be considered as taking something from the poor to give to the rich).

[59] See *Stern Review* at ii-viii, 57, 62-84 (cited in note 29); Posner, *Catastrophe* at 43-59 (cited in note 9).

Exercises

1. Under the United Nations framework convention on climate change, the global warming problem has been discussed and the UN tries to reach some agreements on the limit to greenhouse gas around the world.

   Could you identify the difficulties to solve the global warming problem, given the different stages of economic development? Could you provide some solutions for this?

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