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Environmental Accounting and the Roles of Economics

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Abstract
This paper is about green accounting. It contains a beneficial economic model where government pursues optimal economic policies. The aim of the paper is to serve as an indicator of wealth changes, performance of environment policy and sustainable use of natural capital. All the services are outputs from natural capital, the change of values of natural wealth. The paper also indicates the present and future production, and use of ecosystem services to indicate the sustainability of natural resources. Accounting prices of goods and services are constructed and are shown to reflect social securities.
Keywords: Green accounting, sustainability, NDP and NNP.

1. Introduction

Environmental accounting (EA) is an inclusive field of accounting, management and economics. It provides the following two reports (Bartolomeo et al. 2000):

- *Internal uses*: generating environmental information to help make management decisions on pricing, controlling overhead and capital budgeting.
- *External uses*: disclosing environmental information of interest to the public and to the financial community.

In the society internal use is better termed environmental management accounting (EMA). By increasing social focus on the environment, accounting fills an expectation role to measure environmental performance. A business firm's strategy includes responding to capital and operating of pollution control equipment.

The contribution of multiple disciplines provides a base for determination of environmental impacts and related costs. Impact of business activity on the environment is found in several forms as follows (Yakhou and Dorweiler 2004):

- *Media*: water, air and underground pollution.
- *Targets*: drinking water, land and, habitat for endangered and threatened species.
- *Global sites*: atmosphere, oceans and land mass.

In this paper we emphasis on four monetary sides of green accounting; to serve as i) wealth measurement, ii) indicator of sustainability, iii) Green national accounts for environmental purposes and, iv) accounting growth for local accounting prices. The purpose of this paper is to derive green accounting systems related with economics where the value of changes in natural capital is derived from their production of ecosystem services. Here we have related wealth to society's capital asset, which include all types of capital. The literature on income and wealth has converged to a common agreement on the natural capital stock as the basis for obtaining appropriate welfare measures (Heal and Kriström 2002). This capital base reflects the future capacity of society to produce human well-being. The investment in natural resources must be adjusted with economical sense where the accounting prices of natural resources must be estimated properly. The empirical estimates of accounting prices for green accounting system are mostly lacking, although there exist a few studies (Hamilton 2000). Mohajan (2011a,b,c) has discussed about net national product and sustainability in detail. In this paper we have tried to give a partial idea of green accounting and ecosystem services with introducing a model following Arrow et al. (2002, 2010), Dasgupta (2010, 2008 and 2007), Gren (2003) and (Dasgupta and Mäler 2000, 2001).

2. The Model

In our environmental economic model we consider the production of goods and services where we require labor, manufactured capital, and natural resources. Natural capital consists of a variety of ecosystems, such as wetlands, lakes, forests, agricultural landscape, and coastal water. The output provided by these ecosystems is called ecosystem services. Ecosystems are known to mankind from the ancient period. Most ecosystems produce marketed and non-marketed services. For example, forest produces timber, recreational values, pollutant sequestration, and biodiversity where we find both marketed and non-marketed services. On the other hand wetlands and coastal water provide us food where we find only marketed services.

Here we consider the time $t \geq 0$ is continuous, where $t = 0$ denotes the present time and $t > 0$ denotes the future time. For simplicity, all marketed goods and services are supposed in the compounded good G which uses natural capital $N \geq 0$ (at a finite time t) as a production factor. Environmental services are represented by the single compounded resource R. The marketed good and environmental services also need man-made capital K, and P is emit pollutants, as by products, which are treated as inputs into production of all marketed goods. If we use more inputs as like minerals and fossil fuels which generate emission of nitrogen oxides, carbon dioxide, carbon monoxide, sulphur dioxide etc. and pollute the environment. In environment ecosystem production of non-marketed goods and services is also affected by pollutants. Consider the carbon sequestration of forests and nutrient cleaning by wetlands depend positively on pollutant concentration in air and water respectively which are beneficial sides of environment. Let K_0 and N_0 be the initial stocks. The all purpose goods can be produced with its man-made capital K, and environment resource R. Hence the production function can be written as;

$$G = G(K, R).$$

Again environmental resource R, can be expressed as a function of natural capital N, and environment pollution P i.e.,

$$R = R(N, P).$$

Now the production function can be rewritten as;

$$G = G(K, N, P).$$

We assume that G is an increasing, non-concave and continuously differentiable function each of its variables. Natural capital can be changed by emitted pollution to produce goods and concentration by environment. Again bifurcation may occur and the characteristics of the ecosystem can be changed so it turns into another type of ecosystem. One example is provided by the Laholm Bay at the west of Sweden, which was heavily polluted by nitrogen during 1980s. The vegetation of large sea area bottoms vanished and species like cray fish became extinct. Such changes usually imply non-convexities and difficulties in assessing values of the ecosystems (Mäler 2000), but this type of incident is avoided in our paper. The change in natural capital is determined by its own growth g, ecosystem management and pollutant deposition, i.e., $g = g(N, P)$, where it is assumed that $g_N \geq 0$ and $g_P \leq 0$. Ecosystem management is made at the expenditure X which depends on N, and assumes to be increasing and convex in N. Let $C \geq 0$ denotes aggregate consumption at time t, then the net accumulation of physical capital satisfies the condition:

$$\frac{dK}{dt} = \dot{K} = G(K, N, P) - C - \delta K - X(N), \tag{1}$$

$$\frac{dN}{dt} = \dot{N} = g(N, P), \tag{2}$$

where δ is the capital depreciation rate. In some cases the emission of pollutants amounts directly to a degradation of ecosystems (e.g. loss of biomass); in others it amounts to a reduction in environmental quality (e.g. deterioration of air and water quality), which also amounts to degradation of ecosystems (Dasgupta and Mäler 2000, 2001). Hence resources are a *good* and pollution which is degrader of resources, is *bad*.

Let the natural rate of the resource base be $D(R)$ which is continuously differentiable function. We can augment it by the expenditure X. The expenditure X consists of the costs in the case of minerals and fossil fuels, clean up costs in the case of polluted water etc. Now we define,

$$Z = \int_{-\infty}^{t} E dt \tag{3}$$

where Z would be the measure of stock at time t. In differentiate form we can write (3) as:

$$\frac{dZ}{dt} = E.$$

Let us consider Q (X, Z, N) the rate at which the augmentation occurs. Here Q is continuous and differentiable where $Q_X \geq 0$ and $Q_Z \geq 0$. The dynamics of the resource base can be expressed as (Arrow et al. 2002, 2010; Dasgupta 2010, 2008; Dasgupta and Mäler 2000, 2001);

$$\frac{dN}{dt} = D(N) - R + Q(X, Z, N). \tag{4}$$

The utility in the society is determined by consumption of both marketed goods and services of resource i.e.,

$$U = U(G, R).$$

Again pollutants (P) affect utility directly through its impact on health; therefore the utility can be written as,

$$U = U(G, R, P)$$

which is assumed to be non-decreasing in all its arguments except P. Marketed and non-marketed goods G is the consumption of goods C, so that we can express the utility as,

$$U = U(C, R, P).$$

3. Sustainable Development of Wealth

The social welfare for $t \geq 0$ is determined by current and discounted future streams of utility as follows:

$$W = \int_{t=0}^{\infty} U(C, R, P) e^{-rt} dt, \quad (5)$$

where r is the utility discount rate. Now we consider a time autonomous problem, then (5) can be written in terms of initial stock parameters as;

$$\overline{W} = \overline{W}(K, N, \theta)$$

where $N \in R^n$, (n-dimensional Euclidean space), θ is an optimal resource allocation mechanism which describes the institutional set up for allocating resources among goods and services. The value of change in wealth for t > 0 can be defined as;

$$\frac{d\overline{W}}{dt} = \frac{d\overline{W}}{dK} \cdot \frac{dK}{dt} + \frac{d\overline{W}}{dN} \cdot \frac{dN}{dt},$$

$$\frac{d\overline{W}}{dt} = \lambda \dot{K} + v\dot{N}, \quad (6)$$

where λ is the shadow price of capital and v is the accounting price of the natural asset which can be derived by the maximization of the Hamiltonian (will be discussed below). World Commission on Environment and Development (WCED) [17] defined sustainable development as: "*Sustainable development is an economic program in which, lightly speaking, the well-being of future generations is not jeopardized*".

For sustainability we can write (6) as;

$$\frac{d\overline{W}}{dt} = \lambda \dot{K} + v\dot{N} \geq 0.$$

Hence sustainability implies that the total value of changes in the capital stocks is non-declining and the value of a stock unit is then determined by its accounting price, which, in turn reflects discounted current and future streams of net utility from a marginal change in the capital stock. The accounting price thus reflects the production potential of the capital base. When this production potential declines, it can not provide the same welfare for future as for current generation; at this situation we can say such current use of the resources is unsustainable.

Again we can define sustainability as follows (Arrow et al. 2010, Dasgupta 2010, 2007): "*Sustainable development is an economic program along which average well-being of present and future generations, taken together, does not decline over time*".
An economic development is sustainable if (Dasgupta & Mäler 2000, 2001),

$$\frac{dU}{dt} \geq 0 \quad (7)$$

which offers greater flexibility in ethical reasoning. It permits initial sacrifices in the current standard of living but requires that no future generation should have to experience a decline in their standard of living. If we consider the utility be a function of consumption, C and labor, L then we can write (7) as;

$$\frac{dU}{dt} = U_C \frac{dC}{dt} + U_L \frac{dL}{dt}. \quad (8)$$

Hence in this situation we can write the sustainability as (Dasgupta & Mäler 2000, 2001): "*If sustainable development is taken to mean that, starting from now, utility must never decline, then an economic program corresponds to sustainable development if and only if, the value of changes in the flow of consumption services is always non-negative*".

4. Green National Accounts

We can write the Hamiltonian as (Dasgupta 2008, Gren 2003):

$$H = U + \frac{d\overline{W}}{dt},$$

$$H = U(C,R,P) + \lambda(G - C - \delta K - X(N)) + g(N,P). \tag{9}$$

Hence we see that all changes in market goods and services are captured by net domestic product (NDP) and can be represented in utility terms actually which is the Hamiltonian (9). Taking partial differentiation of (9) for maximization we get (Gren 2003, Mohajan 2011);

$$U_C - \lambda = 0, \tag{10}$$

$$U_R R_N + U_R + \lambda G_R + \nu g_N = 0, \tag{11}$$

$$\dot{\lambda} = \lambda(r - G_K + \delta), \tag{12}$$

$$\dot{\nu} = \nu(r - g_N) - U_R R_N - \lambda(G_N - X_N). \tag{13}$$

From (10) we can write, $\lambda = U_C$, which indicates the marginal utility of consumption equals the shadow price of capital. From (11) we see that optimal use of pollutants is determined where marginal benefit from production of marketed and non-marketed goods and services equals marginal cost. Integrating (13) we get the accounting price of the natural asset ν (t) for $t \geq 0$;

$$\nu(t) = \int_0^{\infty} U_R R_N + U_C(G_N - X_N) e^{(r-g_N)(\tau - t)} d\tau. \tag{14}$$

From (14) we see that the accounting price of the natural asset in time t is thus the discounted streams of current and future net utility from marketed and non-marketed goods and services of a marginal change in $N(t)$. The future values of these services are then discounted by the utility discounted rate. The sum of discount rate and the change in growth rate of the stock would be changed in the previous stock which could be either positive or negative. If the change in the growth rate is positive, the discounting of future net utility is decreased as compared to when $g_N = 0$. Obviously, depending on the stock level, g_N would be either positive or negative.

In practical life we see that increased stock enhance growth at relatively low stock level, but at larger levels a further increase in the stock may imply a reduction in growth.

The current net domestic product, NDP^C, can be expressed as (Gren 2003):

$$NDP^C(t) = NDP(t) + \psi\left(U(P,R) + \int_0^{\infty} U_R U_S \, \dot{S} \, e^{(r-g_N)(\tau - t)} d\tau \right). \tag{15}$$

where $\psi = \frac{1}{U_C}$. Equation (15) indicates that current utility from pollutants and ecosystem services, and change in future utility from ecosystem services caused by the period's change in the stock of natural capital.

5. Accounting Growths

In this section we rewrite the Hamiltonian (9) as follows (Dasgupta 2008, Dasgupta and Mäler 2000):

$$H = U(C,L) + p(G - C - \delta K - X(N)) + qX + sD - R + Q(X,Z,N) \tag{16}$$

where p, q and s indicate the local accounting prices. Dasgupta and Mäler (2000) emphases on the local accounting prices as follows: "*An elementary policy* (t = 0) *reform increases social well-being if and only if it registers an increase in net national product measured in local accounting prices*".

Differentiating (16) for optimization and then for simplification we introduce new variables as follows:

$$n = -\frac{U_L}{U_C},\quad m = \frac{p}{U_C},\quad u = \frac{q}{U_C} \text{ and } x = \frac{s}{U_C}.$$

Hence we can define NNP as follows:

$$NNP = C - nL + m\frac{dK}{dt} + u\frac{dZ}{dt} + x\frac{dN}{dt}\ . \tag{17}$$

We consider the resource augmentation function $Q(X^1, Z^1, N)$ and assume that the output of the production consumption good at time t can be expressed as;

$$Y = e^{\chi t} M(Z^2) G(K, L, R) \tag{18}$$

where $\chi \geq 0$ and $Q'(Z^2) \geq 0$. Here $e^{\chi t} M(Z^2)$ indicates the production of final good. Let p_1 and p_2 be the local accounting prices of Z^1 and Z^2 respectively. Now we can write (17) as;

$$NNP = C - nL + m\frac{dK}{dt} + p_1\frac{dZ^1}{dt} + p_2\frac{dZ^1}{dt} + x\frac{dN}{dt}. \tag{19}$$

6. Concluding Remarks

In this paper we have discussed aspects of green accounting with well being in present and future sustainability. We have included both marketed and non-marketed capitals and the accounting prices to optimize the natural resources in NDP of a country by the Hamiltonian. Natural capital is commonly treated as an externality from production of market goods and services, but here we have shown that the natural capital is instead treated as an input into production of ecosystem services. We have also calculated NNP considering local accounting prices which is an essential part of green accounting.

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