The Sustainable Management of the Renewable Resources

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Abstract: This paper explores the traditional, economic definition of sustainable development along with a multiobjective framework for temporal decision-making. A simple, dynamic renewable resource allocation model is used to look at how resource management objectives and decisions change under warying definitions and problem scope. Impacts from temporal manipulation of how decision-time steps according to initial conditions and time-horizon.

Recent discussions have advocated the adoption of sustainable development policies to ensure that future generations will enjoy a standard of living at least as high as today's, including preservation of the productive capacity and resilience of ecosystems.

Economists have been studying this issue from their perspective since at least 1952 (Ciriacy-Wantrup, 1968), and have been developing definitions for optimal economic activity. Ciriacy-Wantrup defines the optimum state of conservation as: somewhere, in conservation, an economically optimum distribution of rates of use over time is reached. This distribution we call the „optimum state of conservation".

More recently, Tietenberg (1992) described this definition as „dynamic efficiency", standing that: an allocation across time-periods in dynamically efficient i fit maximizes the present value of net benefits that could be received from all the possible ways of allocating those resources over the n periods.

In addition to the above basic definitions, economists have been investigating the economic effects of implementation of environmental policy through the use of models (Xepapadeas, 1992).

Economic analysis

Resource-allocation models for continuous-time dynamic optimal management are familiar in resource economics. Analysis of market conditions and management strategy is made possible by formulating an optimization problem and considering maximization using a Lagrangian method.

A standard form of problem is to maximize the net present value flowing from the use of a resource for a given temporal domain, subject to a description of how the resource changes in time. The general case for a single-resource, and one-control variable in a free-state system, to be maximized for total net present value, is given as equation (1) for a discrete system,

$$\max z = \sum_{t=0}^{T} \mathrm{V}_t \, \mathrm{p}^{\mathrm{t}} \tag{1}$$

where:

V, is a value function at some time t which is dependent on both the state variable,

p – is the discount factor (2)

$$p = (1-\delta)^{-t} \tag{2}$$

The maximum principle, comprised of necessary conditions for the present value Hamiltonian, is used to solve the problem given a convex decision space. A Lagrangian method can be used to examine conditions for economic efficiency through the use of the Hamiltonian function. This solution would involve a present value of shadow price for the state variable given by the Lagrange multiplier. Economists, in many cases, are more interested in the current value of the shadow price for the state variable, obtained by maximizing the current value Hamiltonian.

In this case:

- Pricing is not controlled within the scope of the model;
- There is a given wealth distribution, institutional arrangements, and property rights allocation that will be unaffected by changes in management of the state variable:
- There is free access to enter and exit the market, and effort can be adapted to different industries with no cost or time delay.

The example we will use is a simple model of a fishery resource where X_t is the state variable, a stock of fish subject to an amount of effort, in harvesting the fish

$$V_1 = p\,\mathrm{H}_t \ - C_E E_t \tag{3}$$

The value function we will use (3) defines p as price of fish, H_t as the harvest function for fish – defined for our example as (4) – resulting in an equation of motion (5). F is a natural growth function for the fish stock, q is a scalar coefficient, and C_E is the marginal cost of effort for catching the fish

$$H_t = qX_t E_t \tag{4}$$

$$X_{t+1} - X_t = f - H_i \tag{5}$$

Assuming that a steady state solution to this problem exists, the optimal policy for operating the fishery can be found to define a switching policy function for „bang-bang" control of E_t. This policy type acts towards pushing the stock level to an optimum as fast as possible. Transformation of the solution defines the analytical form for an efficient price

(6). F' is the partial derivate of F with respect to X. By evaluation model conditions, economic policy can be implemented to ensure efficient economic use of the resource.

$$p = \frac{C_E}{qX}\left[1 + \frac{F}{X(\delta - F^{'})}\right] \qquad (6)$$

Recent discussions by economists and non-economists alike have centred on expanding economic analysis to include an assessment of overall social welfare or standard of living that includes social values related to the environment. Non-economists do not centre on how to drive an advanced property rights structure, but discuss the policy framework for sustainable development application.

Sustainable Investment

An example of sustainable development paradigm can be found in Young (1992), which take an ecological viewpoint in defining the required model components in the calculation of a resource price. The assumption made is that all the perceived important non-market ecological factors can be internalized. In this paradigm, the method of internalization is similar to that discussed by Baumol and Oates (1988) in their theory of externalities.

Producers of negative externalities are required to pay to offset or alleviate effects. Beneficiaries of positive externalities must compensate for their use. Development of rules of use for open access or common property resources implies the identification of additional benefits to be realized from internalization.

Young does not discuss the issues involved in achieving this state, such as the transaction costs associated with the exchange of property rights. Negotiating the specifics of agreements may demand extensive costs in determining the types of mitigation and restoration measures required for externalities such as air pollution. The transaction costs of contacting the rights may be identified through the explicit definition of the necessary conditions for sustainable development. Finally, the monitoring networks required enforcing these new rules of use for common property resources needs to be implemented.

Economic market conditions to achieve sustainability are much more closely related to traditional economics than are discussions of decision making such as multiobjective frameworks. When economic market efficiency is the guiding principle, additional subsets of economic conditions can be added. One is intergenerational equity, another is ecological integrity. Economic efficiency, intergenerational equity, and ecological integrity are three objectives for a more complete paradigm for sustainable development. These conditions can be used to define an expanded market system in terms of market price foe a sustainable resource, as described by Young (1992):

$$p = MC_s + MC_{LES} + MC_p + MC_{LFO} = MC_{LREV} + MC_A + MC_{CRD} \qquad (7)$$

where:

MC_S is the marginal cost of supplying the resource;

MC_{LES} is the marginal cost of replacing lost ecosystem support;

MC_P is the marginal cost of any pollution that the resource use imposes on other people;

MC_{LFO} is the marginal cost of offsetting lost future options;

MC_{LREV} is the marginal cost of offsetting lost existence values;

MC_A is the marginal compensation fir additional costs associated with the provision of positive non-market benefits.

MC_{CRD} is the marginal cost of capital associated with resource development.

Both MC_{LFO} and MC_{LREV} reflect social costs from losses in ecosystem diversity and resilience.

The Multiobjective Welfare Model

Non-economist perspectives may be moving away from traditional economic theory in circumstances where the market system fails to account for non-commensurate resources, and value system that are not explicitly defined within the property rights structure. For example, many temporal issues remain outside the market system, as long as perceived marginal benefits are insufficient to offset the marginal costs of brining future social values to bear on our present economies. We can observe an example of this as the industrial world desperately attempts to reduce emissions that contribute to destruction of the ozone layer, invoking large added costs to the production of some goods and a heavy burden on some economies. The economic interpretation of how markets work, and how open access or common property resources are treated within our market system, is merely implied.

The inclusion of multiobjective analysis in decision marking paradigms is not a new concept in sustainable development. Within these paradigms, the role of economics is viewed as one aspect of the problem. Systems approach interpretation envisions a holistic approach that includes multiobjective analysis, risk analysis, impact analysis, scope consideration for selection of multiple decision-markers, and including allowance for interaction among the various ecosystem components.

A multiobjective decision framework may discuss problems in terms of a welfare model that defines welfare efficiency as an equivalent to (1), substituting a welfare function, W for the summation of monetary benefits function, V. The model is dependent on the definition of welfare, which requires a relative valuation of social, and ecosystem components. The efficiency condition in the welfare model, the objective function, considers the practice of discounting future values. Normally, the discount rate in our model would be equivalent to some real cost of borrowing or using capital. An efficient policy is to maximize the value with regard to future values over the lifespan to be considered. In general, greater discount rates result in greater long-term degradation of the resource as policy is geared toward immediate returns. Smaller discount rates are generally associated with preservation of the resource.

Choosing a scalar value such that the discount rate reflects social values may not produce different results from discounts based on inflation. The optimal path may vary, but the inevitable and associated with the governing decision paradigm may be unaltered.

Of, course, considerable uncertainty exists in evaluating future values and in choosing the best option at some point in the future, assuming we are aware of future consequences. Uncertainty breed’s risk-averse decision-making implies a practical or perceived cost of capital at a very high rate. In choosing a lower limit for the resource at the end state, we are selecting a level of conservation or safety factor, but in doing so we usually merely exploit the resource to the lower level.

To make operational decisions, we must also consider the time frame to restrict our analysis. The initial impulse is to extend the time –frame for sustainable development, but it can also be argued that a shorter time-frame may be more appropriate, depending an the pricy definition, because our social values may change over time as understanding of our surroundings improves. Our conscious analytical choice of the time frame defines the problem of intergenerational equity.

One of the possible ways for dealing with intergenerational equity issues is a multiobjective framework. The definition requires the objectives of future generations. Extension of the welfare model is required in order to adjust to the multiobjective structure.

The fishery objective function can be expressed as the weighted combination of future values, such that the sum of the weights equals one:

$$\text{Max} \sum_{t=0}^{T} w_t V_t \rho^t \qquad (8)$$

where

$$\sum_{t=0}^{T} w_t = 1$$

This is not a traditional form of showing a multiobjective model. The different objectives are related to time as opposed to physical objectives.

Application of (8) produces a set of optimum followed by a subjective process to select one of the non-dominated solutions, as a best compromise solution. Assigning the weights to define a system of likely scenarios may allow tracking of different policy perspectives within the dynamic model, although an analytical economic interpretation of this multiobjective paradigm is difficult.

Conclusions

Regardless of whether much is known quantitatively about the behaviour of the resource under either natural conditions and under human pressures, temporal manipulation of the way decisions are made may be powerful tool. The management alternatives spawned from this knowledge may turn out to be considerably cheaper and subtler in the control of individual action.

In terms of practical decision-making, policy measures may need to restrict increasing changes in effort. This serves not only to force a limitation on effort and stock effects but also to foster longer-term decision-making. A stable fishing community may actually learn to circumvent many property rights transfer costs by regulating themselves to preserve their heritage and solve problems associated with the use of the commons, which are no longer considered an open access resource. With reference to equation (7), the fishing community may push the price toward the optimal price based on. Young (1992) by restricting harvests once some of the added benefits of maintaining larger fish populations are appreciated.

Using a multiobjective framework, we were able to change the form of the question to be answered from “what physical aspects apply?” to “what temporal aspects apply?”

Developing policy measures demands creativity to prepare innovative measures to improve readily available alternatives. Unfortunately, bridging the gap between policy-making and securing a promising future for us is very difficult.

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