4D International Journal of Management and Science
ISSN No: 2250-0669
@4D Crossconnect.com, Inc, 2012
www.4dinternationaljournal.com
Vol. 4, Issue3,-2014

ECONOMICS OF SUSTAINABLE DEVELOPMENT

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ABSTRACT

Brundtland Commission Report (1987) has defined sustainable development as "a process which meets the needs of the present generation without compromising the ability of future generation to meet their own needs". Robert Reptto stated that the core idea of sustainability is that current decisions should not impair the prospects for maintaining or improving future living standard, our economic system should be managed so that we can live off the dividends of our resources. In 1993 M. Muna Singhe has discussed three approaches to sustainable development viz.

i. Economic – maximizing income while maintaining a constant or increasing stock of capital.
ii. Ecological – maintaining resilience and robustness of biological and physical systems.
iii. Socio-cultural-maintaining stability of social and cultural system.

The Hartwick – solow approach to sustainability rule postulates that so long as the stock of capital did not decline over time non-declining consumption was also possible. The stock of capital could be held constant by re-investing all Hotelling rents from non-renewable resource extraction in man made capital.

Pearce and Atkinson in 1993 have proposed an indicator of weak sustainability based on new-classical assumption that man made and natural capital are assumed to be perfect substitutes for each other. Pearce – Atkinson Measure is defined as : $PAM = \frac{S}{y} - \left(\frac{\delta_M}{y}\right) - \left(\frac{\delta_M}{y}\right)$ where if PAM > 0, the economy is judged to be sustainable.

The unique feature of common perrings Model of sustainable development is that it attempts to combine ecological concepts of stability with economic efficiency Ecological stability is argued to be a pre-requisite for the sustainability of the economic-ecological system as a whole. Such stability requires eco system resilience i.e. the capacity of the over all eco system to withstand external shocks without losing its self organisation common-perrings demonstrated that while it is not necessary to sacrifice inter temporal efficiency inter temporal price efficiency is not a necessary condition for ecological sustainability and that

inter-temporal efficiency may be inconsistent with ecological sustainability. To preserve ecological stability consistent with inter-temporal efficiency it is inevitable that we should manage economic environmental interactions in such a way which does not interfere with system resilience, which keeps system within their natural resilience boundaries. An ecological economics approach to sustainability requires that resources be allocated in such a way that they do not threaten the stability either of the system as a whole or of key components of the system, an ecological economics approach privileges the requirements of the system above those of the individual. Consumer sovereignty is an acceptable principle so far as consumer interests do not threaten the general system and through this the welfare of future generations.

Technological concerns should aim at :

i. dematerialisation of economic process.
ii. Decarbonisation of energy.
iii. Increasing substitution of non-renewable resources by renewables.
iv. Recycling of wastes by converting it into a man made resource.
v. Non-recyclable waste treatment before disposal.
vi. Enhancement of primary productivity of bio-spheric space in eco-system.
vii. Facilitation of the redistribution process of income by increasing the productivity of wage goods and creating more employment opportunities.

A new paradigm and analytic frame work needs to emerge for the analysis of economic development which would adopt a trans-disciplinary approach to handle issues relating to demographic movements, technological advance and human values. Only the economics and ecology can be combined in an appropriate manner to generate the right policies for sustainable development.

Rates of use of renewable resources should not exceed regeneration rates and non-renewable resources must not exceed rates of development of renewable substitutions as ingredients of sustainability.

Existing reserves should be rationally and efficiently managed. Eco-friendly technology should be deployed for harnessing other renewable resources. Over exhaustion or depletion of non-renewable energy resources can be delayed or postponed by minimizing its use or devising new means of exploration to ensure sustainable economic development.

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INTRODUCTION:

Development is a process that involves use of both natural and man-made resources. Economic development comprises a highly resource consuming activity. The adequate availability of resources like land, water, forests etc. are required not only for a healthy ecosystem, but also for a sustainable long term economic growth. The attempt to large scale production of consumer's goods requires large scale exploitation of these resources, thereby causing environmental problems like deforestation desertification, soil erosion, global warming, ozone depletion, salinity, water pollution, air pollution etc. The growth process causes continuous depletion and degradation of the natural resources. As long as economic activities are at a level below the regenerative capacity, there is no secular decline in the quality and quantity of these natural resources. The problem emerges when these limits are transcended and when secular decline in the quality and quantity of natural resources takes place, as stated by Hirway and Mahadevia in 1999. The problem crops up in two respects, firstly when natural resources are over exhausted and secondly when the discharges from economic activities are more than abating capacity of the nature. In both cases natural resources are depleted, which puts limits to the sustainability of growth process. Thus the limits put to the sustainability of growth process are more in the case of non-renewable natural resources than the limits imposed by renewable natural resources. The qualitative measurement of economic development can be assured by the performance of various economic indicators like per capita income, per capita consumption, growth rate etc.. The partial measurement of development in terms of economic indicators is methodologically incomplete. Economic development, in addition to improvement in income and output involves radical changes in institutional, social and administrative structure as well as in popular attitudes, customs and benefits. This perception assumes development as a long term phenomenon and covers the socio cultural dimensions of the development process. As stated by Amartya Sen, development is a process of expansion of choice in life through improved capabilities, but also macro level capabilities like better environment, safety, security etc.. Two important characteristics emerge, firstly development process should add additional capacity to existing potential and secondly its impact should be all encompassing and comprehensive. These two themes of generating additional capacity and ensuring all round development of the society in long run have attracted the attention of many economists and ecologists in the last three decades which finally resulted in the concept of sustainable development.

The present paper makes an ingenious endeavour to define the concept of sustainable development, to analyse the ways to achieve sustainability, to visualize components of sustainable development, determinants of sustainable development, possible sustainability rules, indicators of sustainability, to explain the models of sustainable development and to suggest policy implications.

II. CONCEPT OF SUSTAINABLE DEVELOPMENT:

It has become one of the catch words of our economic policy. Some vital issues at the crux point emerge; that whether humanity can converge to an infinitely sustainable economy in a way that is reasonably orderly. Peaceful and safe or whether it is on a one way track of disaster. The term sustainability was first introduced in forestry during 18th Century and required that the amount of timber that might be fall in one year be approximately equal to annual growth, so that stock could be maintained and infinitum and encompasses income, growth, population and physical resources. J.R. Hicks in 1946 defined income as the maximum amount that a nation could consume over some time period and still be better off at the end of the period as at the beginning. In the context of environmental economics it became popular in the 70's. The club of Rome's Report. 'Limits to Growth' was the corner stone of sustainable development. It focused the need of a balance between natural resources and its ecology and environment. It further established the complexity of inter related problems of poverty, environmental degradation, industrialization and urbanization. The concept of sustainable development got wider acceptance after publication of the Brundtland Commission Report in 1987. The Commission defined sustainable development as, "a process which meets the needs of the present generation without compromising the ability of the future generation to meet their own needs". Sustainable development is a process of change in which the exploitation of resources, the direction of investment, the orientation of technological development and institutional change are all in harmony and enhance both current and future potential to meet human needs and aspirations. In 1992, R.M. Solow defined sustainability as, making sure the next generation is as well as the current generation and ensuring that this continues for a time. Norwegian economist Ger Asheim has defined sustainability as, "a requirement to our generation to manage the resource base such that the average quality of life we ensure ourselves can potentially be shared by all future generations". Howarth and Norgaard in 1993 stated that the goal of sustainable development is principally an equity, rather than an efficiency. Economic efficiency is not a sufficient condition for sustainable development. Thus removing Govt. policies on market failures which encourage inefficient use of environmental resources may improve the prospects for sustainable development. Achieving sustainable development involves achieving equity both within generations (intgragenerational equity) and across generations (intergenerational equity). Two common features of these definitions of SD emerge: firstly fairness across generations and secondly fairness within generations. It relates to quality of life and raising the average level of well being. Economic growth can be encouraged by efficient resource allocation. Thus there is a potential complementarity between promoting both efficiency and equity.

Robert Repetto focuses his discussion of sustainable development on increasing long term wealth and well being. The core idea of sustainability is that current decisions should not impair the prospects for maintaining or improving future living standards. Our economic systems should be managed so that we can live off the dividends of our resources. H.H. Daly of World Bank suggested an ethical concept when he stressed on increase in moral knowledge or ethical capital for mankind. M. Munasinghe drew the distinction between sustainability and survivability that survivability requires welfare to be above a threshold in all periods and sustainability requires welfare to be non-decreasing in all time periods. John C.V. Pezzy states that survivability means that you are always above some threshold at all points in time, whereas sustainability takes a sort of millennial view that things are getting better all the time in a monotonic way. In 1993 M. Munasinghe discussed three approaches to sustainable development viz..

i. Economic – maximizing income while maintaining a constant or increasing stock of capital.
ii. Ecological – maintaining resilience and robustness of biological and physical systems and
iii. Socio-cultural – maintaining stability of social and cultural system.

Nine ways to Achieve Sustainability:

In 1997, the book entitled 'Measuring Environmental Quality in Asia' by P.P. Rogers, K.F. Jalal et. al discussed nine ways to achieve sustainability as firstly leave everything in a pristine state or return it to its pristine state, while that sounds nice it is not going to happen.

Nobody is going to do that not when people are living, because it would involve a tremendous amount of pain and anguish, secondly develop so as not to overwhelm the carrying capacity of the system. A carrying capacity of 6.3 billion people is possible at some greatly reduced standard of living below the US standard. Thirdly, sustainability will take care of itself as economic growth proceeds. This is sort of a cornucopian view and it is attributed to the economist Simon Kuznets who contended that as per capita income rises, people tend to take care of the environment when you are very poor, you are concerned about surviving and getting along at any cost. As you obtain more and more income, you can achieve environmental sustainability through the production of superior goods as you can divert income to such purposes as air quality. Fourthly Ronald Coase suggested that the polluter and victim can arrive at an efficient solution by themselves. Under the coase theorem, every one should get together and decide on an efficient level of pollution and on an efficient level of degradation of the environment. His theorem works fairly well in small scale situation but seldom works with a large number of people because the transaction costs could be very high.

Fifthly the markets can take care of it. This is another economic solution. If one prices pollution and permits trading of pollution on rights along with similar market operations, then sustainability can be achieved.

Sixthly internalizing the externalities which could provide an elegant solution. According to 1997 Asian Development Bank guidelines for the Economic Analysis of projects an externality is defined as the effects of projects an externality is defined as the effects of an economic activity not included in the project statement from the point of view of the main project participants and therefore not included in the financial costs and revenues that accrue to them. Externalities represent part of the difference between private costs and benefits, social costs and benefits. To internalize an externality the ADB Publication states that externalities should be quantified and valued and included in the project statement for economic analysis.

Seventhly national economic accounting system reflect defensive expenditures. A good way of increasing GDP is to have lots of pollution and lots of sewrage treatment plants, because GDP measures expenditures for all goods and services. This is why building more prisons with more prisoners is good for GDP, the same holds for more schools. However for more money is spent per prisoner than per student. But then more prisons means that GDP increases. Is this a real measure of what we want in terms of sustainability? Since prison expenditures are defensive expenditures, perhaps we should reflect such expenditures in some other way.

Eighthly reinvesting the rents from non-renewable resources. As per Hartwick hypothesis if we are using petroleum resources, then we should take the revenues resulting from such resources and invest them in some other way of dealing with the environment.

Ninthly leaving the future generations the options or the capacity to be as well off as we are which comes from Robert Solow in 1991. We keep on doing more of the same, although it is a truism, certainly in the western industrialized nations that generally each generation is better off than the last one.

Components of Sustainable Development:

SD comprises three Components: Economic, environmental and social. These three are referred to as the triple bottom line and used to gauge the success of a particular development project. Each component is given equal attention in order to ensure a sustainable outcome. This balance becomes obvious when each component is examined individually.

The economic approach: Maximise income while maintaining constant or increasing stock of capital. The core idea of sustainability is that current decisions should not impair the prospects for maintaining or improving future living standards. This implies that our economic systems should be managed such that we can live off the dividends of our resources as stated by Robert Repetto in 1986. Sustainable economic growth means that real GNP per capita is increasing over time and the increase is not threatened by feedback from either biophysical impacts or from social impacts. Sustainable development argues for:

a. development subject to a set of constraints which set resource harvest rates at level not higher than managed natural regeneration rate and

b. use of environment as a waste sink on the basis that waste disposal rates should not exceed rates of managed or natural assimilative capacity of the eco system.

1. Sustainable development implies basing developmental and environmental policies on a comparison of costs and benefits and on careful economic analysis that will strengthen environmental protection and lead to rising and sustainable level of welfare. Sustainable development is an approach that will permit continuing improvements in the quality of life with a lower intensity of resource use, thereby leaving behind for future generations an undiminished or even enhanced stock of natural resources and other assets.

2. The ecological approach: Maintain the resilience and robustness of biological and physical system : Sustainable development – maintenance of essential ecological process and life support systems, the preservation of genetic diversity and the sustainable utilization of species and ecosystem. SD suggests that the lessons of ecology should be applied to economic process. It encompasses the ideas in the world conservation strategy providing an environmental rationale through which the claims of development to improve the qualities of life can be challenged and tested.

3. The Socio-Cultural Approach: Maintain the stability of social and cultural Systems: Sustainable economic development is directly concerned with increasing the standard of living of the poor which can be measured in terms of increased food, real income, education, health care, water supply, sanitation and only indirectly concerned with economic growth at the aggregate. Maurice Strong in 1992 stated that SD involves a process of deep and profound change in the political, social, economic, institutional and technological order including redefinition of relations between developing and more developed countries.

Determinants of Sustainable Development:

The three determinants of SD are consumption, production and distribution which are enumerated below.

Consumption: It is relevant to examine not only the amount of resources consumed but also the patterns in which they are consumed. There are five reasons to examine these patterns.

a. Economic efficiency alone can't meet the natural resource appetite following current consumption patterns.
b. Consumption is the key to understanding policy challenges as they focus on the demand side.
c. Examining consumption patterns reveals what is being consumed and whether it is meeting the basic needs of the people.
d. The pattern will illustrate vividly that the poor not only consume less but also pollute less and they are directly affected if the environment is degraded.
e. Consumption patterns tell a great deal about problematic relationship among economic growth, the satisfaction of basic needs and human aspirations.

Production: The second determinant of sustainable development is production. It is possible that the twenty first century needs a new production revolution through a process that will take into account not only the economic benefit of production but also its ecological and social benefits. This is referred to triple P or the triple bottom line to sustainability profits, people and planet. There are five basic problems with our current production patterns.

a. Use of materials and processes that cause environmental degradation and health hazards.
b. Inefficiency of production which causes system losses and environmental degradation.
c. Failure to reflect negative externalities in product costs.
d. Energy, water and fertilizer subsidies which benefit mostly the non poor.
e. Transaction costs which are significantly higher for the poor.

Distribution:

The third determinant of SD is the distribution of resources. The linkage between poverty and SD and the widening gap between rich and the poor should be reckoned. Poverty falls into two categories i.e. the objective factors based on per capita annual income, expenditure and assets and subjective factors which imply people's perception of poverty. Micro credit organizations help in egalitarian distribution of income but not a panacea for poverty reduction. Statistical evidence shows that inequality in the distribution of assets hinders economic growth. Effects of inequality may be nearly twice as significant for the poor as for the general population. Societies with higher income gap are also likely to exclude a large number of poor people from opportunities that the non-poor enjoy. A major but often underestimated device for poverty reduction is the distribution of income and assets. In the context of global insecurity statistical evidence suggests that there is a close relationship between income inequality and the level of violence and political instability.

III. **Possible Sustainability Rules:**

a. **The Hartwick–Solow Approach :** In 1977 John Hartwick proposed a rule for ensuring non-declining consumption through time, in the case where an economy made use of a non-renewable resource such as oil in its economic process. Hartwick demonstrated that so long as the stock of capital did not decline over time, non-declining consumption was also possible. The stock of capital could be held constant by reinvesting all Hotelling rents from non-renewable resource extraction in made – made capital. These rents are those resulting from the inter-temporally efficient extraction programme for the non-renewable resource, although the price vector used to calculate these rents must be sustainability prices, prices from an inter-temporal model that includes a sustainability constraint. Thus as the stock of oil, a type of natural capital runs down the stock of man made capital is built up in replacement. This result has been very important for the development of economics of SD. It arises in the Hartwick model due to the assumptions that the aggregate production function for consumption goods is a Cobb-Douglas one. This implies that as the amount remaining of the non-renewable resource goes to zero, its average product tend to infinity, so that, even though the natural resource is technically essential for the production of consumption goods, it does not act as a constraint to growth. Man made and natural capital in this model are assumed to be perfect substitutes for each other and the elasticity of substitution is equal to one.

b. **Non-declining natural capital stock approaches:** Van Pelt identifies the problem with the constant natural capital stock concept. This is the problem of spatial aggregation, within which geographic area should be held constant. If the natural capital stock can't be fully aggregated, it may be necessary to compartmentalize it by sector and keep each compartment constant. Van Pelt in 1993 suggests pollution, renewable resources, bio-diversity, pollution assimilation capacity and non-renewable resources as possible categories. The only ways to maintain a constant economic reserve are for new discoveries to equal extraction and for cost per unit extracted to decrease with technological progress as quickly as they rise as a result of cumulative extraction. Given a finite total crustal abundance of each non-renewable resource, only a zero extraction rate is consistent with a constant natural capital stock unless trade off are permitted between renewable and non-renewable resources.

Supposing that the aggregation problem for natural capital can be overcome perhaps by extensive disaggregation into separate classes and physical quantification, a rule for SD suggested by the London School is to prevent reduction in the level of K_n below some constraint value or series of values for the separate classes. The data requirement involve in fully operationalising this procedure, the idea is to impose either a weak or a strong sustainability constraint as a rule for SD. The weak constraint might be stated as assuming that B_1 represent the benefits from the investment portfolio, C_t represent the non-environmental cost and δ_t is the discount factor. Assuming that K_n is measured in monetary units. The normal cost-benefit analysis criterion is that over the discrete time period

$t = 1 \ldots\ldots\ldots\ldots T$

$$\sum_{t=1}^{T} B_t \delta_t - \sum_{t=1}^{T} C_t \delta_t - \sum_{t=1}^{T} E_t \delta_t > 0 \qquad (1)$$

That is the sum of discounted net benefits is positive. The weak sustainability constraint is that

$$\sum_{t=1}^{T} \sum_{i=1}^{n} E_{it} \delta_t \leq \sum_{t=1}^{T} \sum_{j=1}^{m} a_{jt+} \delta_t \qquad (2)$$

Where there are i=1 ………. N projects/ policies in the portfolio and j = 1 ……… m shadow projects, where a' represents the environmental benefits associated with each shadow project a_{jt}. The strong sustainability constraint is

$$\sum_{i=1}^{n} E_i \leq \sum_{j=1}^{m} a_j \qquad (3)$$

Thus in the weak form, the discounted sum of environmental cost must be no greater than the discounted sum of off-setting benefits over the time period. In the strong form environmental costs are no greater than environmental benefits in each time period.

c. **The safe Minimum Standard Approach:** It was identified primarily with ciriacy – want rup in 1952 and Bishop in 1978 and 1993. The SMS approach originates from decision making under uncertainty. The SMS approach originates from decision making under uncertainty. The SMS rule is prevent reductions in the natural capital stock below the safe minimum standard identified for each component of this stock unless the social opportunity cost of doing so are unacceptably large.

d. **Daly's operational Principles:** In 1990 a paper entitled 'Ecological Economics'. Daly identified operational principles for SD. The principles are :

Operation–1. Renewable resources such as fish, forests and game, setting all harvest level at less than or equal to the population growth rate for some pre-determined population size, that density – dependent growth is the rule for such resources.

Operation–2: Pollution, for degradable pollutants, establishing assimilative capacities for receiving eco systems and maintaining waste discharges below these level. Daly proposes no rule for cumulative pollutants, but the implication is that their discharge should be close to zero.

Operation 3: 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 e.g. biomass for oil such that by the time period when the non-renewable resource reaches the end of its economic extraction, an identical level of consumption is available from the renewable substitute. Only the income stream should be available for consumption. The proportion of funds which is necessary to divert to the renewable substitute will depend on its growth rate, the rate of technical progress, the discount rate and the size of non-renewable resources.

Indicators of Sustainability:

a. ***The Solow/ Hartwick approach to sustainability and Green GNP:*** Hartwick's optimal adjustments to the national accounts can be optimized as

Non-renewable resources: Each period we should deduct the Hotelling rents of natural resource extraction from NNP, assuming all inputs/ outputs are valued at their correct shadow prices. Let C denotes aggregate consumption, K denotes stock of man made capital, S denotes stock of non-renewable resources, R denotes current extraction from S, L denotes labour allowed to grow at some rate n, u denotes utility, ρ denotes discount rate. The economic problem is to maximize discounted utility from consumption

$$\text{Max. } \int U(C)\, e^{-Pt} \quad (4)$$

$$\text{Subject to } \dot{K} = F(K, L, R) - C - f(R, S) \text{ and } \dot{S} = -R \quad (5)$$

The first equation in (5) states that the rate of change in man made capital stock K depends on production less consumption less the cost of extracting resources while the second equation in (5) states that the rate of change in the non-renewable resource stock S is equal to annual production R since there is no growth and implicity no new discoveries. ENP is expressed as

$$ENP = C + K - [\, F_R - f_R \,]_R = NNP - [\, F_R - f_R \,]_R \quad (6)$$

Where F_R denotes MP = P of R and f_R denotes marginal extraction cost. The expression in square bracket represents Hotelling rent and it is the correct way of calculating the amount of deduction from conventional NNP as Hartwick shows. If published AC are used then we expect mining companies to be operating where MC > AC, which over states the correct deduction and under states ENP. If new discoveries are made, so that – R over states the actual loss of the non-renewable resource.

Renewable Resources: It differs from non-renewable resources in that positive growth can occur, subject to the population size and the rate of harvesting. Hartwick introduces renewables into the system by including utility function to represent fish catch (E), so that we have a utility function U = U (C,E) where the cost function for fishing is f (E, Z) where Z is the stock of fish. Then we have

$$\dot{K} = F(K, L) - C - f(E, Z) \quad (7)$$

And $\dot{z} = g(z) - E$ where g (z) is the natural growth function eqn. (8)

as constraints in the model. When harvesting exceeds the growth rate, $\dot{Z}$ will be

negative, when the reverse is true, $\dot{Z}$ will be positive, while $\dot{z}$ will be zero if harvesting is equal to the growth rate. Hartwick derives the optimal deduction from NNP to allow for depreciation of the renewable resource (fish) as

$$ENP = NNP - (U_E / U_C - f_E)\dot{Z} \qquad (9)$$

The change in the stock Z valued by the term in parenthesis: this is the ratio of MU = P in a competitive market minus marginal fishing costs. When the harvest rate is less than the growth rate, this adjustment adds to NNP, when harvesting exceeds the growth rate the adjustment reduces NNP.

Pollution/ Environmental Amenity Effects:

Pollution (X) is modeled as a stock which exerts negative effects on production: Production itself adds to this stock $X = - bx + \gamma F(K, L, X)$ (10)

Pollution dissipates at a natural rate b, this could be set equal to zero if the economy generates pollutions for which no assimilative capacity exists when making ENP adjustments for such pollutants and added to by production according to some constant proportion γ. If the only way to reduce pollution is to cut output, the correct adjustment to NNP is

$$\mathbf{ENP = NNP - \dot{V}.X} \qquad (11)$$

Where $V = \dfrac{- U_c / U_c + \rho - F_k}{\gamma F_K}$ (12)

The above equation represents the value of the return on pollution in terms of return on capital in the economy. It would be difficult to calculate. If in addition we allow for direct pollution abatement activities, using a cost function f(b) we get a simpler adjustment since now pollution can be controlled directly. In this case

$$\mathbf{ENP = NNP - \delta (f_b)/\delta_X.\dot{X}} \qquad \mathbf{(13)}$$

Which is the change in the stock of pollution (the amount of pollution abatement) multiplied by the marginal cost of pollution control.

Considering the case of pollution entering directly into the utility function, as well as erting a depressing effect on production. Hartwick models changes in the

stock of pollution so that $\dot{U} = U(C, X)$. This gives the adjustment

$$\mathbf{ENP = NNP - [(- U_X)/ U_C) \dot{X} - (\delta f/ \delta X. \dot{X})]} \qquad \mathbf{(14)}$$

The first term in square brackets is the ratio of marginal disutilities of changes in the pollution stock and consumption (the price of reducing pollution in terms of the value of foregone consumption) multiplied by the change in the pollution stock. This is equal to willingness to pay for pollution reduction times the amount of pollution reduced. The second term in square brackets is the term found in eq (13) i.e. the marginal cost of pollution control times the reduction in the stock. Rewriting eqn.(14) makes the nature of the required adjustment clearer.

$$\mathbf{ENP = NNP - [\ U'_X / U_C\ + f_b/x\ ]\ \dot{x}} \qquad \mathbf{(15)}$$

The term in square brackets is positive, but for increase in the stock of pollution (X > 0), the rent is negative. An increase in pollution (a bad) is treated exactly the same way as a reduction in the stock of either non-renewable or renewable resources (good). Increase in the stock of pollution should lead us to reduce NNP. Decrease in environmental amenity for reasons other than pollution should be allowed for in the national accounts in a manner analogous to the treatment of the 'amenity' effect of pollution as reflected in eqn. (14).
Making adjustments along these principles yields an indicator approximate to ENP i.e. AENP indicating Environmentally Adjusted National Product which might be a reliable proxy indicator of sustainability.

b. Pearce – Atkinson Measure:

Pearce and Atkinson in 1993 have proposed an indicator of weak sustainability based on the neo-classical assumptions inherent in the Hartwick/ Solow approach, in that man made and natural capital are assumed to be perfect substitutes for each other. This is different from the weak sustainability criterion when shadow projects are available. PAM is defined as

$$PAM = \left(\frac{S}{y}\right) - \left(\frac{\delta_M}{y}\right) - \left(\frac{\delta_n}{y}\right) \qquad (16)$$

Where if PAM > 0, the economy is judged sustainable. Eqn. (16) states that PAM will be positive if savings exceed the sum of depreciation on man made (δ_M) and (δ_N) capital. Pearce and Atkinson have argued that this is a useful rule, in that if countries fail even this weak test of sustainability, they are unlikely to pass a stronger test.

IV. The common – perrings model of sustainable Development: The unique feature of this model is that it attempts to combine ecological concepts of stability with economic efficiency. Ecological stability is argued to be a pre-requisite for the sustainability of the economic-ecological system as a whole. Such stability requires ecosystem resilience, i.e. the capacity of the overall eco system to withstand external shocks without losing its self-organisation. Protecting ecological sustainability is achieved by protecting eco system resilience. The concept of economic sustainability is represented by the Hartwick rule common – perrings show that while it is not necessary to sacrifice intertermporal efficiency, inter-temporal ecological sustainability and that intertemporal efficiency may well be inconsistent with ecological sustainability. Ecological sustainability is characterized formally using the approach of Holling, where in general the resilience of an ecosystem is an increasing function of the diversity of that system. Holling resilience is characterized in the model by the condition that the rate of change of the natural parameters of the eco system Z_t, with respect to economic activity be non-positive. These natural parameters include the rate of net primary production in the system or population growth rates. Complex dynamic feed backs between eco systems and the economy specify the problem of environmental control and that of achieving SD.

Common and perrings argue that the main distinguishing feature of their model is the incorporation of a pair of constraints that are sufficient for ecological and economic sustainability. These constraints are endogenous, in the sense that they are dynamically interdependent, reflecting the co-evoluation of the over all system. The objective function is dependent on discounted welfare.

The Model: Let the X_t (X = 1 ……….. n) be the resources available to the economic system at time t. these include natural capital, man made capital and consumption goods. $\mathbf{U_t}$ are a sub set of these resources that have private property rights attached to them and economically exploitable. The distribution of the parameters of the eco systems which make up the natural environment, represented by Z_t, defined by a probability density function Z_t = Pr [Z_t]. At any point of time, the eco system parameters Z_t are a function h of the amount

of disturbance to the eco system indicated by $\hat{X}_t$. This disturbance is assumed equal to the level of economic resources, U_t. Undistributed values of X_t are shown as $\overline{X_t}$. Defining

$Z_t = h\,(\hat{X}_t, \overline{X_t})$ then the equation of motion for the system is

$$\boldsymbol{\delta X_t / \delta_t = \dot{x} = f\,(\overline{X_t}, U_t, Z_t, t)} \qquad \textbf{(17)}$$

Thus the growth in resources depends on natural growth X_t and economic use of the resources U_t. Use itself depends on relative prices P_t, so that $U_t = U\,[\,P_t, t\,]$. The objective function in this modes is given as

$$\boldsymbol{J = W\,(T)\,[\,X_T, Z_T, T\,]\,e^{-rt} + f^T{}_0\,Y_t\,[\,X_t, \overline{U}_t, Z_t, t\,]\,e^{-rt}, dt} \qquad \textbf{(18)}$$

This is a conventional neo classical expression indicating that over the time period ending in period T, we add up economic benefits Y_t which depend on consumption, contained in U_t on the natural state of the eco system and on the system parameters of the eco system (Z_t) at any point in time discounted at a rate r equal to marginal efficiency of capital, plus a term expressing welfare W in the final period T [W(T)] which depends on the level of remaining resources X_t and also on the system parameters of the eco system discounted again at the rate r. the constraints on this optimization problem are given in the equation of motion of the eco system (eqn. 17), the initial level of resource stocks and prices:

$$\boldsymbol{X\,(0) = X_0 \text{ and } P\,(0) = P_0} \qquad \textbf{(19)}$$

and an ecological sustainability constraint. It requires that the economic process does not have a destabilizing effect on the eco system represented in the constraint.

$$\boldsymbol{\delta \dot{X}_t / \delta_t = Z_t \le 0} \qquad \textbf{(20)}$$

Given that W and Y are also a function of Z_t, then W and Y will themselves only be stable i.e. $\delta_w / \delta_t = \delta Y / \delta t = 0$ if $Z_t = 0$. This implies a constant structure of preferences, for which Holling sustainability is both a necessary and sufficient condition.

Thus eqn. (2) can be expressed as a strict equality $\boldsymbol{\dot{Z}_t = 0}$ (21)

This condition as common and perrings show is sufficient for eco system sustainability or Holling resilience. This is guaranteed by $U_t = 0$, constant consumption and capital stocks over time a zero rate of economic growth. Finally an intertemporal efficiency constraint is imposed. This is basically a Hartwick rule requiring resource rents to be equal to net investment, both evaluated at their socially optimal values. The model can be epitomized as :

1. Along an optimal yet sustainable path, the marginal benefits for a reduction in the value of the resource base X_t, should grow at a rate equal to the discount rate (Hotelling rule).
2. Ecological sustainability reduces the desirability of economic growth, in that along an optimal, sustainable path, any undesirable effects on eco system resilience must be deducted from pure economic benefits.
3. An inter temporally efficient price path is not necessary or sufficient for ecological sustainability. Such a price path may in some cases be compatible with sustainability, which can be shown as, Holling resilience of the system that can be depicted as

   $$\dot{Z}(t) = h'_u \dot{U}(t) \leq 0 \qquad \textbf{(22)}$$

   where = h'_u is the derivative of the h ( ) function mentioned above with respect to U

   and $\dot{U}$ is the rate of change of economic resources. The value of U is given by

   $$U_t = U[P_t, t] \qquad \textbf{(23)}$$

   So that $\dot{Z}_t = 0$ is consistent with $\dot{P}_t = 0$. However this is unlikely since this would imply over time that changes in the economic resource base have no effect on real

   prices, so that what is required is either $\dot{U}_t = 0$ or $h'_u = 0$. Daly has referred to steady state or stationary economy, which maintains constant its matter – energy throughout. In the second case there is no effect on eco-system parameters of changes in u.
4. From (3) it follows that to preserve or attain ecological stability which is consistent with inter-temporal efficiency requires that we manage economic environmental interactions in a way which does not interfere with system resilience, which keeps systems within their natural resilience boundaries. On the other hand even an inter-temporally efficient development path will not be ecologically sustainable if system resilience is adversely affected and there is nothing about a purely economically efficient time path which guarantees that system's resilience will be kept in tact.
5. While the Solow/ Hartwick notion of sustainability allows for a sustainability indicator which is value based such as environmentally adjusted GNP. Holling sustainability requires a set of physical indicators which measure the resilience of eco-system. Since resilience is an increasing function of diversity, preserving bio-diversity is vital for ecological sustainability.

The concept of ecological sustainability as common and perrings note, possible at odds with the contention in consumer sovereignty. If consumers hold preferences which imply unsustainable consumption paths, Govt. will have to over rule these preferences if they wish to achieve sustainability. As no markets exist for many environmental goods, increasing environmental scarcity can not be picked up by rising relative prices, so that even given a set of preferences consumers may not alter their behaviour in a sustainable direction. The message of this model is that, even if all environmental resources were correctly valued, this would not guarantee sustainability. As succinctly stated by common and perrings:

An ecological economics approach to sustainability requires that resources be allocated in such a way that they do not threaten the stability either of the system as a whole or of economic approach privileges the requirements of the system above those of the individual. Consumer sovereignty in such an approach is an acceptable principle only in so far as consumer interests do not threaten the general system and through this the welfare of future generations.

V. Policy implications of sustainable development:

Role of Technology and Human Values: How can technology relax the bio physical limits on economic process and create space for sustainable upward movement of economic well being index in the face of growing human population ? Technological development need to relax the constraints imposed by the ecological principle to the functioning of the economy through appropriate interventions. The development of the knowledge base for such technical change has to take due account of the ecological principles that govern the eco-systems interfacing the economy. By considering resource constraints and the problem of man made wastes, technological concern should broadly aim at the following:

a. dematerialisation of economic process.
b. Decarbonisation of energy
c. Increasing substitution of non-renewable resources by renewables.
d. Recycling of wastes by converting it into a man made resource.
e. Non-recyclable waste treatment before disposal.
f. Enhancement of primary productivity of biospheric space in eco-systems.
g. Facilitation of the redistribution process of income by increasing the productivity of wage goods and creating more employment opportunities.

Neo-classical Economics has unfortunately conceived man’s essence at an individual level to be one of self interest maximization in a conflict situation with nature and of competition with others in society. Sustainability of human well being requires that man’s essence should be the spirit of individual’s co-operation with nature and society. A new paradigm and analytic framework needs to emerge for the analysis of economic development which would adopt a trans-disciplinary approach to handle issues relating to demographic movements, technological advance and human values only the economics and ecology can be combined in an appropriate manner to generate the right policies for sustainable development.

The following policy measures may be undertaken for the sustainability of natural resources:

a. Pollution monitoring and control.
b. Environmental impact assessment.
c. Natural living resources conservation.
d. Ecological development programme.
e. Environmental research promotion.
f. Environmental awareness.
g. Poverty alleviation measures to dispense with degradation of natural forestry.

ICUN in the 'Strategy for Sustainable Living' in 1991 proposed that sustainable use means use of an organism, eco system or other renewable resources at a rate within its capacity for renewal. Operating within the capacity for renewal is one of the key elements of sustainability. Daly in 1991 gave a wide scope of the rate of resource use by specifying that rates of use of renewable resources must not exceed regeneration rates. Rates of use of non-renewable resources must not exceed rates of development of renewable substitutions as ingredients of sustainability.

The present reserves of resources should be managed rationally. Eco-friendly technology should be deployed for harnessing other renewable resources. Technological innovation should pave the way for devising new means of non-renewable energy resources so that depletion of petroleum resources can be postponed. Besides technological innovation should minimize the use of both renewable and non-renewable resources to ensure sustainable economic development.

REFERENCES:

1. Adger N (1993) Sustainable Environmental Economics and Management, London Belhaven Press.
2. Ahmad Y. S. Elserafy and E. Lutz (ed.) 1989 Environmental Accounting for sustainable Development A UNDP – World Bank Symposium, Washington DC World Bank.
3. Asheim G.B. (1991) Defining Sustainability when resource management does not have deterministic consequences, mimeo, Deptt. of Economics, University of Oslo.
4. Bishop R.C. (1993) Economic Efficiency, sustainability and biodiversity, Ambio.
5. Bartelmus (1994) Environment, Growth and Dev. Routledge, London.
6. Burndtland G.H. (1987) Report of the World Commission on Environment and Development, Oxford University Press, Oxford.
7. Common M and C. Perrings (1992) Towards an ecological economics of sustainability, Ecological Economics.
8. Daly H.Y and Cobb J.B. (1989) Redirecting the economy towards community, the Environment and sustainable future, Beacon Press, Boston.
9. Field B.C. & Field M.K. Environmental Economics, An Introduction (2002) Mc Graw Hill, Higher Education, Irwin, New York.
10. Hanley Shogren and White (1997) Environmental Economics, In Theory and Practice, Mac Millan India Ltd., New Delhi.
11. Hanley Shogren and White (2001) Introduction to Environmental Economics, Oxford University Press, Oxford.
12. Hartwick J.M. (1977) Intergenerational Equity and the investing of rents from exhaustible resources, American Economic Review.
13. Hartwick JM (1990 b) Natural Resources, National Accounting and Economic Depreciation, Journal of Public Economics.
14. Holling C.S. (1973) Resilience and Stability of ecological systems, Annual Review of Ecology and Systematics.
15. Kolstad C.D. (2003) Environmental Economics, Oxford University Press, New York.

16. Pearce D and G. Atkinson (1993) Capital Theory and the measurement of weak sustainability Ecological Economics.
17. Pezzey J (1992) Sustainable Development concepts, An Economics Analysis, Environmental Paper No. 2, Washington D.C., World Bank.
18. Pezzey J (1994) The Optimal Sustainable depletion of non-renewable resources, paper to EAERE Conference, Dublin.
19. Repetto R (1993) How to account for environmental degradation, Economic Perspectives, Wallingfoed.
20. Rogers Peter P, Jalal K.F. and Boyd J.A. (2006): An Introduction to sustainable Development Easter Economy Edition, Reprint in India.
21. Sengupta Ramprasad (2004) Ecology and Economics, An approach to sustainable Development, Oxford University Press, New Delhi.