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RESEARCH ARTICLE

Measures of Sustainability and Evolving Relation with Variation in Depletion of Natural Resources

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ABSTRACT

The immense emphasis given to economic growth has shifted in the last two decades to concerns with sustainable development. A development path is considered to be sustainable if it ensures that the stock of overall natural capital remains constant or increases over time. The new advances in the field of accounting theory renewed the importance of 'greening' the national income accounts. That is, the depreciation or depletion of natural capital should be included in any aggregate indicators of net national output. This led to the evolution of the concept of Environmentally Adjusted Net National Product (eaNNP) which takes account of an economy's national product after adjusting for environmental aspects and Adjusted Net Savings (ANS) as a comprehensive measure of a country's rate of saving after accounting for investments in human capital, depreciation of produced assets, and depletion and degradation of the environment. The objective of this article is to establish the connection between ANS and eaNNP as well as analyse the simultaneity hypothesis across variation in ANS and several other depleted natural resources.

INTRODUCTION

The last decade has witnessed great changes in the global environmental conditions as an aftermath of immense changes in human conditions. There has been an unprecedented population growth along with rapid economic expansion. These twin phenomena have fuelled an ever-growing demand for resources, i.e. for food and drink, energy, transport, electronic products, living space and space to dispose off wastes like carbon dioxide from burning fossil fuels. As a result, there has been a wanton extraction of environmental resources without any concern to meet the multiplicity of human needs.

It is evident that human activities while making use of the ecosystem services put pressure on the biodiversity that supports these services. The five greatest direct pressures exerted by humanity according to living planet report (2010) are:

1. Habitat loss, alteration and fragmentation: mainly through conversion of land for agricultural, aquaculture, industrial or urban use; damming and other changes to river systems for irrigation, hydropower or flow regulation; and damaging fishing activities.
2. Over-exploitation of wild species population: harvesting of animals and plants for food, materials or medicine at a rate above the reproductive capacity of the population.
3. Pollution: mainly from excessive pesticide use in agriculture and aquaculture; urban and industrial effluents; mining waste; and excessive fertilizer use in agriculture.
4. Climate change: due to rising levels of greenhouse gases in the atmosphere, caused mainly by the burning of fossil fuels, forest clearing and industrial processes.
5. Invasive species: introduced deliberately or inadvertently to one part of the world from another; they then become competitors, predators or parasites of native species.

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As a consequence of this biodiversity loss our ecosystem is likely to become stressed or degraded and can eventually collapse. This poses a serious threat to the very existence of human race. The united nations environment programme (UNEP), the organisation for economic cooperation and development (OECD), WWF and others have taken initiative in drawing attention of the world to the services provided by our ecosystem, the increasing costs of biodiversity loss and ecosystem degradation. They have pointed out that technology can replace some of the ecosystem services and can buffer against their degradation but they cannot be altogether replaced. Therefore it has become of utmost importance that we understand our interaction with our ecosystem in order to safeguard future human security, health, wealth and wellbeing.

As a result of the world wide emphasis given on the conservation of the ecosystem and need for decoupling development from growing demands on the natural resources most governments of the world have adopted sustainable development as their national goal. Sustainable development as defined by the world commission on environment and development (1987), widely known as the Brundtland commission is –"development that meets the needs of the present without compromising the ability of future generations to meet their own needs". It implicitly implies that the current use of resources should not diminish the value of assets available to future generation.

Over the last two decades there has been various attempts to find appropriate sustainability measures. Often the per capita gross domestic product (GDP) tend to be used as measure of sustainability but it does not include transboundary flow of income nor does it allow for consideration of depreciation , depletion of any type of capital resources. A better measure seems to be net national product (NNP) which accounts for depreciation of capital assets as well as includes trans-boundary flow of net income. However even then it suffers from non consideration of transboundary flow of pollutants and depreciation and depletion of natural and human capital stock. This snag is tried to be rectified by introducing the notion of eaNNP (environmentally adjusted NNP) as a more comprehensive measure of sustainability as it accounts for the depreciation or consumption allowance of all types of capital and covers transboundary flows. This serves as the true measure of steady or enhanced human well being after allowing for the sustainable and undiminished use of all types of capital. This seems to be very much related to the notion of genuine savings more currently known as adjusted net savings (ANS) which reflects what is left for further productive investment after allowing for depreciation of all types of capital resources.

Savings is the core aspect of development and ANS measures the actual rate of savings of an economy as it takes into account gross savings adjusted with depreciation of physical capital, depletion of natural resources and damages caused by pollution together with investment in human capital. Measurement of ANS is done following the standard accounting concepts. ANS is obtained using the identity given below:

ANS=(Gross national savings - consumption of fixed capital + current non-fixed expenditure on education – rent from depletion of natural capital – damages from carbon dioxide emission) / GNI , all the terms are expressed as a % of GNI , where GNI refers to gross national income.

ANS is a measure of net changes in the value of a country's capital stocks, where that includes both natural and human capital. It implies that an economy is sustainable if savings are larger than the aggregated depreciation of human, man-made and natural capital. It refers to savings net of capital consumption allowance and represents the potential to net increase in a country's capital stock. Consistently negative or even a diminishing but positive ANS rate for several years indicates that the country is moving on an unsustainable path. For example we find empirical evidence (in World Bank report 2005) that OECD countries as well as East and South Asia never had negative ANS during the period 1980–2000; whereas many African nations and the Middle East had negative value for this indicator during this same period. Therefore, according to ANS, most developing countries, dependent on natural resources exploitation, are unsustainable whereas results for developed nations do not indicate unsustainability. Thus Countries with negative adjusted net savings, such as Angola and Republic of Congo, are depleting natural capital without replacing it and becoming poorer over time. Countries with positive ANS, such as Botswana and China, are adding to wealth and well-being and reducing natural resource depletion by investing in other types of capital. It is important to note that the notion of ANS is based on two basic components like gross savings and depreciation of natural capital Hence just as depletion issues of different type of environmental assets have direct impact on the variation of ANS, similarly changes in ANS generated mainly through a rise/fall in domestic savings component may have influence in replenishing the depleted part of natural capital and their variation.

In this backdrop it seems worthwhile to explain what is meant by eaNNP and explore the connection between eaNNP and ANS as the latter is considered to be the most used recent measure of sustainability as well as to analyse the relation between variation in ANS and the depleted or depreciated part of diverse natural resources on the presumption that they are intertwined in a simultaneous equation relationship. So major purpose of this article is to establish the connection between eaNNP and ANS as well as analyse the simultaneity hypothesis across variation in ANS and several other depleted natural resources.

Environmentally Adjusted Net National Product (eaNNP) as a linearised Hamiltonian and relation with ANS

One major feature of any sustainability measure is to reflect undiminished or possibly enhanced human well being over future time dimension. In formal sense, in terms of optimal control theory, this is supposed to be achieved by maximising discounted value of utility over an infinite time horizon subject to the stock dynamics.

The relevant optimisation problem is

Max $\int_0^\infty u(c)e^{-rt}\,dt$ (here r is the social rate of time preference)

Where c =f(x, s)

Subject to the following dynamics

$\dot{X} = g(x_t) - R_{2t}$ (dynamics of renewable resource)

$\dot{S} = N_t - R_{1t}$ (dynamics of non – renewable resources)

$\dot{K} = Q_t(R_{1t}, R_{2t}, K_t, F_t) - C_t - \delta K_t - G_{1t}(S_t, R_{1t}) - F(N_t, S_t) - G_{2t}(X_2, R_{2t}) - E(F_t)$

$\dot{P} = F_t - A_t$

Here $g(x_t)$ refers to the growth of renewable resources. R_{2t} is the amount extracted from the stock of renewable resources. Therefore $\dot{X}$ implies the net change in the stock of renewable resources. Similarly, N_t refers to the discovery of new stock of non-renewable resources. R_{1t} is the amount extracted from the stock of non-renewable resources (i.e., metals and ores etc). $\dot{S}$ is the net change in the stock of non - renewable resources . Q_t is the output function and it is a function of renewable resources , non - renewable resources , man – made capital and pollution. C_t is consumption. δ_{kt} is the rate of depreciation of man – made capital. $G_{1t}(S_t,R_{1t})$ is the cost of extraction of non - renewable resources. $G_{2t}(X_2, R_{2t})$ is the cost of harvesting and transportation of renewable resources. $F(N_t,S_t)$ is the expenditure incurred for the discovery of new stock of non-renewable resources. $E(F_t)$ is the expenditure incurred in assimilating the pollution levels. $\dot{K}$ is thus net investment. F_t is the flow of, pollution. A_t is the assimilation of pollution. Thus $\dot{P}$ is the net change in the stock of pollution levels.

The current value Hamiltonian therefore can be written in the following form:

$$H_c = U(C_t) + \lambda_{1t}\{ g(x_t) - R_{2t}\} + \lambda_{2t}(N_t - R_{1t}) + \lambda_{3t}\{Q_t(R_{1t},R_{2t},K_t,F_t) - C_t - \delta K_t - G_{1t}(S_t,R_{1t}) - F(N_t,S_t) - G_{2t}(X_t,R_{2t}) - E(F_t)\} + \lambda_{4t}(F_t - A_t)$$

The control variables are R_{1t} ,R_{2t} ,C_t , F_t

$\partial H_c/\partial C_t = U_c - \lambda_{3t} = 0 \Longrightarrow U_c = \lambda_{3t}$

$\partial H_c/\partial R_{1t} = - \lambda_{2t} + \lambda_{3t}Q_{R1t} - \lambda_{3t}G_{1R1t} = 0 \Longrightarrow \lambda_{2t} = \lambda_{3t}(Q_{R1t} - G_{1\,R1t})$

$\partial H/\partial R_{2t} = - \lambda_{1t} + \lambda_{3t}\, Q_{R2t} - \lambda_{3t}\, G_{2R2t} = 0 \Longrightarrow \lambda_{1t} = \lambda_{3t}\,(Q_{R2t} - G_{2R2t})$

$\partial H/\partial F = \lambda_{4t} + \lambda_{3t}\, Q_F - \lambda_{3t}\, E_F = 0 \Longrightarrow \lambda_{4t} = \lambda_{3t}\,(E_F - Q_F)$

Now if we assume a linearised utility function like $U(C_t) = U_c\, C_t$, we get

$$H_c = U_c\, C_t + \lambda_{3t}\,(Q_{R2t} - G_{2R2t})\dot{X} + \lambda_{3t}\,(Q_{R1t} - G_{1\,R1t})\,\dot{S} + \lambda_{3t}\,\dot{K} + \lambda_{3t}\,(E_F - Q_F)(F_t - A_t)$$

$$\frac{Hc}{Uc} = C_t + I_t - \delta K_t - (Q_{R2t} - G_{2R2t})\,(- g(X_t) + R_{2t}) - (Q_{R1t} - G_{1\,R1t})\,(- N_t + R_{1t}) - (Q_F - E_F)(F_t - A_t)$$

$$H^* = C_t + I_t - \delta K_t - (Q_{R2t} - G_{2R2t})\,(R_{2t} - g(X_t)) - (Q_{R1t} - G_{1\,R1t})(R_{1t} - N_t) - (Q_F - E_F)(F_t - At)$$

The right hand side represents NNP less the depreciation of non – renewable resource stock, measured as total Hotelling rent which is marginal rent multiplied by extraction net of new discoveries, together with depreciation value of renewable resource which is similarly measured by the product of marginal rent and harvest net of intrinsic growth as well as rent value of net pollution

= Environmentally adjusted net national product (eaNNP)

Thus here H^* as the linearlized Hamiltonian equals the value of eaNNP.

Link with ANS

Now taking into consideration three types of capital viz., man made (K_1) , human (K_2) and natural (K_3), their depreciation factor (δ) and investment in these three types of capital as I_1 , I_2 and I_3 respectively, modified or environmentally adjusted GNP (eaGNP) may be written as the sum of consumption (C) and saving (S). The part may partly be used for fresh capital generation and partly for meeting deprecation / depletion of used capital. Thus we may write:

eaGNP = $Y = C+ S= C + I_1 + I_2 + I_3 + \delta K_1 + \delta K_2 + \delta K_3$
eaNNP = $Y - (\delta K_1 + \delta K_2 + \delta K_3) = C + I_1 + I_2 + I_3$ = consumption + genuine investment
Again, $S - (\delta K_1 + \delta K_2 + \delta K_3) = I_1 + I_2 + I_3$
i.e., genuine saving =genuine investment
Conceptually genuine saving may be identified with ANS in broad sense. therefore, eaNNP = consumption + ANS

Simultaneous Equation Model

Now using a simultaneous equation model we explore the relationship between degradation of natural resources and changes in adjusted net savings. Here some relevant dimension of environmental degradation/depletion are sought to be explained by a number of economic and ecological factors which are supposed to be locked in an endogenous and exogenous variable relationship. In this analysis natural resource degradation is accounted by the indices of deforestation, organic water pollution, co_2 emission and ore and metal exports (used as a proxy for depletion of non – renewable resources). Extent of deforestation and organic water pollution are taken to be the endogenous variables determined by the interlinkages of economic and ecological factors. While ANS itself is assumed to be explained by the indices of both of the aforesaid indices as well as other exogenous ecological and economic factors. Thus we can write the simultaneous equation system in the following way:-

where

$$Y_{1it} = \alpha_1 + \beta_{12}\, y_{2it} + \beta_{13}\, y_{3it} + \lambda_{11}\, x_{1it} + \lambda_{12}\, x_{2it} + \lambda_{13}\, x_{3it} + \lambda_{14}\, x_{4it} + \lambda_{15}\, x_{5it} + u_{1it} \quad \text{.........................(1)}$$

$$Y_{2it} = \alpha_2 + \beta_{21}\, y_{1it} + \lambda_{23}\, x_{3it} + \lambda_{26}\, x_{6it} + \lambda_{27}\, x_{7it} + \lambda_{28}\, x_{8it} + u_{2it} \quad \text{.........................(2)}$$

$$Y_{3it} = \alpha_3 + \beta_{32}\, y_{2it} + \lambda_{36}\, x_{6it} + \lambda_{39}\, x_{9it} + u_{3it} \quad \text{.........................(3)}$$

Y_1 = adjusted net savings as a % of GNI
Degradation of resource stocks are captured by Y_2 and Y_3 , where
Y_2 = deforestation (in % form) , and
Y_3 = organic water pollution in terms of BOD (biological oxygen demand) emission (ton per day)
These stocks are in turn affected by factors given below:
X_1 = fertiliser, herbicides and insecticides used (metric ton) per sq kilometre of arable land. This accounts for the investment in renewable resource like land for maintaining its fertility.
X_2 = gross fixed investment as a % of GNI
X_3 = ores and metal exports as a % of total exports (it is used as a proxy of total extracted minerals and also as an indicator of degradation of non –renewable resources)
X_4 = co_2 emission (metric ton per capita)
X_5 = Labor force participation rate (it is the proportion of the population ages 15 and older that is economically active: all people who supply labor for the production of goods and services during a specified period. It is used as a proxy for human capital)
X_6 = population density per sq kilometer
X_7 = Permanent cropland (% of land area)
X_8= crop production index (1999-2001 = 100)
X_9 = Livestock production index (1999-2001 = 100)
u_{1it} , u_{2it} and u_{3it} are random disturbance terms, assumed to have zero mean, to be homoscedastic and mutually uncorrelated at time t. These random terms partly account for the market imperfections that may be present in an economy during any time. The first equation (1) captures the variables that are likely to influence the variation in adjusted net savings. Since it is supposed to be explained by deforestation and water pollution as the two endogenous variables , the variation of which are also determined from within the system and several other exogenous variables, there is introduced some degree of simultaneity in the model. Organic water pollution has profound impacts on the health of species and habitats. In addition it also results in loss of fishery and other aquatic resources, the shadow value of which is reflected in ANS and it influences its movements. Deforestation leads to loss of multiple economic and ecological functions which is captured by the variation in the values of ANS and some other relevant exogenous variables. It has therefore become important to evaluate the factors affecting the degradation of these natural resources so that they can be brought under control for preventing further degradation.

The second equation (2) assumes that ANS and deforestation are negatively related. Since it is often seen that agricultural cropland are expanded at the expense of forest area it is assumed that cropland and deforestation are positively related. Further it is argued that in order to increase crop output different grades of forest areas are converted into cropland. Thus crop production index and land used as cropland are considered as exogenous variables affecting deforestation. Moreover, it is seen that with the increase in the demand for food crop, production activity is gradually extended from high quality to low quality land resulting in decreasing productivity due to diminishing fertility of soil. Thus, there seems to exist an imperfect correlation between cropland and crop output. Besides this since mining primarily takes place in the forest area therefore there is a negative relationship between exports of ores and metals and deforestation. Again, since rising population density requires more area for housing therefore it also affects deforestation.

The last equation (3) shows that deforestation has severe impact on water pollution. Deforestation results in soil erosion and leaching of soil nutrients increases in deforested area especially during rainy season. Again, it is seen that with a rise in livestock, there will be greater water pollution resulting from the run –off of an increased quantity of dung into various water system. But contrary to this it is also found that with the increase in the quantity of dung, it is better collected and used as domestic bio fuel and also as manure in the fields. Thus we find lessening of the adverse impact on water pollution with a rise in the rearing of livestock. The ultimate impact is determined by the relative strength of these two countering forces. Organic water pollution is also caused by the disposing off of untreated sewage and toxic wastes into the water bodies. A situation which is further aggravated by high and rising population density. The simultaneous equation model composed of equations (1), (2) and (3) constitutes a schematic and efficacious representation of the multifaceted nature of relationship between ANS and degradation of natural resources.

DATA SOURCE AND METHODOLOGY

The present study is based on secondary data set .The model is estimated using data from a sample of 22 developing countries (i = 1 to 22) covering the period 1980 to 2008 (t = 1 to 29). The required data for the most relevant variables like ANS, organic water pollution in terms of BOD emission, ores and metal exports as a % of total exports, CO_2 emission are obtained from World Bank Development Indicators (WDI) Database (http://www.worldbank .org/data). Deforestation data is obtained from data provided by the World Resources (A guide to the global environment), The Food and Agriculture Organization of the United Nations, Global Forest Resources Assessment (2005 & 2010) and the State of the World's Forests (2009, 2007, 2005, 2003, 2001) report. Deforestation data are constructed on the basis of average annual deforestation in the considered countries. The 22 developing countries included in our study are those countries which rely on their stocks of natural resources and its extraction for their economic development. We have taken countries from three different regions (Asia, Latin America and Sub-Saharan Africa) of the world. Thus the countries included and belonging to Asia are India, Pakistan, Bangladesh, Nepal, China, Indonesia, Malaysia and Philippines. From Latin America we have selected Argentina, Bolivia, Brazil, Chile, Colombia, Ecuador and Peru. From Sub-Saharan Africa we have chosen Cameroon, Ghana, Kenya, Madagascar, Malawi, Mauritius and Nigeria.

Since our study is based on panel data we could have used the fixed effect model with variation of the intercept parameters in the structural equations. This method involves using dummy variables to estimate the fixed effects that allows the intercept term to vary over time and cross- sectional units. But as our model involves 22 countries over 29 year period , the dummy variable technique would lead to serious reduction of degrees of freedom by an amount (22-1) + (29-1) = 49 for each equation. Further this method is also unable to explain the reasons behind the shifting of regression equation over time and cross sectional units. Due to these problems encountered while using the fixed effect model we have adopted simple pooling using 2SLS technique for estimation purpose in this case. The simultaneous equation model composed of equations give rise to an over – identified structure. Therefore estimation is carried out with pooled data on the basis of two stage least square technique. The reduced form equations corresponding to the above structure can be expressed in the following form:

$$Y_{1it} = \alpha_1 + \pi_{11} x_{1it} + \pi_{12} x_{2it} + \pi_{13} x_{3it} + \pi_{14} x_{4it} + \pi_{15} x_{5it} + \pi_{16} x_{6it} + \pi_{17} x_{7it} + \pi_{18} x_{8it} + \pi_{19} x_{9it} + v_{1t}$$

$$Y_{2it} = \alpha_2 + \pi_{21} x_{1it} + \pi_{22} x_{2it} + \pi_{23} x_{3it} + \pi_{24} x_{4it} + \pi_{25} x_{5it} + \pi_{26} x_{6it} + \pi_{27} x_{7it} + \pi_{28} x_{8it} + \pi_{29} x_{9it} + v_{2t}$$

$$Y_{3it} = \alpha_3 + \pi_{31} x_{1it} + \pi_{32} x_{2it} + \pi_{33} x_{3it} + \pi_{34} x_{4it} + \pi_{35} x_{5it} + \pi_{36} x_{6it} + \pi_{37} x_{7it} + \pi_{38} x_{8it} + \pi_{39} x_{9it} + v_{3t}$$

The estimation of the above structure depends on the following assumptions:

1. The error terms of the reduced form equations v_{kt} (k = 1,2,3) are assumed to satisfy the usual stochastic assumptions like zero mean, constant variance and zero covariance. These requirements are met whenever we assume that the random terms in the structural model u_{1it}, u_{2it} , u_{3it} have zero mean, are homoscedastic and mutually uncorrelated at time t . This is so because v is an exact linear function of the structural error u . Further it is assumed that v_ks are independent of all exogenous variables ($x_1, x_2, x_3, x_4, x_5, x_6, x_7, x_8, x_9$) in the entire model . Thus we have $\mathrm{Cov}(x_{jit}, v_{1t}) = 0$, $\mathrm{Cov}(x_{jit}, v_{2t}) = 0$, $\mathrm{Cov}(x_{jit}, v_{3t}) = 0$ for j = 1 to 9
2. It is assumed that even though multicollinearity exists, there should not be perfect multicollinearity among the explanatory variables. In this regard it may be mentioned that even though there may be some degree of correlation between crop production index and land area under crop production they are assumed to be imperfectly correlated, their inclusion as separate explanatory variable in the model does not pose any serious problem. This is because of the fact that as the production process is extended to lower quality of land in a bid to increase production of output, we find diminishing productivity of land.
3. The sample is assumed to be sufficiently large such that the number of observations exceeds the number of exogenous variables in the structural model. If this assumption is not satisfied, it will not be possible to obtain significant estimates of the reduced form coefficients. In our study we have combined cross section and time series data, generating a large data set and thus enabling estimation of the model.

RESULTS OF THE ESTIMATION

It is observed from the following tables that the R^2 value is quite low in case of all the three equations. Nevertheless, treading on the lines of Pindyck and Rubinfeld (1998) who state that when cross section data are involved the model may still be satisfactory with a lower value of R^2 because of wide variability of data, we observe that in the Tables below the occurrence of lower value of R^2 do not deter the regression equations from being good fit.

The above result shows that ANS is negatively related with deforestation, it falls by 3.681% with one % rise in deforestation. This shows that deforestation has serious implications on sustainability and it reinforces the need on the part of forest department to introduce effective and judicious management policies of this resource. It is seen that organic water pollution (in terms of BOD emission) has a very small negative (the coefficient is 0.000000597) but insignificant impact on ANS. Application of fertiliser, herbicides and insecticides is treated as investment in renewable resources and it has a significant positive impact (with a value 0.1364) on ANS. But it should be kept in mind that excessive use of fertiliser, herbicides and insecticides leads to gradual decline in the fertility of soil . However the loss of rent due to this damage has not been considered in ANS. Gross fixed investment in physical capital has an expected positive impact on ANS with its coefficient having a significant value of 0.776. CO_2 emission has a significantly high negative impact on ANS. ANS falls by 2.011% with 1% increase in emission thus requiring adoption of an effective emission regulation policy by the government. Ores and metal export which is taken to be a proxy for depletion of exhaustible resources is found to have an expected negative impact on ANS, its coefficient has a significant negative value of -0.167. This shows that prudent control and judicious management is needed in the case of extraction of minerals. Labour force participation rate, a proxy for human capital investment has a positive impact on ANS, it rises by 0.02 % against a 1% increase in Labour force participation rate . Two stage least square regression estimates pertaining to the 2nd structural equation are given in the following Table

From the above result it is observed that variation in ANS figures has a significant negative impact on deforestation, it falls by 0.0486% with 1% increase in ANS. Ores and metal extraction and export has a positive influence on deforestation. Deforestation increases by 0.018% with 1% increase in ores and metal extraction and export. As expected population density has a positive impact (with a value 0.00105) on deforestation because the increasing population density requires more space for housing , roads for transportation and market place for transactions and all these requirements are met at the expense of forest areas. It is seen that along with the increase in the

Table 1. Results of estimation of 1st structural equation

Variable	Coefficient	Std. Error	t-Statistic	Probability
Fertiliser application	0.136427	0.028264	4.826839	0.0000
Ores and metal ext	-0.167730	0.026507	-6.327794	0.0000
Co_2 emission	-2.011555	0.439336	-4.578629	0.0000
Labor participation	0.021188	0.044315	0.478108	0.0327
Gross fixed investment	0.776791	0.100880	7.700172	0.0000
Deforestation rates	-3.681958	1.129440	-3.259985	0.0012
Organic water pollution	-5.97E-07	7.27E-07	-0.821937	0.4114
C	-1.534525	4.650212	-0.329990	0.7415
R-squared	0.414807			0.000000
F-statistic	60.85883			

Table 2. Results of estimation of 2nd structural equation

Variable	Coefficient	Std.	t-Statistic	Probability
Ores and metal ext	0.018687	0.002957	-6.319984	0.0000
Population density	0.001059	0.000226	4.679320	0.0000
Crop land	0.030920	0.009380	3.296361	0.0010
Crop prod	-0.007906	0.001877	-4.212467	0.0000
ANS	-0.048670	0.009261	-5.255267	0.0000
C	2.101813	0.160527	13.09324	0.0000
R-squared	0.151723			0.000000
F-statistic	21.57048			

permanent cropland area there is an increase in deforestation rate too. This proves that the land required for increased crop production is being obtained by clearing off forest area. Again, we find that crop production (it has a value 0.007) and deforestation are negatively related. The reason for this is that increasing deforestation to meet the consumption needs of the multiplying population has adversely affected the biologically mediated climatic processes at global and local levels resulting in global warming and declining precipitation. Thus we find that although the cropland area is increasing through deforestation, the unfavourable climatic conditions is resulting in declining crop production output. This phenomenon is being experienced in the developing as well as developed countries of the world.

Table 3. Results of estimation of 3rd structural equation

Variable	Coefficient	Std. Error	t-Statistic	Probability
POPULATION DENSITY	1417.173	270.8625	5.232076	0.0000
LIVE STOCK	-15933.27	2326.496	-6.848616	0.0000
DEFORESTATION	1524818.	135682.0	-11.23817	0.0000
C	3276546.	295184.2	11.10001	0.0000
R^2	0.175563			
F-statistic	42.94478			0.000000

The results show that population density has a positive impact on water pollution and 1% increase in population density leads to increased BOD emission of about 1417.173 ton per day in the water bodies. Surprisingly it has been found that livestock production index has a significantly negative impact on BOD emission. The explanation for this is that with the increase in the number of livestock, scientific rearing and management of livestock becomes possible and their dung are more efficiently collected and converted into bio – fuel and used as organic manure in the agricultural production activities. This results in lesser quantity of dung being run-off into the water bodies and lesser BOD emission. Further it is observed that deforestation has a significantly positive influence on BOD emission. On an average, a 1% increase in deforestation leads to increased BOD emission of about 1524818 ton per day in the water bodies. This rate is alarmingly high and calls for serious considerations on the part of the concerning authorities. Thus it can be stated that the ecological factors considered in the model are interactive in nature having a dynamic impact on the depletion and degradation of renewable resources. Here we see that apart from serving as an indicator of sustainability ANS also acts as a policy indicator. It reinforces the need for sound environmental and resource management policies but does not undermine the macroeconomic objectives of economic growth and poverty alleviation. It recognises the fact that some level of depletion and degradation is unavoidable in the process of economic progress but it also emphasizes that degradation scale must be minimised and the long term costs associated with it should also be accounted for, instead of just focussing on short term benefits. Thus it asserts that although negative ANS figures is acceptable in the short run but it should bounce back to positive levels once the appropriate corrective measures are adopted in the longer horizon of time.

Conclusion

It is important to note that there is a glaring neglect in neoclassical literature of the role of natural capital in production and their depreciation. It was relegated to the backyard on the presumption that natural resources are free, available in plenty and their marginal value is nil. In recent times effort has been given to rectify this error by reinstating the importance of accounting for the contribution of natural resources in production and their depreciation in the green accounting frame. In weak sustainability (Pearce, D., Atkinson, G., 1993) sense it is held that human well being in an economy with the provision of undiminished consumption prospect can be kept intact if the productive capacity of all sorts of capital viz. physical, human and natural be maintained over time. This however assumes perfect substitutability of all sorts of capital. Considering the fact that there are some critical non substitutable natural capital, efforts should be taken to preserve intact some of these resources or keep the provision of undertaking relevant depreciation to retrieve these resources in their pristine form. It is also important to note that man made capital is not independent of natural capital since the latter is often required to make the former. Further the multifunctionality implied in the characteristics of natural capital indicates that unless proper care be taken to preserve them, the flow of services of man made capital can be at stake. Hence the notion of eaNNP or its variant ANS serves as good measure of the sustainability of productive services in an economy and noticing their movement over time an economy can take corrective measures. A negative value of ANS or even a downward movement in ANS figures for a number of consecutive years should alert the Government about the slipping of the economy to unsustainable dimension.

The results of the foregoing empirical analysis emphasises the fact that the developing countries who are most dependent on the exploitation of natural resource are most vulnerable to the depreciation of natural capital. The estimated negative relationship of ANS with deforestation, export of ores and metals, CO_2 emission and BOD (insignificant), indicate that developing country Governments need to consider natural resources as assets and pollution stocks as liabilities in their national balance sheet and that there is a need for strong measures on their part to alter the current trend of depletion of natural resources. Unless this is done ANS will continue to fall and it in the long run it will not be possible for them to sustain their consumption stream. For the policy makers the linkage of sustainable development to ANS indicates that there are scope for many possible interventions to increase sustainability, from the macroeconomic perspective to the purely environmental.

But it should also be noted that the policy prescriptions for boosting ANS in order to achieve the defined long term sustainability norms should never altogether stop extracting resources or emitting pollutants. Rather resources and pollutants should be priced correctly and property rights be enforced strongly which will lead to efficient levels of exploitation of the environment, reducing incentives to exploit high-grade resources or pollute indiscriminately. It is evident that optimal resource management and efficient environmental policies will maximise ANS and bring about sustainable development.

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