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Intertemporal and Intergenerational Pareto Efficiency Revisited

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This paper demonstrates that Bishop's formulation deviates in a fundamental way from our model and, in so doing, Bishop has assumed the problem away. Bishop utilizes a utility function that is *too general* to discriminate the time pattern of consumption from that of production. Hence, the intertemporal nature of the goods that we analyzed cannot be captured by Bishop's representation. Furthermore, we show that current benefit cost methods that discount the benefit stream of a *public asset* are *Pareto intertemporally inefficient.*

The allocation of resources over generations has been the subject of considerable discussion in the recent literature, particularly insofar as these resources are nonrenewable.[2] As a result of this attention and an apparent failure to fully define the implications of efficient intertemporal and intergenerational resource allocations, we proposed in an earlier paper [12] a generalization to the concept of Pareto efficiency for such conditions.[3] Moreover, we argued that this generalization had particularly important implications for the conventional criteria used in public expenditure analysis involving certain types of public goods (e.g., removal of mutagenic substances, disease eradication). The purpose of this paper is to extend this discussion further in response to the comment by Bishop [2] which contends that our conclusions concerning the appropriate role of discount-

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[2] Some recent examples of this concern are the 1974 special issue of the *Review of Economic Studies* with a Symposium on the Economics of Exhaustible Resources; the special issue of *Social Science Quarterly,* "Scarcity and Society," September 1976; and the Resources for the Future Forum on the Economics of Natural Resource Scarcity, October 1976.

[3] Since the publication of our first paper we became aware of an alternative definition of intertemporal Pareto efficiency in [1, Chapter 5]. However, the objective of their analysis was directed to a derivation of the pricing rules required for a Pareto efficient allocation of exhaustible resources.

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ing would have been "revolutionary" if they had been correct.[4] In what follows we argue that we are neither revolutionaries nor incorrect in our original discussion.

Section I reviews the essential elements in Bishop's argument and indicates why his model deviates in important aspects from that used in our earlier analysis. The second section reviews the reasons why Bishop's concerns are important ones, though not directly relevant to our analysis, and the last section summarizes the discussion.

I. AN APPRAISAL OF BISHOP'S ARGUMENTS

Bishop begins his argument by correctly noting that one must differentiate the definition of an efficient resource allocation from the mechanisms available to attain it. Since discounting arises out of perfect markets, accounting, in effect, for the time sequencing of production and consumption decisions, he concludes it is incorrect to oppose discounting as inefficient. His argument begins with private goods and follows the discussion of a popular micro-text.[5] In considering the problems which may be associated with public goods, he assumes knowledge of individual demand curves for these goods so that the information conveyed by a perfectly functioning market (in the case of private goods) is available for public goods as well. Thus, the discount rate is seen as a "signal" to assure optimality rather than an impediment to it.

The fundamental difference between our arguments resides in two of his simplifying assumptions. First, rather than define, as in our original paper, distinct utility functions for each individual in each time period, he specifies a single general function for each individual encompassing all periods' consumption.[6] This specification obscures a key effect for public goods, discussed at some length in [12]. That is, goods were able to be public in their effects across both individuals (in the same generation and future generations) *and time*.[7] Thus, while an individual might consume a unit of y in period k, that proposed consumption could (in our most general specification) yield utility to the person in all other periods as well.[8] It follows that in Bishop's framework the marginal rate

[4] Strictly speaking, Bishop's summary of our conclusion concerning discounting is misleading. He omitted our description of the circumstances. Specifically we noted: "We shall confine our attention to public goods. Pareto-efficient resource allocation over time requires that we treat each person's incremental benefits from public good in question *equally* regardless of the time they receive the benefits" [12, p. 158].

[5] See [4, Chap. 8].

[6] His argument is that our specification is more cumbersome and his general format yields more straightforward results without apparent injustice to our analysis. Unfortunately, this observation is not correct. See footnote 8 for a discussion of the specific relationship between the two approaches.

[7] It should be noted that we differentiated three of the cases considered according to the intertemporal linking of the consumption of a public good and the intertemporal pattern of utilities derived by the individual. See [12, pp. 155–157] for further discussion.

[8] In what follows we utilize the same notation as in our article; see [12, Table 1] for the details.

Formally we can state the difference between Bishop's specification and ours using the Kuhn–Tucker equivalence theorem [7, Theorem 6], which indicates that the Lagrangian expression in our Eq. (4) in [12] is equivalent to:

$$L = u^1[u^{11}(\cdot), u^{12}(\cdot), \ldots, u^{1T}(\cdot)] + \sum_{i=2}^{S} \lambda^i \{u^i[u^{i1}(\cdot), u^{i2}(\cdot), \ldots, u^{iT}(\cdot)] - k^i\} + \sigma F(R; X_1, \ldots, X_T; y_1, \ldots, y_T)$$

of substitution between a public good provided in period p and a numeraire, r, is the sum of the marginal rates of substitution for these goods for each of the T utility functions (corresponding to time periods of enjoyment) under our specification, as in Eq. (1) below:

$$\overline{\mathrm{MRS}}_{y_p r}{}^{i} = \sum_{j=1}^{T} \mathrm{MRS}_{y_p r}{}^{ij} \tag{1}$$

where $\overline{\mathrm{MRS}}_{y_p r}{}^{i}$ = marginal rate of substitution between y_p and r for individual i with Bishop's utility function; and $\mathrm{MRS}_{y_p r}{}^{ij}$ = marginal rate of substitution between y_p and r for individual i in period j with our framework. Therefore, Bishop's formulation fails to identify the fact that it matters *for public goods* which measure of value is used. An individual's demand for y_p in period j is but a component of his demand for y_p. Since we did not compare an individual's decision on a public good *to be provided in period p with a private good to be provided in period p + k*, there was not the necessity to deal with what capital markets allowed. After all, as Bishop would agree, our intention was with a definition of intertemporal efficiency not with the mechanism to attain it.

Capital markets, when properly functioning, allow the individual consumers' and producers' rates of time preference to be collectively revealed. Accordingly, their existence permits an individual to make allocation decisions with long gestation periods without the need to be present when the returns are realized. The property rights to these returns can be transferred in such markets. This point is *not* at issue here. What is at issue is the practice of public expenditure analysis where it is the absence of markets that, in many cases, is the motivation for public intervention. Accordingly, our intention was *not* to evaluate whether markets accurately conveyed all information so resources could be allocated to their highest valued uses. Rather, it was to use our definition of intertemporal efficiency to evaluate the practices of applied welfare economics.[9] It is in the evaluation of these practices that Bishop's second assumption is important to our conclusions. He assumes [2, p. 8]:

> It is sufficient for our purposes however, to say that if all S people in the economy could be transformed into Samuelson's "parametric decentralized bureaucrats," the individual demand curves for Y in all periods could be derived and summed vertically; marginal cost functions could be determined via the production function and P_{ct} (competitive price of c, input resource

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$$+ \sum_{j=1}^{T} \Phi^j\Big(\sum_{i=1}^{S} x_{ij} - X_j\Big) + \sum_{j=1}^{T} \gamma^j\Big(\sum_{i=1}^{S} r_{ij} - R_j\Big),$$

where $u^{ij} = u^{ij}(x_{i1}, \ldots, x_{iT}; r_{ij}; y_1, \ldots, y_T)$.

From this equation, the class of utility functions that we considered consists of

$$U = \{u^i \mid u^i = u^i[u^{i1}(\cdot), u^{i2}(\cdot), \ldots, u^{iT}(\cdot)]$$

with $u^{ij} = u^{ij}(x_{i1}, \ldots, x_{iT}; r_{ij}; y_1, \ldots, y_T)\}$. Bishop examined the class that consists of $V = [u^i \mid u^i = u^i(x_{i1}, \ldots, x_{iT};\ r_{i1}, \ldots, r_{iT};\ y_1, \ldots, y_T)]$. Since $u^i \in U$ implies that $u^i = u^i(x_{i1}, \ldots, x_{iT}; r_{i1}, \ldots, r_{iT}; y_1, \ldots, y_T)$, $U \subset V$; however, V is not contained in U since $u^i = u^i[u^{i1}(x_{i1}; r_{i1}, y_1), u^{i2}(x_{i2}; r_{i2}; y_2), \ldots, u^{iT}(x_{iT}; r_{iT}; y_T)]$ is contained in V, but this u^i is not an element of U.

[9] Equation (6) was therefore not an optimality condition but rather our expression for the marginal condition which would be implicit in the discounting practices of cost–benefit as applied to intertemporal and intergenerational public goods.

to his model) for all t; and the optimum amounts of Y determined for each period $1, \ldots, T$.

If markets worked perfectly for all goods and services there could be no motivation based on efficiency criteria for "complimentary institutions for group decisions and collective action ...." [6, p. 267] to serve economic wants not accounted for by the market or accomplished inefficiently.

Accordingly, it would appear that what is at issue in our argument versus that of Bishop is the practices of benefit–cost analysis in developing values for y_p. The quote cited earlier indicates that *Bishop assumes the problem away.*[10] When, as in the discussion in [12, p. 158], the decision is whether or not to provide a public good, y, in *period p* and it is being made in period 1, then the analysis must reflect all the values resulting from y_p in advance of consumption (i.e., $\sum_{i=1}^{S} \sum_{j=1}^{p-1} \mathrm{MRS}_{y_p r}{}^{ij}$) and those after consumption (i.e., $\sum_{i=1}^{S} \sum_{j=p+1}^{T} \times \mathrm{MRS}_{y_p r}{}^{ij}$). These values must be treated equally with the value generated at the period of y_p's consumption (i.e., $\sum_{i=1}^{S} \mathrm{MRS}_{y_p r}{}^{ip}$). More specifically, can the values used in benefit cost analysis be treated as an approximation of $\mathrm{MRS}_{y_p r}{}^{ij}$ or $\sum_{i=1}^{T} \mathrm{MRS}_{y_p r}{}^{ij}$?

In our judgment they are more likely to reflect the former than the latter. However, there is certainly scope for debate depending upon the particular application, provided it is consistent with our cases 1 through 3. For cases 4 and 5, the issue becomes more involved and the discrepancy introduced by Bishop's reformulation more severe.

Consider our case 4, where a public good once provided is available at no additional cost for all T periods. It is public across individuals in all periods. Even if we grant that benefit–cost analysis uses the second of the alternatives mentioned above, thereby avoiding the effects of discounting over a given individual's intertemporal enjoyment, current practice will discount across periods, when efficiency requires that they be treated equally. Equation (2) repeats the results here.

$$\sum_{p=1}^{T} \sum_{i=1}^{S} \sum_{j=1}^{T} \mathrm{MRS}_{y_p r}{}^{ij} = \mathrm{MRT}_{yR}. \tag{2}$$

Benefit–cost methods as they are presently practiced (and this would also follow from Bishop's framework) *would incorrectly discount each period's* $\sum_{i=1}^{S} \sum_{j=1}^{T} \times \mathrm{MRS}_{y_p r}{}^{ij}$.[11] They would not be acting to move the allocation of resources toward efficiency. Therefore, if we define a *public asset* as a resource whose services are public goods over time, then it is possible to state the following theorem on the basis of (2).

THEOREM. *Discounting the estimates of the marginal value* ($\sum_{i=1}^{S} \sum_{j=1}^{T} \mathrm{MRS}_{y_p r}{}^{ij}$) *of the services of a public asset in each period over the life of the asset will lead to a Pareto-inefficient allocation of resources.*

[10] We should note that Bishop's Eq. (11) is a misleading interpretation of our analysis. In order to conform to it, the equation should read:

$$\sum_{i=1}^{S} \frac{u_{y2}{}^{i}}{u_{xi2}{}^{i}} = \frac{G_{y2}}{F_{xk2}{}^{i}}.$$

[11] See [15] for a discussion of conventional practices.

II. THE INTERTEMPORAL EFFICIENCY OF MARKETS

Bishop's comment does serve to emphasize an important aspect of markets in allocating resources. As Stiglitz recently noted in considering nonrenewable resources [14, p. 5]:

> The fundamental principle of efficient inter-temporal resource allocation is that the present discounted value of the (net) marginal product be the same at all dates, i.e., that the value of the marginal product rises at the rate of interest. This is ensured in a competitive economy by having the price rise at the rate of interest.

Unfortunately, these Pareto efficiency conditions are *not* satisfied by markets when there are external effects associated with the resources. That is, when the goods or services traded in these markets have some of the attributes of "publicness," markets cannot be relied upon to assure an efficient intertemporal allocation. Market signals may not convey sufficient information to assure that a reshuffling of the resources from the market attained pattern will not improve any individual's position while still leaving all others unaffected.

There are many examples in which these considerations cannot be taken lightly. For example, consider the case of extractive natural resources, such as coal or petroleum, it may well be that the use of such resources requires the services of a common property resource such as air or water.[12] The market transactions in coal or oil alone cannot be relied upon to reflect the side effects on the common property resources of their use patterns (e.g., effects of a buildup in carbon dioxide with its associated effects; see [9]). Additional examples are easy to come by in the long-term side effects of new chemicals. While problems with persistent materials such as the synthetic organic chemicals, cadmium, and mercury are becoming well known, it has only recently been recognized that fairly commonplace substances—PVCs, cyclamates, and certain nitrogenous compounds—may be carcinogens with long latency periods.[13] Use of these materials in private goods introduces the potential for external effects that are intertemporal and in some cases intergenerational in character. Bishop's comment serves a useful function in identifying the distinction between the definition of intertemporal efficiency and the properties of any institutional mechanism involved in resource allocation. One reason for concern over a definition of intertemporal and intergenerational efficiency is the existence of cases where private transactions are also yielding intertemporal external effects. Accordingly, it becomes necessary to understand the requirements for an efficient allocation of resources over time periods and generations and to evaluate the current practices of market intervention in terms of this standard.

III. SUMMARY

We have deliberately avoided consideration of other decision rules which argue for zero discount rates in evaluating the intertemporal allocation of private resources since they are implicitly or explicitly based on some departure from a

[12] This point was made by John V. Krutilla during the discussion at Resources for the Future's Forum on the Economics of Natural Resource Scarcity and is further elaborated by Fisher [3].

[13] See Kneese and Schulze [5] for further discussion.

strict efficiency criterion in evaluating resource allocations.[14] Our objective has been to clarify the implications of our definition of intertemporal and intergenerational Pareto efficiency conditions for the application of the current practices of cost–benefit techniques to a wide class of public good-related problems.

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[14] There are a variety of alternative justifications for zero discounting which do *not* have a basis in efficiency considerations. Ramsey [10] argues such discounting would be unethical while Solow [13] argues any discounting procedure can be rejected if one extends Rawls' principle of justice to an intergenerational context. See Mishan [8] for a discussion of these arguments.