Environmentally Sustainable Income and Shadow Prices of Natural Resources

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Abstract

Valuation of environmental resources is needed for making investment decisions in environmental management, for designing environmental policy, and for measuring environmentally corrected national income. Waste disposal services offered by the environmental media to the industry are productive inputs along with the conventional inputs. Industry uses pollution abatement technologies comprising end of pipe treatment, process changes in production, and changes in the use of inputs and products for reducing pollution loads as per the environmental regulation. In this type of situation the assumption of free disposal of pollution is not appropriate in describing the technologies of firms generating pollution. For a firm with a resource constraint, the reduction leads in turn to the reduction of production of output. A description of the technology of a polluting firm as one of producing jointly good and bad outputs with the weak disposability assumption makes it possible to account for the loss in the production of good output to reduce the bad output, pollution. The output distance function in the theory of production describes the technology of a polluting firm in this way. The shadow prices of environmental resources are derived in a general framework of an overall planning problem for the economy in which environmental inputs are productive inputs in the industry, use of environment by the industry affects the utility of people, and industry uses abatement technologies to reduce the pollution. Models for deriving shadow prices are provided with alternative specifications about the technology of polluting firms. It is shown that in case there is a fall in the environmental quality with the economic development, the defensive expenditures estimated at shadow prices have to be deducted from NNP to arrive at ENNP. It is shown that a pollution tax levied on the firms equal to the marginal cost of abatement at optimum guarantees the market efficiency in the dynamic model. In a sub-optimal or second best economic program, effects of an investment project on the net national product can be evaluated using local or second best prices. The second best prices are suitably adjusted market prices for private goods and the estimated prices using data collected through specially designed survey methods for public goods or environmental services.

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1 Introduction

Valuation and accounting of environment resources are needed for three important reasons: (a) for making investment decisions in environmental management, (b) for designing economic instruments for controlling environmental externalities, and (c) for accounting environmental services in the valuation of national income. There is a lot of theoretical and empirical literature on the valuation of environmental resources (Freeman, 1993; Mitchell and Carson, 1989). Also there is a growing literature on the accounting of environmental resources in the valuation of national income (Hartwick, 1990; Maler, 1991; Dasgupta and Maler, 1998; UN, 1993a,b). The rules for the sustainable use of natural resources are found in various studies on optimal inter-temporal resource allocation and sustainable development (Hotelling, 1936; Solow, 1974; Hartwick, 1978a,b).

Hartwick (1990) and Dasgupta and Maler (1998) have shown that the net national product (NNP) along the optimal path of the economic programme can be measured at shadow prices of consumption, labour, man made capital and natural capital. In a non-optimizing economy, local prices or second best prices can be used to measure NNP. These findings provide a justification for using suitably corrected market prices for private goods and estimated prices for public goods or environmental services using survey data in the estimation of environmentally corrected NNP.

The United Nation's methodology of integrated environmental and economic accounting (UN, 1993b) discusses various methods of estimating environmentally corrected NNP using market prices for private goods and the estimated shadow prices for the non-marketed environmental services. These methods provide for accounting both productive and consumptive services of environmental resources.

The remaining paper is organized as follows: Section2 discusses the issue of environmentally sustainable income. Section 3 presents an analytical framework for the derivation of shadow prices of environmental resources. Section 4 discusses alternative specifications of technologies of polluting firms in deriving shadow prices of pollutants. Section 5 deals with dynamic efficiency and pollution tax. Section 6 discusses NNP and shadow prices. Section 7 presents a case for using the local shadow prices in the measurement of net national product. Section 8 provides a brief review of integrated environmental and economic accounting while Section 9 provides the conclusion.

2. Environmentally Sustainable Income

There are many definitions of sustainable income (Hicks, 1946). The general view about sustainable income is that it is the maximum attainable income in one period with the guarantee that the same level of income will be available in future periods given the constraints on the resources: labor, man made capital and natural capital. Therefore, income is straightaway related to the availability of man made and natural capital. Alternatively, in the neo-classical approach to sustainability, sustainable income is defined as the maximum amount spent on consumption in one period without reducing the real consumption expenditures in future periods. In the face of changing prices and interest rates over time, this is the most appropriate definition of sustainable income. The same concept is implicit in Hotelling's rule for the efficient intertemporal allocation of exhaustible resources (Hotelling, 1931) which states that the price of an exhaustible resource should increase at the rate of interest. The use of this definition in the theory of sustainable resource utilization attempts to establish how real consumption expenditure based on the exploitation of natural resources might remain constant over time. Maintaining real consumption expenditure constant over time requires maintaining a constant means of production including man made capital, natural resources, technology, and the level of learning (human capital). The environmentally corrected net national product (ENNP) shows the amount of this productive base that can be used up over time. There is now a lot of literature about the problem of estimating ENNP and the sustainable use of environmental resources. Among these the significant contributions include Hartwick (1977, 1990,a,b); Maler, (1991); Weitzman, (1976); Solow, (1974, 1986, 1992); Ahmad et al. (1989); Lutz, (1993); and theUN, (1993).

Studies by Solow, (1974) and Hartwick, (1977, 1978a,b) have tried to derive the conditions under which real consumption expenditure might be maintained despite declining stocks of exhaustible resources. The main result of these studies known as the Hartwick rule, states that consumption may be held constant in the face of exhaustible resources only if the rents deriving from the inter-temporally efficient use of those resources are reinvested in the reproducible capital. The relationship of the Hartwick rule with sustainable income hinges on the assumption of the substitutability between man made capital and natural capital. Solow (1974) using the Rawlsian maximin principle has shown that in the case of homogenous capital the optimal inter-temporal resource allocation requires the maintenance of existing capital stock by making the investment exactly equal to depreciation. Even in the case of heterogeneous capital stocks, it is shown that it is possible to derive the investment rule that maintains the productive capacity of capital stock provided there is sufficient substitutability between man made capital and natural capital (Hartwick, 1978,b).

The main criticism about the Solow-Hartwick definition of sustainable income is that the man made capital could not be substituted by natural capital. Natural capital can be exploited by man, but could not be created by man. According to the thermodynamic school (Christensen, 1989), natural capital and man made capital are not substitutable. One can think of two subsets of inputs, one containing the natural capital stock `primary inputs' and another containing man made capital and labor, the `agents of transformation'. The substitution possibilities with in each group can be high while they are limited between the groups. Increasing income means increasing the use of inputs from both groups. Given the limited substitutability between man made capital and natural capital, it is necessary to maintain some amount of the natural capital stock constant in order to maintain the real income constant at the current level over time (Pearce et al., 1990; Klaasen and Opschoor, 1991; Pearce and Turner, 1990). This can be a heavy restriction on development if the current levels of natural capital stocks are chosen as a constraint, since it requires a banning of all projects and policies impacting the natural capital stock. As a way out of this problem, Pearce et al. suggest the use of shadow projects. These are the projects and policies designed to produce environmental benefits in terms of additions to natural capital to exactly offset the reduction in natural capital resulting from the developmental projects and policies. Daly (1990) has suggested some operational principles for maintaining natural capital at a sustainable level. For example, (1) in the case of renewable resources, set all harvest levels at less than or equal to the population growth rate for some predetermined population size, (2) for pollution, establish assimilative capacities for receiving ecosystems and maintain waste discharges below these levels, and (3) for non-renewable resources, receipts from non-renewable extraction should be divided into an income stream and an investment stream The investment stream should be invested in renewable substitutes (biomass for oil).

In the neo-classical definition of sustainable income, it is important to know what constitutes the consumption expenditures especially when environmental resources and people's preferences for them are involved. The concept of consumption in neo-classical economics implies two key assumptions: an exogenously determined set of preferences and an exogenously determined heritage comprising both a set of resources and the property rights that map those resources into the consumer constraint set. In the case of environmental resources, because of their public good properties, the exogenously given consumer preferences are not readily translated into prices through markets and the property rights can not be defined and implemented to map them into the consumer constraint set. Therefore, the notion of consumption should also imply exogenously given instruments and the institutions to deal with environmental externalities. Instruments like pollution taxes or marketable pollution permits help to impute prices for environmental resources so that consumer preferences for them are reflected in the consumer budget decisions. In most of the models dealing with sustainable development in natural resource economics, this feature of environmental resources is not explicitly incorporated. The environmental services are public goods requiring non-market solutions to manage them efficiently. These solutions should form part of a model of sustainable development.

3 . Shadow Prices of Natural Resources

Some recent studies (Hartwick, 1990b; Maler, 1991; Dasgupta and Maler, 1998) have derived shadow prices for environmental resources with different descriptions of the technology of polluting firms. Given the environmental regulation ,firms choose a combination of technologies comprising end of pipe treatment, process changes in production, changes in the quality of products and input choices. The pollution loads accepted by the environmental media may be regarded as environmental inputs that the industry receives. The environmental inputs can be considered as productive inputs along with conventional inputs. The demand for environmental services can be interpreted as a derived demand arising out of use of certain inputs in the production of a commodity. Alternatively, the firm can reduce pollution loads by reducing its production implying that the pollution load is not freely disposable[1]. Also, the technology of a polluting firm can be described as one of joint production of good and bad outputs, the bad output being pollution load. The output distance function with a weak disposability assumption describes this technology (Shepard, 1953,1970; Fare et al.,1994; Fare and Primont,1995).

The description of the technology of polluting firms by the distance function accounts for all the possible pollution abatement technologies that the firm uses.

Consider an economy producing a commodity X_t using capital, K_t, labour L_t and environmental inputs M_t at time t. The production function of X_t is given by :

$$X_t = F(K_t, L_t, M_t) \qquad (1)$$

F is concave and an increasing and continuously differentiable function of each of its variables. Environmental inputs here may refer to the waste disposal services provided by water resources and atmosphere. Let C_t represent aggregate consumption at time t and E_t, the pollution abatement expenditure in the production of X at time t. The net accumulation of physical capital therefore satisfies the condition (2).

$$\dot{K} = \frac{dK_t}{dt} = F(K_t, L_t, Mt) - C_t - E(A_t), \qquad (2)$$

where A_t is the rate of pollution abatement.

Let S_t represent the stock of environmental resource (quality of water resource or atmosphere) at time t, $N(S_t)$ the natural rate of regeneration of this stock (natural rate of assimilation of pollution loads), M_t, the rate of depletion of this stock (rate of degradation of environmental quality). Therefore, the net accumulation of the stock of environmental resource satisfies the condition (3),

$$. = \frac{dS_t}{d_t} = N(S_t) - M_t + A_t \qquad (3)$$

Assuming that the utility depends on the change in stock of environmental resource[2], the inter-temporal utility function in the utilitarian form is given as ,

$$\int_o^\infty U(C_t, L_t, \dot{S})e^{-\mathrm{rt}}d_t \quad , \qquad (4)$$

where U is strictly concave, increasing in C and decreasing in . and L and r is the rate of discount or interest rate. Let us consider the planning problem of government consisting of variables (C,L,M,A,K and S). Given the initial values of man made capital and natural capital, Ko and So, this planning problem is feasible if it satisfies conditions (1), (2) and (3).

Choose the control variables (C, L, M, A) to maximize,

$$\int_o^\infty U(C_t, L_t, \dot{S})e^{-\mathrm{rt}}d_t$$

subject to the conditions

$$\frac{dK_t}{d_t} = F(K_t, L_{t,Mt}) - C_t - E(A_t) , \qquad (5)$$

$$\frac{dS_t}{d_t} = N(S_t) - M_{t} + A_t$$

Increase in the use of waste disposal services by the industry results in the decrease in environmental quality and hence a fall in the utility of its users for consumptive purposes. On the other hand, pollution abatement by the industry results in improved environmental quality and increase in utility. Let p_t and q_t represent the shadow prices associated with the constraints on man made capital (K_t) and natural capital (S_t). The Pontryagin Maximum Principle Arrow and Kurz, (1970) states that the shadow price system satisfies in addition to feasibility constraints (1), (2) and (3) the following equations :

$$\frac{dp^*_t}{d_t} = p_t^*(r - F_k) \qquad (6a)$$

$$\frac{dq^*_t}{d_t} = q_t^*(r - N'(S)) \qquad (6b)$$

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[1] Hartwick (1990) considers the pollution load as an argument of the production function assuming higher pollution load leads to lower production. Given the environmental regulation, higher pollution loads generated require higher reductions of loads resulting in lower production of good output. It implies that pollution is not freely disposable.

[2] Hartwick (1990) also considers this type of utility function in measuring the pollution effects on NNP.

These two conditions (6a) and (6b) define the optimal time path of prices of man made capital and natural capital in the economic program. In the case of man made capital K, the appreciation of price over time should be equal to the rental on capital (p_t*r) minus the dividend p_t *F_k .In the case of natural capital, the appreciation of its price should be equal to royalty (q_t* r) minus bonus for the regeneration of capital due to maintenance of stock (q_t* $N^/$ (S)). Alternatively, along the optimal time path we have

for man made capital,

$$\frac{dp_t^*}{d_t} + p_t^* F_k = r p_t^* \qquad (7a)$$

Price appreciation + Dividend = Rental

for natural capital,

$$\frac{dq_t^*}{d_t} + q_t^* N^/(S) = r q_t^* \qquad (7b)$$

Price appreciation + Bonus for regeneration = Royalty for holding the stock of natural capital

Now the current value Hamiltonian of the economic program (5) can be written as,

$H_t = U(C_t, L_t, .) + p^*_t (F(K_t, L_t, M_t) - C_t - E_t) + q^*_t (N(S_t) - M_t + A_t)$, (8)

where C_t, L_t. M_t, A_t are control variables, K_t, S_t are state variables, and p_t*, q_t* are co-state variables. Maximisation of H_t with respect to C_t, L_t, M_t and A_t yields the canonical equations

$U_c = p^*_t$, (8a)

$-U_l = p^*_t F_L = w$ (8b)

$-U_. + p^*_t F_M = q^*_t$, (8c)

$-U_. + p^*_t E = q^*_t$, (8d)

From (8c) and (8d) we have,

$F_M = E$ (8e)

Equations (8a) and (8b) imply respectively that along the optimal path the price of consumption is equal to its marginal utility, and that wage rate is equal to marginal disutility of labor. The pollution load accepted by the environmental media is the environmental input in the production of commodity X and it also enters in the utility function as environmental pollution providing disutility. The industry has a pollution abatement activity the cost function of which is given as $E(A_t)$. Equation (8c) explains that the industry uses waste disposal services upto the level at which its price is equal to the net marginal benefits (marginal value productivity of environmental services minus the marginal disutility from pollution). Equation (8d) shows that the industry carries pollution abatement upto the level at which the net marginal cost of abatement (marginal cost of abatement minus marginal utility from the reduced pollution) is equal to the price it has to pay for the waste disposal services. Equations (8c) and (8d) together yield equation (8e) which shows that the industry uses environmental input and does pollution abatement upto levels at which the marginal productivity of waste disposal services is equal to the marginal cost of pollution abatement. Using Euler's theorem, it can be written that $U(C_t, L_t, .) = U_c C + U_l L + U_. .$ Therefore, equation (8) can now be written as

$$H_t = C + \frac{U_l L}{p^*_t} + \left\{\frac{U_. + q^*_t}{p^*_t}\right\} . \quad \text{or} \qquad (9)$$

$$H_t = C + \frac{U_l L}{p^*_t} + \dot{K} + E' .$$

The first three components on the right hand side of equation (9) constitute the conventional national income. If .is less than zero, it means that environmental quality falls with the economic development, equation (9) shows that defensive expenditure (E′ .) has to be deducted from national income to get ENNP.

4. Valuation of Environmental Resources: Alternative Models

Demand for waste disposal services may be considered as derived demand arising out of the use of certain inputs in the production of X_t. Use of coal and other fossil fuels by the industry creates a demand for waste disposal services. The industry can reduce pollution through appropriate input choices. Assuming that the pollution load generated by the industry is proportional to the coal used in production of X_t, the pollution load is given as

$M_t = \alpha Y_t$ where Y_t is the amount of coal used by the industry and α is the ratio of pollution load to coal used. The Hamiltonian of the planning problem in this case can be written as

$$H_t = U(C_t, L_t, .) + p^*_t (F(K_t, L_t, Y_t) - C_t - m_t Y_t - E_t) + q^*_t (N(S_t) - M_t + A_t) \qquad (10)$$

Maximisation of H_t with respect to C_t, L_t, Y_t and A_t yields

$$U_c = p^*_t, \qquad (11a)$$

$$-U_l = p^*_t F_L = w \qquad (11b)$$

$$-\alpha U_. + p^*_t F_Y - m_t = \alpha q^*_t, \qquad (11c)$$

$$-U_. + p^*_t E = q^*_t, \qquad (11d)$$

(11c) can be written as

$$-U_{.} + \frac{p^*_t F_Y - m_t}{\alpha} = q^*_t, \qquad (11c')$$

From (11c′) and (11d) it follows that

$$\frac{p^*_t F_Y - m_t}{\alpha} = E \qquad (11e)$$

Also from (11e), it follows that

$$p^*_t F_Y = m_t + \alpha E \qquad (11e')$$

This equation shows that the polluting input is used by the firm upto the level at which its marginal value productivity is equal to its market price plus the cost of abatement of pollution generated by using one unit of this input at margin. Equation (9) for environmentally corrected NNP can be rewritten in this case with E taking the value given in (11e).

Alternatively, the technology of a polluting firm can be described as one of producing bad and good outputs jointly by the output distance function in defining the environmentally corrected NNP.

With the assumption that a firm could not dispose bad output environmental pollution freely, the marginal cost of abatement or shadow price of bad output can be defined by using the output distance function. Consider $X_t = F(K_t, L_t, M_t)$ as the output distance function where X_t and M_t are good output and bad output (pollution) produced jointly by a firm. With the weak disposability assumption, it follows that $dX_t / dM_t > 0$. That means that the firm has an opportunity cost of reducing bad output in terms of good output that is also the shadow price of pollution. The Hamiltonian of the planning problem is now given as,

$$H_t = U(C_t, L_t, .) + p^*_t (F(K_t, L_t, M_t) - C_t) + q^*_t (N(S_t)-M_t) \qquad (12)$$

.

The canonical equations are given as,

$$U_c = p^*_t, \qquad (12a)$$

$$-U_l = p^*_t F_L = w \qquad (12b)$$

$$-U_{.} + p^*_t (dX_t / dM_t) = q^*_t, \qquad (12c)$$

Using (12) and (12c), the Hamiltonian for the environmentally corrected NNP can be written as

$$H_t = C + \frac{U_1}{p*1} L + \dot{K} + (dX_t / dM_t) \quad . \qquad (13)$$

5 Dynamic Efficiency and Pollution Tax

To appreciate the public good character of environmental quality, let us assume that there are **R** consumers and G firms producing the commodity X. Let c^i, and l^i denote consumption and wage labor of individual i and let f^j, x^j, l^j, k^j, m^j,e^j, and a^j, represent respectively the production function, commodity produced, labor, capital, and environmental inputs, pollution abatement expenditure, and pollution abatement for firm j. Then the Hamiltonian can be written as,

$$H_t = \sum_{i=1}^{R} u^i (c_t^i, l_t^i, .) + p^*_t \sum_{j=1}^{G} (f^j(k_t^j, l_t^j, m_t^j) - \sum_{i=1}^{R} c_t^i - \sum_{j=1}^{G} e_t^j)$$

$$+ q_t(N(S_t) - \sum_{j=1}^{G} m_t^j + \sum_{j=1}^{G} a_t^j) \qquad (14)$$

Since environmental quality is a public good, . enters the utility function of all consumers. We also have $M_t = \sum_j m_t^j$, $L_t = \sum_j l_t^j$, $E_t = \sum_j e_t^j$ and $A_t = \sum_j a_t^j$,

In this case, the optimality conditions for the private goods C, L and M and for the public good . are given as follows:

$$u_c^i = p^*_t, \qquad (14a)$$

$$-u_l^i = p^*_t \, f_l^j = w \qquad (14b)$$

$$-\sum u^i_. + p_t^* \, f_m^j = q^*_t, \qquad (14c)$$

$$-\sum u^i_. + p_t^* \, e_t^j = q^*_t, \qquad (14d)$$

From (9c) and (9d) it follows $p_t^* \, f_m^j = p_t^* \, e_t^j = q^*_t + \sum u^i_.$ yielding

$$f_m = e \qquad (14e)$$

If a pollution tax t is levied on each firm such that $t = p_t^* f_m = p_t^* e$, the profit function of firm j can be written as

$$\Pi^j = p^*_t \, x_t^j - w \, l_t^j - e_t^j - t(m_t^j - e_t^j) \qquad (15)$$

Maximization of (10) with respect to m_t^j and a_t yields,

$$p_t^* \, f_m^j - t = 0 \qquad (15a)$$

$$- p_t^* e_t^j + t = 0 \qquad (15b)$$

(15a) and (15b) together yield the condition (8e) for optimal use of environmental input and the optimal abatement by the firm.

6. Net National Product and Shadow Prices

The net national product can be expressed as linearized Hamiltonian given the shadow prices (Dasgupta and Maler, 1998). The solution of the economic program described above is also the solution of the following optimization problem. Choose control variables (C_t, L_t, M_t, A_t) so as to maximize,

$$\int_0^\infty (p_t^* c_t - w_t^* L_t) dt ,$$

subject to the conditions

$$dK_t \mid dt = F(K_t, L_t, M_t) - C_t - E_t , \qquad (16)$$

$$d S_t \mid dt = N(S_t) - M_t + A_t ,$$

where K_o and S_o are given initial conditions. The current value Hamiltonian in this case is

$$H_t = p^*_t C_t - w^*_t L_t + p^*_t \{F(K_t, L_t, M_t) - C_t - E_t\} \qquad (17)$$

$$+ q^*_t \{N(S_t) - M_t - A_t\}$$

Taking consumption as numeraire, define $w_t = w^*_t \mid p^*_t$, $q_t = q^*_t \mid p^*_t$.

$I^k_t = d k_t / dt$, $I^s_t = d S_t \mid dt$

We can then express (17) in terms of consumption numeraire as

$$H_t = C_t - w_t L_t + I^k_t + q_t I^s_t \qquad (18)$$

The conventional measure of NNP is (C_t - w_t L_t + I^k_t) which does not account for the contribution of environmental resource as a public good ($q_t I^s_t$).

7. Local Shadow Prices and NNP

A movement to the first best optimum program requires a policy reform involving non-marginal changes in both stock and flow variables starting from the initial program (C_0, L_0,M_0, A_0, K_0, S_0). There can be several constraints (political and economic) to undertake such a non-marginal policy reform. In reality, government can undertake only marginal policy reforms in terms of investment projects resulting in marginal increase in man made and natural capital. For example, investment in effluent treatment by the industry can result in marginal increase in air and water quality, afforestation projects can result in the increasing stock of forest resources during a short period. However, due to various constraints, these investments are not made upto the level at which marginal social benefits are equal to marginal abatement cost, the first best rule given by the equation (8e) in Section 4. The first best environmental regulation: Pigouvian tax or marketable pollution permits are not normally used. Instead ,second best methods like tax/permits and environmental standards or even more inefficient methods like command and controls are used.

In practice, we have to deal with economic programs with many constraints so that it is not possible to have the first best program. We can therefore, at the utmost have a second best or third best program through policy reforms. To evaluate the policy reforms, NNP measured at second best or third best prices has to be used. The literature on social-cost benefit analysis (Dasgupta, Sen and Marglin, 1972; Drez and Stern, 1990) has recognized this problem and suggests methodologies to compute the second best shadow prices (shadow prices of investment, foreign exchange and unskilled labour) for the evaluation of marginal projects. Maler, 1998 and Dasgupta and Maler, 1998 are the first to discuss the problem of using local or second best prices in the measurement of sustainable NNP. For the evaluation of a policy reform, the local prices are suitably adjusted market prices for private goods and the prices estimated with the specially designed methods (hedonic prices, estimated willingness to pay using contingent valuation survey methods) for public goods or environmental services.

Dasgupta and Maler (1998) define a resource allocation mechanism as follows: Given the initial capital stocks (Ko, So), the institutional structure of the economy (market and property rights and taxes) and the behavioural characteristics of various agencies (households, firms, government), it would be possible to make a forecast of the economic program $(C_t, L_t, M_t, A_t, K_t, S_t)_o^\infty$ that would be expected to unfold. They call this relationship a resource allocation mechanism. A resource allocation mechanism (a) is a mapping from initial capital stocks (K_0, S_0) into the set of economic programs $(C_t, L_t, M_t, A_t, K_t, S_t)_o^\infty$ satisfying the conditions (1), (2), (3), (4) and (5). The social well being at time t is written as,

$$V_t(\alpha, K_t, S_t) = \int_t^\infty e^{-r(t-t)} U(C_t(a), L_t(a), \dot{S}(a)) dt \tag{19}$$

The local prices along the economic forecast can be defined as :

$$p_t(a) = \frac{\P V_t}{\P K_t}, q_t(a) = \frac{\P V_t}{\P S_t} \tag{20}$$

These prices measure the social scarcity of the economy's capital assets. The NNP computed on the basis of local prices, can be used to evaluate policy reform.

The change in Vo as a result of the policy reform can be expressed as :

$$\Delta V_o = V_o(a + \Delta a, K_o, S_o) - V_o(a, K_o, S_o) \tag{21}$$

$$= \int_o^t e^{-rt}[U(C(a + \Delta a), L(a + \Delta a), \dot{S}(a + \Delta a)$$

$$- U(C(a), L(a), \dot{S}(a)] dt .$$

$$+ e^{-rt}[V_t(a, K_t + \Delta K_t, S_t + \Delta S_t)$$

$$-V_t(a\ ,K_t,S_t)]$$

Using equations in (20) and accumulation equations in (5) we can write (21) as

$$\Delta V_o = te^{-rt}(U_c\Delta C + U_l\Delta L + U_{\dot S}\ \Delta\dot S) + e^{-rt}(V_k\Delta K + V_s\Delta S) + e(t)\ , \tag{22}$$

where $e(t)$ is an error term. Now consider perturbations in the capital assets as a consequence of reforms,

$$\Delta K_t = \int_0^t \Delta(dK_t/dt)dt = t\Delta(dK_t/dt) + b(t)$$

$$\Delta S_t = \int_0^t \Delta(dS_t/dt)dt = t\Delta(dS_t/dt) + g(t)$$

where $b(t)$ and $g\ (t\ )$ are error terms

Therefore, equation (22) can be written as ,

$$\Delta Vo\ /\ t\ = e^{-rt}(U_c\Delta C + U_l\Delta L + U_{\dot S}\Delta\dot S + p_o\Delta(dK_t/dt)_{t\ =\ 0} \tag{23}$$

$$+q_o(dS_t\ /\ d_t)_{t\ =\ 0} + q\ (t\ )\ ,$$

where $q\ (t\ )$ is an error term.

The left hand side of (23) is a change in social well being per unit of time during (O,t). Since we are interested in small perturbation, letting $t \to o$, the LHS of (19) becomes the change in social well being due to a reform and the right hand tends in the limit to,

$$U_c\Delta C_0 + U_L\Delta L_0 + U_{\dot S}\Delta\dot S + p_0\Delta(dK_t/dt)t = 0 + q_0\Delta(dS_t/dt)t = 0 \tag{24}$$

$$U_cC_t - U_LL_t + U_{\dot S}\Delta\dot S + p_tdK_t/dt + q_tdS_t/dt\ , \tag{25}$$

which is familiar as NNP in utility terms. Expression (24) can now be seen as a change in NNP as a result of reform.

To study the dynamics of stock prices, consider the current value Hamiltonian associated with the policy reform α.

$$H_t = U(C_t, L_t, \dot S) + p_t\frac{dK_t}{dt} + q_t\frac{dS_t}{dt} \tag{26}$$

From (19) we have the differential of V_t with respect to t as ,

$$dV_t/dt = rV_t - U(C_t, L_t, \dot S) \tag{27}$$

Since $V_t = V_t(a, K_t, S_t)$, using (14) we have,

$$\frac{dV_t}{dt} = p_t \frac{dK_t}{dp_t} + q_t \frac{dS_t}{dq_t} + dV_t / dt \tag{28}$$

Combining equations (25), (27) and (28) we have ,

$$H_t = rV_t - \partial V_t / \partial t \tag{29}$$

If the policy reform is chosen independent of calendar time, V_t does not depend on it so that

$\partial V_t / \partial t = 0$. Therefore, equations (29) reduces to ,

$$H_t = rV_t \tag{30}$$

Equation (30) says that the Hamiltonian is equal to return on social well being (Dasgupta and Maler, 1998).

8 .Integrated Environmental and Economic Accounting

United Nations (1993) provides a methodology to estimate environmentally sustainable NNP (ENNP). The more general concept of ecologically sustainable income requires the integrated economic and environmental accounting to consider possible ecologically sound balances between nature and man and account for actual imbalances. The objective here is to have an optimal balance between human and non-human claims. The less general concept of environmentally sustainable income considers the anthropocentric point of view, the natural environment exists for the benefit of human beings, especially in the context of various economic activities promoting human welfare. The recent literature in Environmental Economics has called for a synthesis of ecological and anthropocentric points of view. The exploitation of the environment has reached a stage where human beings are impairing their own living conditions. For instance, the waste disposal function of the environment may compete with the physiological need for its provision of clean air and water. Therefore, the integrated framework for economic and environmental accounting should help in identifying the strategies of sustainable development that balance the satisfaction of human needs with the long-term maintenance of environmental functions.

The natural environment and the economy could be taken as two sides of the same coin.

There are two important aspects in the development of integrated economic and environmental accounting. First, the description of environment in physical terms by defining an asset boundary that is more extensive than that given in the conventional national accounts. A distinction has to be made between natural and man made assets. Natural assets consists of biological assets, land and water areas with their ecosystems, subsoil assets and air. Table 1 provides a description of man made and natural assets. The second is the valuation of natural assets. Natural assets provide both marketable and non-marketable services and therefore their valuation requires the use of market and non-market valuation techniques. Also it is not possible to value all ecosystem functions of natural assets that are described in the physical accounts that show the economy and environment inter-linkages.

The methods of valuation of environmental services could be classified as three different valuation types: (a) market valuation according to the concept of the non-financial asset accounts in the conventional system of national accounts, (b) maintenance valuation, which estimates the cost necessary to sustain at least the present level of natural assets, and (c) hypothetical behavioral methods like contingent valuation and other behavioral methods like hedonic property values, travel cost and household production functions for estimating the value of consumptive services of natural environment. The maintenance valuation method uses actual or hypothetical cost data. Expenditures required for maintaining the services of natural environment constitute the actual cost. These are the costs for the mitigation of damage caused by the decreased environmental quality or for an increase in environmental protection activities that prevent degradation of natural assets. These costs will not capture the entire value of decrease in environmental quality and they can be interpreted as the minimum value of change in environmental quality. The estimates of damages to households using direct valuation methods may be higher than these cost estimates. The hypothetical cost of using environment is the cost that would have been incurred if the environment had been used in such a way that would not affect its future use. The rationale behind using this method of valuation is the concept of sustainable income discussed in the earlier sections. There is a lot of literature now about the use of behavioral methods for valuing environmental resources (Freeman, 1993; Mitchell and Carson, 1989)[3]. The hypothetical behavioral methods comprising contingent valuation and other variants of this can be used to measure both user benefits from environmental resources. The other behavioral methods indirectly use market information to estimate user benefits.

Figure 1describes a system of integrated economic and environmental accounting (SEEA). It shows environmental accounting as a satellite system of a core system of conventional national accounts. Part A provides the environment related desegregation of conventional national accounts. Part B describes the interrelationships between the natural environment and the economy. Figure 2 provides a simplified scheme of inter-relationship between the economy and environment. Part C deals with the problem of valuation of natural assets in addition to the market valuation already done in the conventional national accounts. Part D explains the case for an extension of the production boundary of SEEA to include household activities. The analysis of household activities can contribute a better understanding of the

[3] See Murty (2000) for the review of studies about using various valuation methods for estimating the environmental value of water resources in India.

social and demographic forces behind the impacts of human activities on the natural environment and of the effects on human welfare.

Figure 3 explains the data sources for integrated economic and environmental accounting. SEEA requires the following data: (i) Transaction and other economic and stock elements of the conventional accounting system (SNA) (Fig 3, parts of block 6), (ii) environmental stocks and flows to which alternative non-market valuations are applied (Fig 3, box 5), (iii) physical data on the flows of natural resources from the natural environment to the economy and their transformation within the economy, and on the flows of residuals of economic activities to the natural environment (Fig 2.3, boxes 2 and 3), and (iv) a description of natural environment in physical terms in so far as it is necessary for the purpose of analysing the impact of human use (Fig 3, part of box 1).

9 .Conclusion

Valuation of environmental resources is needed for making investment decisions in the environmental management, for designing environmental policy, and for measuring environmentally corrected national income. Waste disposal services offered by the environmental media to the industry are productive inputs along with the conventional inputs. Industry uses pollution abatement technologies comprising end of pipe treatment, process changes in production, and changes in the use of inputs and products for reducing pollution loads as per the environmental regulation. In this type of situation the assumption of free disposal of pollution is not appropriate in describing the technologies of firms generating pollution. For a firm having resource constraint, the reduction leads to the reduction of production of output. The description of the technology of a polluting firm as one of producing jointly good and bad outputs with the weak disposability assumption makes it possible to account for the loss in the production of good output to reduce the bad output, pollution. The output distance function in the theory of production describes the technology of a polluting firm in this way.

The shadow prices of environmental resources are derived in a general framework of overall planning problem for the economy in which environmental inputs are productive inputs in the industry, use of environment by the industry affects the utility of people, and industry uses abatement technologies to reduce the pollution. Models for deriving shadow prices are provided with alternative specifications about the technology of polluting firms. It is shown that in case there is a fall in the environmental quality with the economic development, the defensive expenditures estimated at shadow prices have to be deducted from NNP to arrive at ENNP. It is shown that a pollution tax levied on the firms equal to the marginal cost of abatement at optimum guarantees the market efficiency in the dynamic model.

In a sub-optimal or second best economic program, the effects of an investment project on the net national product can be evaluated using local or second best prices. The second best prices are suitably adjusted market prices for private goods and the estimated prices using data collected through specially designed survey methods for public goods or environmental services.

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Figure 1

SNA (satellite) system of integrated environmental and economic accounting (SEEA)

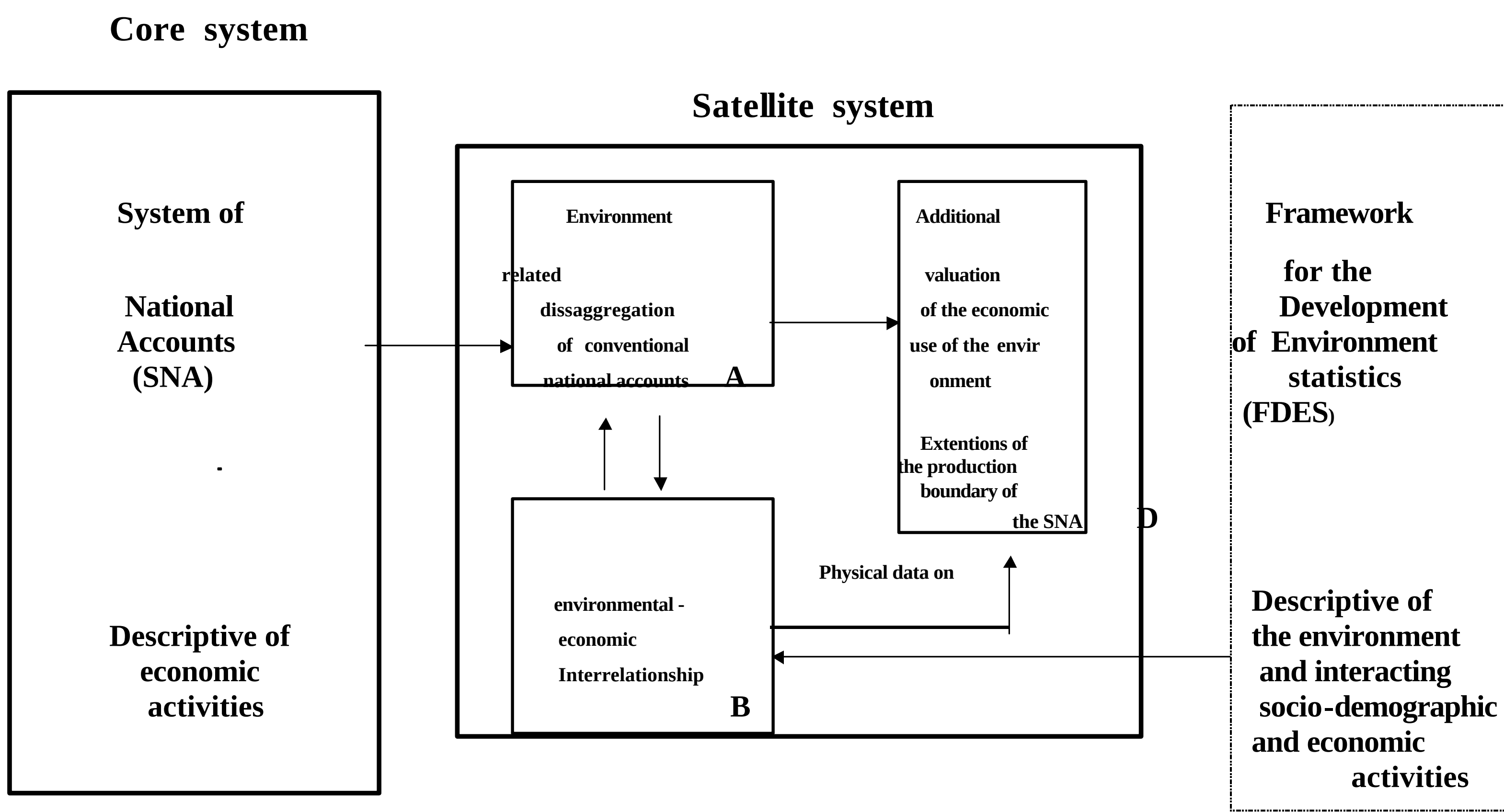


Figure 2
Interrelationships between the economy and the natural environment (simplified scheme)

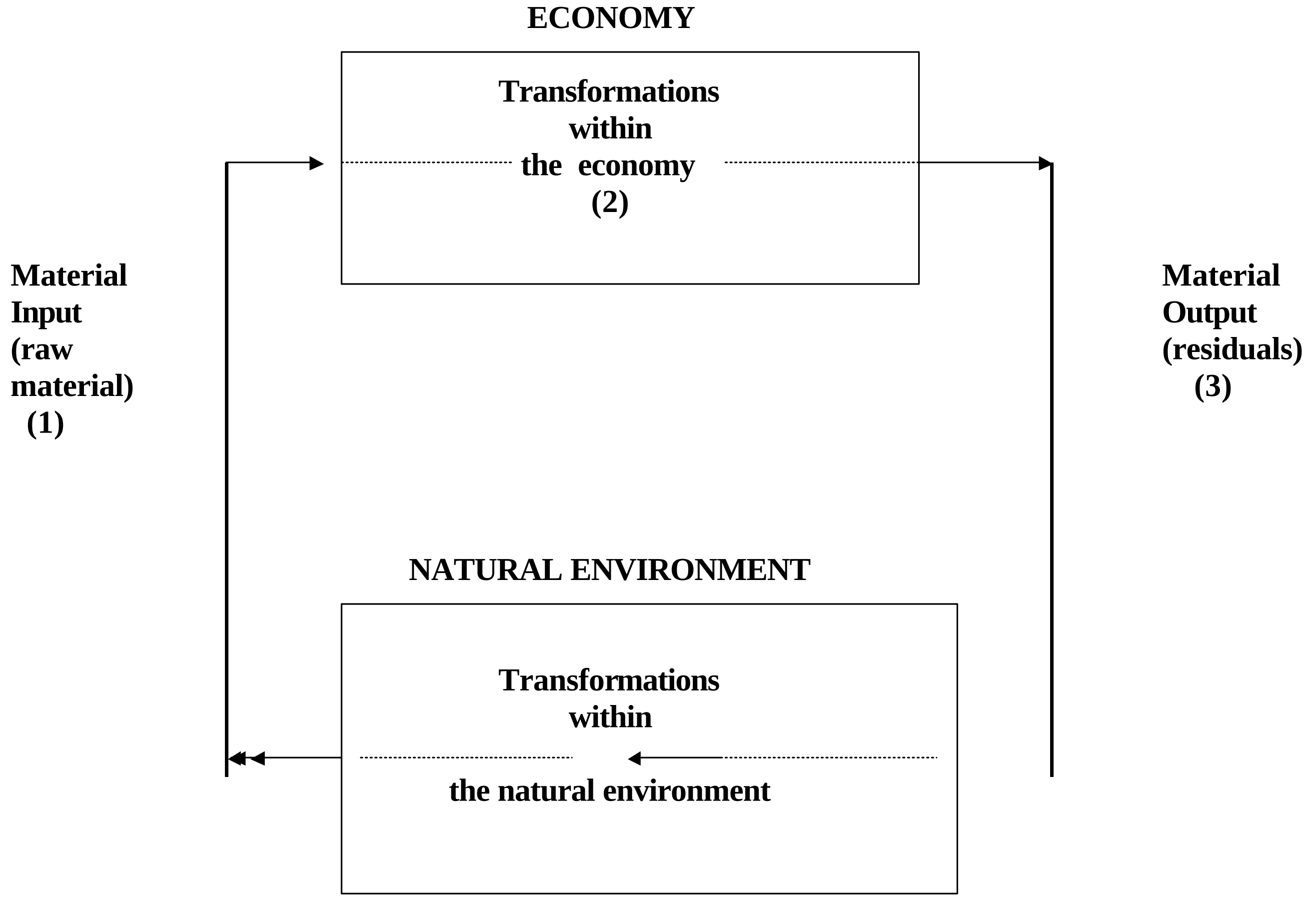
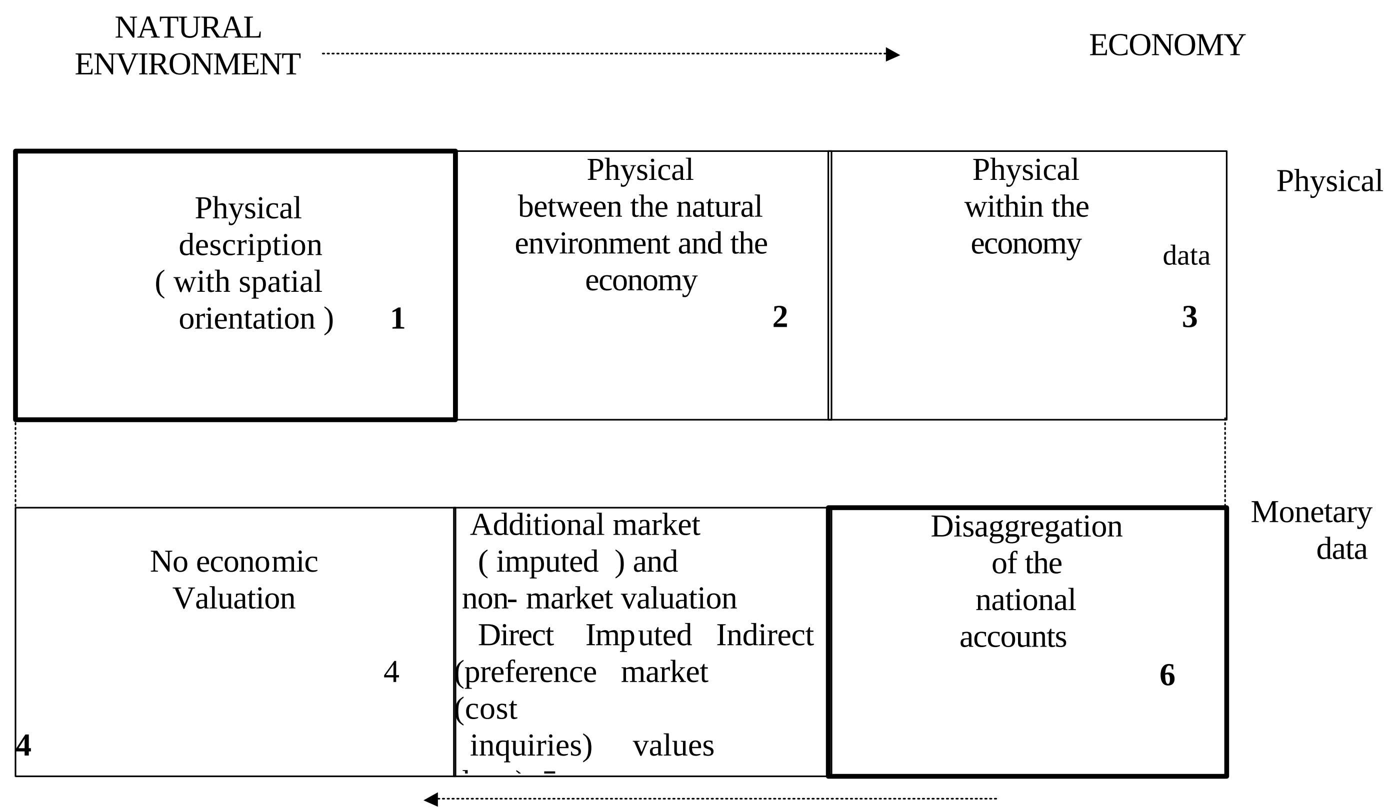


Figure 3
Data Source for SEEA
Data Sources of integrated environmental and economic accounting



1 : **Environment statistics system**
2 **in a narrow sense**
6 : Economic accounting system (SNA)
2 +3+5+6+ part of 1 :
(Satellite) system of integrated environmental and economic accounting (SEEA)

1 + 2 : Natural resource accounts and environment statistics in a broader sense

2 + 3 : Material / energy balances

5 + 6 : Extended economic accounting system

Table 1
Man - Made and Natural Assets

	Man -made assets	Natural Assets				
		Biological Assets	Land (with ecosystems)	Subsoil	Water	Air
Description in physical terms	Economically produced	Economically produced	Economically used	Developed	Economically stored	
		Wild	Uncultivated etc.	Undeveloped	Other bodies of Water	
Monetary Valuation	Market Value	Market Value	Market Value	Market value (proved reserves)	Market value Non - market Value	Non - market value

Table 2
Materials/energy Balances : Physical Accounts

		Domestic economy									
		Economic activities (processes)			Produced assets					Rest of the World	
		Environmental protection activities	Other production activities of industries	Household activities	Environmental protection	Other production purposes	Consumer durables	Produced biota	Domestic natural environment (non-produced)	Economic transactions	Natural environment (non - produc
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
	1 Input / destination										
1	1.1 Opening stocks				**X**	**X**	**X**	**X**			
2	1.2 Use of (non-produced) raw materials	**X**	**X**	**X**					**X**		
3	1.3 Use of products	**X**	**X**	**X**	**X**	**X**	**X**	**X**		**X**	
4	1.4 Destination of products	**X**			**X**				**X**	**X**	
	2 Transformation (extraction , conversion , manufacturing)		↓	↓	↓	↓	↓	↓	↓		
	3 Output/origin										
5	3.1 Closing stocks				**X**	**X**	**X**	**X**			
6	3.2 Origin of (non-produced) raw materials								**X**		
7	3.3 Supply of products	**X**	**X**	**X**		**X**		**X**		**X**	
8	3.4 Origin of residuals (all causes)	**X**	**X**	**X**	**X**	**X**	**X**	**X**		**X** **X**	

Table 3
Natural resource accounts : physical accounts

		Biological assets			Water		Air		Land (including ecosystems)		
		Produced	Wild	Sub-soil assets (proved reserves)	Quantities	Quantities (constituents)	Quantities	Quantities (constituents)	Soil	Area	Uncultivated (area)
		1	2	3	4	5	6	7	8	9	10
1	**1 Opening**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**
	+2 Increase										
2	**2.1 Gross natural**	**X**	**X**	**X**	**X**				**X**	**X**	**X**
3	**increase**		**X**	**X**	**X**						
4	**2.2 Discovery of**									**X**	**X**
	resources										
	-3 Decrease										
5	**3.1 Decrease**	**X**	**X**	**X**	**X**				**X**	**X**	**X**
6	**due to natural**										
7	**causes**										
	3.2 Depletion due	**X**	**X**	**X**	**X**				**X**		
	to										
	economic									**X**	**X**
	causes										
	+/-4 Adjustments										
8	**4.1 Technical**		**X**								
9	**improvements**		**X**	**X**	**X**						
10	**4.2 Changes in**		**X**	**X**	**X**						
	prices ,costs	**X**		**X**	**X**				**X**	**X**	**X**
11	**=5 Closing stocks**	**X**	**X**	**X**	**X**	**X**		**X**	**X**	**X**	**X**

Table 4
Environmental and Economic Functions of Tangible Assets

Type of use	Man-made assets (including historical monuments)	Natural Assets				
Quantitative (flow of goods, Depletion of stocks)	Economically produced goods: input of further production, household consumption	Food for man and animals, Raw materials for clothing, wood products etc.	Nutrient flows	Raw material for economic production and energy sources	Drinking Cooling Process water Irrigation	Physiological purposes (life of humans, animals, plants)
Qualitative (flow of services , degradation of fixed assets)	Buildings machinery, equipment etc: means of production Historical monuments: aesthetic use	Fruit - bearing (for example, vineyards and orchards) Stockbreeding Production Aesthetic use	Area for buildings, roads etc. Agriculture, forests Recreation Aesthetic use Habitat for plants and animals		Recreation Navigation Habitat for plants and animals Hydropower	Sensory perception (hearing, smell, sight) Wind, heat: energy source
Quantitative (disposal service, flow of residuals, degradation of environmental media)		Decomposers of residuals		Mines for storing nuclear wastes	Storing/absorbing residuals	Storing/absorbing residuals radiation Transmission of noise