Environmental Policy Under a Non-Market Discount Rate

John K. Horowitz

Department of Agricultural and Resource Economics
University of Maryland
College Park MD 20742-5535

August 1995

** I thank Erik Lichtenberg, Ted McConnell, Lars Olson, and 2 anonymous referees for helpful comments. This is Scientific Article No. ______, Contribution No. ________ from the Maryland Agricultural Experiment Station.

Send correspondence to:
John K. Horowitz
Department of Agricultural and Resource Economics
University of Maryland
College Park MD 20742-5535

Phone: (301) 405-1273
FAX: (301) 314-9091
e-mail horowitz@arec.umd.edu

August 3, 1995, 10:34 am

Environmental Policy Under a Non-Market Discount Rate

Abstract
This paper looks at pollution emissions when a non-market discount rate is used to evaluate environmental policy, and policy is subject to continuous review through time. It is shown that a non-market rate leads to time inconsistent policy: Future regulators will want not to follow the current regulator's optimal plans, even when the current regulator has perfect foresight and there is no uncertainty.

Therefore, the discount rate has different effects depending on whether government can commit to future environmental regulation. We then show in a simple linear model that when the "environmental" discount rate is below the market rate, pollution is higher under no commitment than under commitment. Even under no commitment, however, a lower discount rate leads to lower emissions.

We argue that the debate might be better framed over "prices" (i.e., the value of the environment in the future) rather than the discount rate. This treatment removes the inconsistency problem yet ensures that future generations' interests are represented in policy decisions.

Keywords: Discount rate, time inconsistency, benefit-cost analysis, environmental policy

1. Introduction

The idea that future environmental degradation should be discounted at a rate lower than the market rate is old, and continues to be remarkably pervasive.[1] Numerous justifications are given but most revolve around intergenerational equity and a desire to lessen any adverse effects of current choices on future generations. These reasons are sometimes combined with a belief that time preference is irrational and therefore not defensible for policy. For example,

> "[T]here is wide agreement that the State should protect the interests of the future in some degree against the effects of our irrational discounting and of our preference for ourselves over our descendants. The whole movement for 'conservation' in the United States is based on this conviction." (Pigou, 1920)

Marshall and Ramsey held similar views (Robinson, 1990). More recently, Daly and Cobb (1989, p. 152) state: "It is worth the effort, therefore, to look at the issue of discounting closely to see why it is not a reliable method of reflecting the needs of the future into the present." These arguments are directed primarily at the discounting of public goods such as climate, wildlife habitat, or stratospheric ozone, where government intervention is most clearly warranted, but could conceivably be extended to petroleum, minerals, or even generic capital.

Many of these authors have also addressed the discount rate question with a positive, rather than normative, perspective; that is, by looking at the discount rate's effects on currently optimal or planned regulation. This analysis has largely proceeded without looking at the opportunities for future policy re-evaluation and it has therefore missed the role that re-evaluation plays in determining the consequences of the chosen discount rate. This lack is particularly important since periodic re-evaluation of policy is an integral part of the policy process. Re-evaluation and the possibilities for policy revision can be important even in the absence of uncertainty about future costs, benefits, or regulator behavior.

This paper looks at the time path of pollution emissions when a non-market discount rate is used for policy and policy is continuously re-evaluated. We first show that the time path of emissions with a non-market rate is time inconsistent.[2] This means that future governments will not want to follow today's government's optimal plans. This claim is equivalent to the following: If today's government could commit to future environmental policy, it would choose a different policy from the one that will actually prevail if it couldn't commit and future policies were chosen by future governments themselves.

Therefore, the discount rate has different effects depending on whether the current government can commit to future environmental regulations. We then show in a simple linear model that when the "environmental" discount rate is below the market rate, pollution is higher under no commitment than under commitment. It follows that the marginal effect of the discount rate is smaller under no commitment. However, even when the government cannot commit to future regulation, pollution will be lower when a below-market rate is used for policy design.

Our conclusion, which we articulate in Sections 4 and 5, is that in many situations, the debate might be better conducted by arguing about the future "price" (*i.e.*, value) of the environment, not the discount rate. A high value of future environmental amenities, discounted at the market rate, will on paper look much the same as a low environmental discount rate. Yet this price approach avoids the inconsistency problem and, at the same time, ensures that future generations' interests are adequately represented in policy analysis.

2. Benefit Cost Analysis

We model income and pollution tradeoffs in a simple continuous time, infinite horizon model with no uncertainty. Let income at time t be y(t); in this simple model income, production, and consumption are synonymous. A byproduct of income/production/consumption is pollution emissions, written g(y) with $g'(y), g''(y) > 0$. The variable g(y) may represent sulfur dioxide or greenhouse gas emissions into the air or heavy metal discharges into water. This set-up can be extended to include most intertemporal pollution models (*e.g.*, Weitzman, 1994). Most importantly, it can easily be extended to models with explicit pollution abatement activity (Biglaiser et al., 1995).

Let z(t) be the pollution stock. The pollution stock evolves according to:

$$\dot{z}(t) = g(y(t)) - \alpha z(t) \tag{1}$$

where $\alpha > 0$ is natural decay of the pollutant and $z(0) = z_0$ is given.

The social costs ("damages") of pollution are D(z), with $D'(z) > 0$, $D''(z) \geq 0$. These represent citizens' disutility from environmental degradation, which is caused by pollution. We do not cover damage measurement; this is touched on, tangentially, in Section 4. Damages are assumed to arise from the stock of pollution rather than flow, are time-invariant, and do not (directly) depend on income; analogously, environmental degradation does not affect production.

The regulator maximizes discounted production minus damages. She uses a market discount rate r on income and a social discount rate γ on pollution damages. Social welfare is:

$$\int_0^\infty [e^{-rt}y(t) - e^{-\gamma t}D(z(t))]dt \tag{2}$$

The discount rate γ is meant to embody an objective whose justification, of whatever validity, exists outside the model. The model absent the discount rate complication is loosely based on Forster (1973). Readers familiar with optimal control may recognize (2) as a problem whose solution will be time inconsistent.

The analysis below depends on (2) being an accurate objective for policy evaluation with an "environmental" discount rate. One simple way to see that pecuniary costs or benefits must be discounted at the market rate is to consider preferences when the path of pollution is given; the regulator will then want the policy with the highest market value of the income stream, which he can ensure by applying a rate r to y(t).[3] No such argument induces him to apply any particular rate to pollution damages. One can also interpret (2) as a benefit cost model in which -y(t) represents pollution abatement expenditures. Given a path for the pollution stock, the regulator should minimize the present discounted value of abatement expenditures using the market rate r. Another argument that the market rate must be used for abatement costs can be applied if pollution depends on both abatement and the overall level of economic activity. To apply a non-market rate to abatement expenditures in this case would imply that the government should intervene in the economy even when emissions create no disutility.

Of course, one may argue that the government should intervene in the economy to reduce the market rate until γ becomes appropriate for both y(t) and D(z(t)). This is a considerably more extreme prescription and is not a central element in the environmental discount rate debate.

We might also consider a more detailed model of consumer preferences in which the intertemporal budget constraint is explicit and separate; for example, an objective function such as $\int e^{-\beta t}u(c(t),z(t))dt$ where c(t) is consumption.[4] In this case, β is unrestricted. Our inconsistency result applies to functionals of the form $\int[e^{-\beta t}u(c) - e^{-\gamma t}v(z)]dt$ where v(z) is utility from pollution. This functional form has not, however, been suggested to our knowledge.

3. Intertemporal Pollution Emissions

If the regulator can choose at time 0 the entire time path of income and emissions, she selects the open-loop control strategy that maximizes (2) subject to (1), initial conditions, and nonnegativity constraints. The relevant Hamiltonian is $e^{-rt}y - e^{-\gamma t}D(z) + \lambda(g(y) - \alpha z)$ where $\lambda(t)$ is the costate variable. First order conditions are:

$$e^{-rt} + \lambda(t)g'(y(t)) = 0, \tag{3}$$

$$-e^{-\gamma t}D'(z(t)) - \alpha\lambda(t) + \dot{\lambda}(t) = 0. \tag{4}$$

Together these give:

$$-\frac{g''}{g'}\dot{y}(t) - (r+\alpha) + e^{(r-\gamma)t}D'(z)g' = 0. \tag{5}$$

Differential equations (5) and (1) can then be combined to solve for y(t) and z(t). We interpret the solution in the linear case below.

When $\gamma \neq r$, the solution is time inconsistent because the last term of (5) depends on t. At the beginning of the planning horizon, the planned time derivative of y(t) is given by (5). But when t arrives, the planning horizon starts over.[5] If plans could unexpectedly be revised at t, the actual time derivative would satisfy:

$$-\frac{g''}{g'}\dot{y}(t) - (r+\alpha) + D'(z)g' = 0, \tag{6}$$

which is different from (5). Therefore, the solution in (5) is time inconsistent; it will not be followed by future decision-makers.

To understand the time inconsistency, consider the marginal rate of substitution between income and emissions both in the present and future. An environmental discount rate below r means that the "return" on pollution control is greater than the return on consumption. Therefore, the regulator wants to "invest" in future pollution control, which he does by *planning* to produce less in the future. When the future arrives, the marginal rate of substitution between income and emissions is 1, leading to no favorable treatment of pollution control. The planned pollution control is then pushed further into the future.

We next solve for and compare the commitment and no-commitment policies. Damages are assumed linear, D(z) = δz, where δ is the time invariant, constant marginal pollution damage. While linearity is clearly unwarranted in the large, it allows a simple demonstration of the effects of time inconsistency. Nonlinear damages are discussed below.

Commitment Solution

We first solve for emissions and the pollution stock when the regulator can commit to future policy. The first order condition for z is:

$$-e^{-\gamma t}\delta - \alpha\lambda(t) + \dot{\lambda}(t) = 0, \tag{7}$$

which yields $\lambda(t) = -e^{-\gamma t}\delta/(\alpha+\gamma)$. Multiply (7) by e^{rt} to get (8), which is analogous to (3):

$$1 - e^{(r-\gamma)t}\frac{\delta}{\alpha+\gamma}g'(y*(t)) = 0. \tag{8}$$

The optimal pollution regulation can be treated as an implicit emissions tax. When γ = r, it is as if the government imposed a tax $\delta/(\alpha+\gamma)$ on emissions, which is the present value marginal damage. When r > γ, the implicit tax is $e^{(r-\gamma)t}\delta/(\alpha+\gamma)$, which is increasing over time. In this case, the regulator wants higher future emissions taxes because it wants to induce less future pollution, which is optimal given the lower discount rate on pollution damages. When the future arrives, the regulator wants to delay imposing a higher tax.

From (8), optimal consumption and therefore optimal emissions are falling over time. That emissions fall over time is the main implication of having an environmental discount rate lower than the market rate in this model.

Define y* as the optimal consumption path and g* as optimal emissions under commitment. In this model, a lower discount rate leads to lower emissions at each t, $dg^*(t)/d\gamma > 0$ for all t. (To see this result, differentiate (8) to get $dy^*(t)/d\gamma \geq 0$.)

No Commitment Solution

To find the no commitment (closed-loop) solution for the linear model, we impose that the solution not depend on t. In our model, it does not matter whether the regulator takes into account the optimal choices of future regulators or assumes they will follow the current plan, because the solution to (8) is unaffected by the choice of y(s), s > t. Define y^{**} and g^{**} as the optimal paths under no commitment. Each time is the present; thus $y^{**}(t) = Y^{**}$, a constant, and Y^{**} solves $1 = \delta/(\alpha+\gamma)g'(Y^{**})$. Define $g^{**} = g(Y^{**})$. Note that a lower discount rate leads to lower emissions, $dg^{**}/d\gamma > 0$, as in the commitment case.

The no commitment solution can be rationalized *ex post.* The path g^{**} is identical to what would prevail if the regulator had discounted damages at r (so that choices would have been consistent) but treated emissions as if they decayed at a lower rate, $\alpha^* = \alpha + \gamma - r < \alpha$.

Comparison of Commitment and No Commitment

Emissions are higher under no commitment than under commitment, at each t, whenever $r > \gamma$. To see this, note $g(Y^{**}) = g(y^*(0))$; current emissions are unaffected by lack of commitment. Because commitment consumption, $y^*(t)$, and emissions, $g^*(t)$, fall over time, it follows that $g^{**} > g^*(t)$, $t > 0$.

Lowering the environmental discount rate will reduce emissions, but by a smaller amount under no commitment than under commitment for $r > \gamma$: $dg^{**}/d\gamma < dg^*(t)/d\gamma$ for all t. First note that $dY^{**}/d\gamma = dy^*(0)/d\gamma$. The result follows from calculating $d(dY^{**}/d\gamma - dy^*(t)/d\gamma)/dt$. This derivative is proportional to $t(\gamma+\alpha)(\gamma-r) - (\alpha+r)$, which is negative. In words, the effect of lowering the social discount rate is much smaller than would be predicted by policy-makers who did not recognize its time inconsistency and believed the open-loop control would be followed.

Further Issues

In a broader context, time inconsistency may also change the type of environmental policy. If future regulators are unlikely to follow current plans, then current regulators may use environmental regulations that require a large capital investment that cannot be easily reversed, or that produce more permanent environmental benefits (see Biglaiser et al., 1995, for a game-theoretic example). These activities reduce the future benefits of deviating from current plans, but they are a form of commitment that is costly in the present and that would not occur in the absence of time inconsistency of the currently optimal policy. For discussion of this issue for government policies in general, without the discount rate underpinnings, see Gersbach (1993) and Glazer (1993).

Finally, we consider the effects of convex damages, $D''(z) > 0$. When damages are convex, the current government can indirectly influence future governments' choices by increasing current emissions; since this raises the marginal cost of emissions to future governments, they pollute less. This commitment is costly and therefore incomplete, and the currently optimal emissions path would still be inconsistent. It can be shown with convex damages that the closed loop emissions path cuts the open loop path from above; in other words, emissions are initially higher. An explicit solution is derived in Horowitz (1995).

4. Don't Adjust That Discount Rate. Look At Future Prices Instead.

The commitment solution $\{y^*,g^*\}$ will also arise under a different set of circumstances. Define current value "green income" as $y(t) - p(t)z(t)$ where $p(t)$ is the current-value shadow price of pollution. Suppose the regulator maximizes the present value of green income using the market discount rate. If price follows $p(t) = \delta e^{(r-\gamma)t}/(\alpha+\gamma)$ then the objective function for the regulator is identical to (2), the solution is $\{y^*,g^*\}$, and this is time consistent. Under this scenario, the price of pollution rises over time if $r > \gamma$. When pollution's shadow price is rising, optimal emissions will be falling, even when a market rate is used for policy.

Increasing marginal damages (i.e., $D(z)$ strictly convex) are one rationale for an increasing price. Weitzman (1994) proposes another: If society is growing richer and at higher incomes will purchase more pollution abatement, and if pollution abatement has an upward sloping marginal cost curve, then the shadow price of pollution must be rising. In both of these cases, to derive time consistent regulatory policies, future pollution should be valued at its contemporaneous price then discounted to the present using a market rate.[6,7]

Because price and the discount rate are so intertwined, does it matter how environmental benefit-cost accounting is framed? The answer must be yes. If a non-market rate is used, policy will be time inconsistent. If a market rate is used, the commitment problem does not arise. Of course, both formulations must also specify prices, *i.e.* the damage function. Externalities and, by extension, prices for each time t should reflect the preferences prevailing at t, and the generations then linked by a market discount rate.

5. Concluding Comments

Those philosophies for which a social discount rate argument is accepted should also calculate the time path of policy that that discount rate implies. We have shown that in at least one simple case, optimal policy will be time inconsistent and the actual policy path different from what is planned.

Time inconsistency, on its own, is not an argument against a social discount rate, which, as we have said, depends on arguments outside any particular model. But if the argument behind the social rate is that it is needed in order for present decision-makers to adequately account for future costs and benefits, then time inconsistency is troublesome because it leads to a disregard for the choices made by future regulators. This discrepancy is further troublesome because future pollution damages can indeed be accounted for by valuing them at future prices in current policy evaluation and using a market discount rate.

What we hope to have demonstrated is that in many situations, the debate over environmental policy should be *fundamentally* a debate about future prices, not the discount rate. We note that the current "price" (*i.e.*, value) of environmental amenities is already the center of much economic research and discussion. Future prices should be part of the same debate. Of course, predicting future prices will involve both controversy and uncertainty, but using them and applying a market discount rate may at least make clearer what the debate is over. Using future prices should also help ensure that current environmental policies are consistent with the actions and desires of future citizens.

References

Arrow, K.J. and Kurz, M., 1970. Public Investment, the Rate of Return, and Optimal Fiscal Policy. Johns Hopkins University Press, Baltimore.

Biglaiser, G., Horowitz, J.K. and Quiggin, J., 1995. Dynamic Environmental Regulation. Journal of Regulatory Economics 8: 33-44.

Daly, H.E. and Cobb, J.B., Jr., 1989. For the Common Good. Beacon Press, Boston.

Forster, B., 1973. Optimal Consumption Planning in a Polluted Environment. The Economic Record, 534-545.

Gersbach, H., 1993. Politics and the Choice of Durability: Comment. American Economic Review 83: 670-73.

Glazer, A., 1993. Politics and the Choice of Durability: Reply. American Economic Review 83: 674-5.

Horowitz, J.K., 1995. Optimal Control When the Open Loop Solution Differs from the Closed Loop Solution. Unpublished manuscript.

Howarth, R. and Norgaard, R., 1993. Intergenerational Transfers and the Social Discount Rate. Environmental and Resource Economics 4: 337-58.

Karp, L. and Newberry, D.M., 1993. Intertemporal Consistency Issues in Depletable Resources. In: A.V. Kneese and J.L. Sweeney (Editors), Handbook of Natural Resource and Energy Economics. Elsevier, Amsterdam.

Kolb, J. and Scheraga, J., 1990. Discounting the Benefits and Costs of Environmental Regulations. Journal of Policy Analysis and Management 9: 381-90.

Kydland, F. and Prescott, E., 1977. Rules Rather Than Discretion. Journal of Political Economy 85: 473-91.

Lesser, J.A. and Zerbe, R., 1994. Discounting Procedures for Environmental and Other Projects: A Comment on Kolb and Scheraga. Journal of Policy Analysis and Management 13: 140-56.

Lyon, R., 1990. Federal Discount Rate Policy, the Shadow Price of Capital, and Challenges for Reforms. Journal of Environmental Economics and Management 18: S-29-50.

Machina, M., 1989. Dynamic Consistency and Non-expected Utility Models of Choice Under Uncertainty. Journal of Economic Literature 27: 1622-68.

Markandya, A. and Pearce, D.W., 1991. Development, the Environment, and the Social Rate of Discount. World Bank Research Observer 6: 137.

Pearce, D.W. and Turner, R.K., 1990. Economics of Natural Resources and the Environment. Johns Hopkins University Press, Baltimore.

Pigou, A.C., 1920 (Reprinted 1960). The Economics of Welfare. Macmillan, London.

Robinson, J.C., 1990. Philosophical Origins of the Social Rate of Discount in Cost-Benefit Analysis. The Milbank Quarterly 68: 245-65.

Scheraga, J., 1990. Perspectives on Government Discounting Policies. Journal of Environmental Economics and Management 18: S-65-71.

Sterner, T., 1994. Discounting in a World of Limited Growth. Environmental and Resource Economics 4: 527-34.

Strotz, R., 1956. Myopia and Inconsistency in Dynamic Utility Maximization. Review of Economic Studies 23: 165-80.

Turnovsky, S. and Brock, W., 1980. Time Consistency and Optimal Government Policies in Perfect Foresight Equilibrium. Journal of Public Economics 13: 183-212.

Weitzman, M., 1994. On the 'Environmental' Discount Rate. Journal of Environmental Economics and Management 26: 200-209.

Endnotes

1. See Daly and Cobb (1989), Howarth and Norgaard (1993), Markandya and Pearce (1991), and Pearce and Turner (1990), among others. Lyon (1990) and Scheraga (1990) address conceptual and practical issues in choosing a discount rate. Much of the environmentalist literature argues against "discounting." In some cases, this means a zero discount rate should be used, in which case the current paper is applicable. In other cases, "no discounting" means an (unspecified) non-utility-theoretic decision rule; it is less clear how the current paper might be used in this case.

2. Both the literature on potential time inconsistency of government decision-making and on the appropriate discount rate are vast. For inconsistency, see Kydland and Prescott (1977), Turnovsky and Brock (1980), or Karp and Newberry (1993). The behavioral approach is due to Strotz (1956), which remains interesting and instructive 40 years on.

3. Similarly, Howarth and Norgaard (1993) show that in an overlapping generations model with exhaustible resources, a competitive equilibrium is not Pareto optimal when a non-market discount rate is used to weight generations.

4. Arrow and Kurz (1970) and Lind (1984) use such a framework to discuss the correct opportunity cost of capital, which is a separate issue from this paper. See Sterner (1994) for an application where there are "limits to growth."

5. One solution to inconsistency is to allow reoptimization but not have the planning horizon start over (Machina, 1989). This approach does not make sense when there are different decision-makers at each t.

6. Weitzman (1994) starts with an argument about (implicit) prices, thus his conclusions about an environmental discount rate are correct and not subject to the criticisms of our paper.

7. A paper that comes close to recognizing potential time inconsistency and its connection to prices is Lesser and Zerbe's (1994) comment on Kolb and Scheraga (1990). Both papers address conceptual and practical issues in choosing a discount rate.