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Abstract: Sustainability requires that the productive base measured in terms of comprehensive wealth of a society should be increasing on per capita basis. Comprehensive wealth includes manufactured, human and natural capital along with knowledge base and institutions. This study offers methodological improvements and provides estimates of the growth rate of per capita comprehensive wealth over the period 1970-2006 for Indian economy. It considers air, water and soil degradation along with energy, minerals and forests depletion. To measure the value and composition of investment in natural capital, it estimates resource depreciation allowances on the basis of Hotelling rent; it adjusts education expenditure for depreciation in human capital; and uses the estimates of TFP that takes into account natural capital in the production of commodities and services. The empirical application suggests that Indian economy is barely sustainable. Growth rate of per capita comprehensive wealth was virtually near zero, it was only 0.15 percent per year for the study period. The growth rate was negative till 1983. Thereafter it became positive; however it was less than one percent in 1980s and 1990s. In recent years the growth rate was about 4 percent. Despite certain limitations, the study underscores the need for vigorous public policies that help in preventing excessive resource depletion and promoting higher genuine investment.

Keywords: Sustainability, development, Comprehensive wealth, Hotelling rent, India

JEL Classification: Q01, E01

1. INTRODUCTION

Indian economy is growing at an average rate of 8.7 percent per year since 2003-04 and per capita income is increasing at the rate of about 7.5 percent. Tireless efforts to accelerate economic growth had kept environmental considerations as secondary objectives in policy making. It has been a tough trade-off decision between economic growth and environmental protection. For example, damage caused by pollution in India is estimated to cost $14 billion annually; amounting to close to 4.5% to 6% of GDP (Government of India, 1999). This indifference towards environmental protection has been threatening the sustainability of growth trajectory.

Modern growth theories suggest in a world of finite resources environmental sustainability is potentially not compatible with continuous economic growth. Failure to achieve environmental sustainability even becomes an obstacle in achieving long-term economic growth. Given the trade-offs between environment and development, the issue is not to achieve the maximum economic growth or total maintenance of environment, but is one of arriving at optimality both in economic progress and environmental protection, and the concept of sustainable development may be the guiding force.

The Brundtland Report defines sustainable development as "development which meets the needs of the present without compromising the ability of future generations to meet their own needs". This definition requires that future generations should at least get as much resources as we have, to meet their needs, but the question is how to judge whether a generation is bequeathing behind adequate resources for their successors. That is, it lacks tractability as it embeds many complex economic ideas, especially when one is interested in measuring whether an economy is on a sustainable growth path (Vouvaki and Xepapadeas, 2008).

In order to make the definition of sustainable development operational and useful for developing indicators of sustainability and designing policies that make the growth trajectory sustainable many attempts have been made in the literature.[1] Partha Dasgupta (2007a) provides a working definition; "Economic development is sustainable if, relative to its population, a society's productive base does not shrink". Productive base can be defined in terms of stock of capital assets and institutions. Capital assets include manufactured capital, human capital and knowledge, and also natural capital. Sustainability, thus, can be equated to non-declining value of the productive base. To get an idea of whether India's development has been sustainable over a period of time, estimates of the changes that took place over the period in its productive base, relative to its population are required. This is precisely the purpose of this paper.

A large number of studies have tried to measure genuine investment or savings[2] in various countries[3]. Hamilton and Clemens (1999) estimate genuine savings for large number of countries for 1998. Arrow et al (2004) using the World Bank framework estimate growth rate of per capita genuine wealth[4] over the period 1970-2000 for sub Saharan Africa, South Asia, China, UK and US. Similarly, World Bank (2006) provides assessments of changes in comprehensive wealth for nearly every county of the world.

The present paper aims to advance genuine wealth accounting in several ways. First, it offers a comprehensive measure of natural resource accounting. To measure the value and composition of investment in natural capital, it accounts for the extraction of fossil fuels and minerals, depletion of forest resources and agricultural soils. It takes into consideration the degradation of atmospheric environment by measuring the values of particulates, CO_2 emissions, and industrial water pollution. Second, it presents estimates of resource depreciation allowances based on the Hotelling rents, not total rents; provides a theoretical sound base for evaluating the long run impacts of natural resource depletion and degradation on welfare and sustainability. Thirdly, it offers an improved approach for measuring changes in human capital; it adjusts education expenditure for depreciation in human capital. Fourth, to account for the changes in knowledge base and institutions; it adjusts the estimates of the growth rate in per capita genuine wealth by

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[1] Solow 1974, Hartwick 1977, Pearce et al. 1989, Dasgupta and Mäler 2000, Pezzy 2004, Arrow et al. 2003, among others.

[2] The term genuine investment refers to change in productive base. The term is more formally defined in equation (2). Hamilton and Clemens (1999) use the term genuine domestic saving and Arrow et al. (2004) use genuine investment. I follow Arrow et al.

[3] Pearce and Atkinson, 1993, Hamilton and Clemens, 1999, Arrow et al., 2004, 2007 among others

[4] Terms genuine wealth and comprehensive wealth are used interchangeably.

total factor productivity (TFP) estimates that take into account some indices of the use of natural capital.

The paper is organized as follows: Section 2 outlines, in brief, the theoretical linkages between well-being, sustainability and productive base of an economy. Section 3 describes the estimation procedure. The empirical application is discussed in Section 4. Section 5 offers some concluding remarks.

2. WELL-BEING, SUSTAINABILITY AND PRODUCTIVE BASE

Generally the performance of an economy is measured in terms of growth in GDP (gross domestic product) or per capita GDP. GDP may provide some hint about the performance of an economy but it does not capture many important aspects of well-being. As the term 'gross' suggests GDP ignores the depreciation of capital assets. It is common to find a positive relationship between the growth rates of GDP and capital assets, if so the country is no doubt on a development path, but it is also possible that during the periods when the GDP is growing capital assets (e.g. natural capital) may be shrinking which is not immediately obvious and if the capital assets are shrinking then sooner or later economic growth will stop and reverse sign (Dasgutpa, 2007b).

Hicks (1946) suggests measuring well-being in terms of income which is available for consumption without consuming the stock of capital, and NNP (net national product) is considered as a proxy for the national income. Samuelson (1961) argues that the rigorous search for meaningful welfare concept leads to a rejection of all current income concepts like NNP and end up with something closure to a 'wealth like magnitude', such as the present discounted value of future consumption. Weitzman (1976), using linear social welfare function, shows that NNP is a proxy for the present discounted value of future consumption. Mäler (2007) demonstrates that the linear social welfare function implies reduction in consumption to zero in an optimal situation which may last for considerable time. This entails higher present consumption at the costs of future consumption. Moreover, the linear social welfare function requires that income elasticities for all goods and services must be equal to one which is empirically not observed. Mäler suggests the use of Ramsey-Koopmans (R-K) formulation as a basis for national income accounting.

Arrow et al. (2003) demonstrate that the time derivative of R-K social welfare function, at a given time *t* measures the rate of change of current social welfare. If the derivative is positive, it implies that current social welfare is positive and genuine investment is increasing. Negative derivative implies that the productive base is in decline and the development is unsustainable.

Arrow et al (2004) define intertemporal social welfare function in terms of consumption and utility. Intertemporal social welfare function V_t at time *t* is the present discounted value of flow of utility at a positive constant discount rate δ. More formally, assuming continuous time,

$$V(t) = \int_{s=t}^{\infty} U[C(s)]e^{-\delta(s-t)}ds \qquad (1)$$

where *C(s)* denotes aggregate consumption function and *U[C(s)]* is the flow of utility at time *t*. *s* and *t* variously denote time ($s \geq t$) and marginal utility is assumed to be positive.

Current productive base determines both the flows of consumption and future capital stocks. Let K_t denote the productive base which is a vector of stocks of all the capital assets at t. If V is stationary, then $V_t=V(K_t)$; the time derivative of V is

$$dV/dt = \sum_i (\partial V/\partial K_{it})(dK_{it}/dt) = \sum_i p_{it} I_{it} = \textit{Genuine Investment} \qquad (2)$$

where K_{it} is the stock of the i^{th} capital at time t; p_{it} ($\equiv \partial V/\partial K_{it}$) is the shadow price of capital K_{it}; and I_{it} ($\equiv dK_{it}/dt$) is the rate of change in K_{it}. Equation (2) shows that intertemporal social welfare is non-decreasing if and only if genuine investment is non-negative. Genuine investment is defined as the change in society's productive base.

To express the sustainability criterion in terms of rate of change in genuine wealth, take the manufactured capital assets as numeraire and assume that the marketed price of manufactured capital is equal to its shadow price. The stock of genuine wealth then is simply $W = \sum_{i=1} p_i K_i$ and the rate of growth of genuine wealth is $\sum_i p_i I_i / \sum_i p_i K_i$ and this has to be non-negative for sustainable economic development in a constant population economy and in an economy where the population is growing the per capita genuine wealth must not decline overtime (Arrow et al. 2004).

The maintenance of productive base does not necessarily imply that a particular type of capital asset to be maintained. For example if exhaustible natural resource base is declining, equation (2) could nevertheless be satisfied if other capital assets were accumulated sufficiently to offset its decline.[5] Note that though equation (2) allows for substitution between different forms of capital, the substitutability is not perfect since the shadow prices don't remain constant overtime. The dynamics of the shadow prices of different forms of capital assets can take care of the degree of substitution between the capitals and their essentiality. If a particular asset is essential and lacks substitutes in welfare function, the shadow price of the asset will rise fast and sustainable development will not be feasible with a continued depletion of the asset (Mäler, 2007).

3. ESTIMATION PROCEDURE

Change in genuine wealth or productive base is equal to the value of genuine investment at time t. Genuine wealth includes manufactured capital, human capital, natural capital and knowledge base, and evaluates them at their shadow prices. The World Bank data is used for estimating change in value and composition of genuine investment. Since 1999, the World Bank provides estimates of adjusted net savings, known as genuine savings, for a large number of countries starting from

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[5] In the literature the maintenance of aggregate capital stock is known as the condition of weak sustainability. Pearce et al (1989), in the *Blueprint for a Green Economy*, define the weak sustainable development as "...that the next generation should inherit a stock of wealth, comprising man-made assets and environmental assets, no less than the stock inherited by the previous generations", and strong sustainable development is defined as "that the next generation should inherit a stock of critical environmental assets no less than the stock inherited by the previous generation".

1970 through the World Development Indicators (WDI).[6] Gross savings are adjusted for depreciation of manufactured capital, depletion of energy-[7] and mineral resources[8], change in forest stock, CO_2 emissions and particulate matters. To account for change in human capital, the World Bank makes adjustment in gross saving for public education expenditure. Note that the estimates are based on some crude assumptions.[9]

(a) Valuing Natural Resource Depletion

Hartwick rule states that the Hotelling rent received from the extracting of natural resources should be invested in manufactured and human capital so that the current consumption level in a country could be sustained over the period to time. If a country wants higher consumption level, in order to expand the economy's total capital stock, it is necessary that more than Hotelling rent be invested in manufactured and human capital. Hotelling rent is measured as the product of marginal rent (price minus marginal cost) times quantity extracted in the case of exhaustible resources and marginal rent times net quantity extracted (quantity extracted minus resource growth) in the case of renewable resources.

Estimation of the Hotelling rent is core of the analysis for valuation of depletion of natural capital. First step in estimating the Hotelling rent is to estimate total rent received from the extraction of a resource. World Bank publishes figures for total rent for energy, minerals and roundwood.[10] Total rent is equal to price of the resource times quantity extracted (total revenue) minus total extraction cost. Resource accounting requires use of shadow prices. In imperfect economies, market prices deviate from the shadow prices. The study uses border prices (international prices) as proxies for the shadow prices. Generally the international prices are higher because only better quality commodities tend to be traded. Total rent figure for each of the energy and mineral resource are obtained by multiplying the figures of extraction with average rent (price minus average extraction cost). Next step is to convert the total rent figures into the Hotelling rent. Vincent (1997) shows that in a standard model of optimal resource depletion, the Hotelling rent is equal to:

$$HR = TR \times (1+\beta)/[1+\beta(1+i)^{T}] \qquad (3)$$

where *HR* and *TR* stand for the Hotelling and total rent respectively, β is the elasticity of marginal cost curve, i is the discount rate, and T is the number of years until resource exhaustion. Equation (3) shows the relationship between the Hotelling- and total rents. As the resource approaches exhaustion the Hotelling rent approaches to total rent, but in the beginning of resource exploitation the Hotelling rent is only a fraction of total rent. The formula also shows that a country has to invest more in manufactured and human capital to offset the economic depreciation of natural capital as the resource approaches exhaustion.

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[6] http://devdata.worldbank.org/dataonline

[7] Energy resources include oil, natural gas, coal and lignite.

[8] Minerals include bauxite, copper, lead, nickel, phosphate, tin, zink, gold, silver, and iron ore. For India data is available for 8 minerals, i.e., it is not available for nickel and tin.

[9] For the World Bank methodology of computing adjusted net savings and data sources see Bolt et al. (2002).

[10] http://web.worldbank.org/WBSITE/EXTERNAL/TOPICS/ENVIRONMENT/EXTEEI/0,,contentMDK:20502388~menuPK:1187778~pagePK:148956~piPK:216618~theSitePK:408050,00.html as accessed on July 30, 2008

To use formula, estimates of elasticity of marginal cost curves, discount rate and reserve to production ratios as a proxy for the life that the resource in question are needed. Marginal cost curves are estimated using the World Bank data of total extraction costs and are given in Table A1.[11] Discount rate is set equal to 12 percent. This discount rate is commonly used by the Planning Commission for project evaluations. It is assumed that in 1970 all the resources had a life of 50 years, implying that all the natural resources will be exhausted by 1919 if current extraction rates continue.

(b) Valuation of Land Degradation

Land degradation is a serious environmental problem in India. It occurs through the natural and man-made processes of wind erosion, water erosion, and water-logging. It is estimated that about 57 per cent of the total land is under some form of degradation. Under a business as usual scenario, it is estimated that India loses about 40 million tones of major soil nutrients annually (Pachauri, 2004).

The value of economic depreciation of land quality is equal to the change in the discounted sum of agricultural rents that arise in the presence of land degradation. If land markets are working efficiently and all other factors that determine current and future agricultural land rent remain constant except land quality, then the economic depreciation of land is equal to the change in land value between time periods. In India, land markets are too distorted. Therefore, following Vincent and Castaneda (1997), productivity change method is used. According to productivity change method the depletion value of a unit of soil is equal to the capitalized value of future agricultural revenue that is forgone due to the loss of that unit. The economic depreciation of land degradation is computed as a product of the following three items: (i) value added in the agriculture sector, (ii) the percentage of degraded agricultural land, and (iii) the ratio of capitalized value of foregone future agricultural revenue to current value added.

For item (i) data is taken from WDI. In India about 57 percent of the total land area is degraded in mid 1990s (item ii). This figure refers to all vegetated land degraded due to all causes, not just agricultural land degraded by human actions. Therefore in the absence of data on land degraded by human actions, it is assumed that percentage of agricultural land degraded by human actions is equal to the percentage of degraded vegetated land; though it is a very strong assumption.

The estimates of degradation of land do not indicate the severity of degradation that strongly affects item (iii). In the computation of item (iii), following Vincent and Castaneda (1997), it is assumed that about 39 percent of the total degraded land is 'lightly' degraded, about 45 percent land is 'moderately' degraded and another 15 is 'severely' degraded. It is also assumed that lightly degraded soil was equivalent to 10 percent of current value added, moderately degraded soils to 40 percent, and severely degraded soil to 100 percent. Thus the value of item (iii) is equal to 36.9 percent (39% times 10% plus 45% times 40% plus 15% times 100 percent).[12]

(c) Valuation for Air and Water Pollution

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[11] The estimated marginal cost elasticity of gold extraction is statistically insignificant and the fit is very poor, therefore we assume unit marginal cost of extraction for the resource.

[12] Vincent and Casataneda (1997) estimates concerning the severity of land degradation are based on a WRI (1992) study. WRI classified about 39 percent of the total degraded land is lightly degraded, about 45 percent land is moderately degraded, another 15 is severely degraded and zero percent as extremely degraded by human activities in Asia.

To value the atmospheric degradation, damages caused by CO_2 emissions generated in the economy and particulate matters are accounted for. Existing convention followed by the World Bank in accounting for CO_2 and particulates emissions is adopted. World Bank values the emissions of CO_2 at a rate of US$ 20 per tone of emissions at 1995 prices. The valuation of damages due to particulates is based on the various estimates of willingness to pay. Note that the World Bank provides estimates of damages caused by particulates since 1990; the study extrapolates for the earlier period using the average damage estimates of the later period for which data is available.

Untreated water from urban settlements and industrial activities, and run-off from agricultural land carrying chemicals are primarily responsible for the deterioration of water quality and the contamination of lakes, rivers, and groundwater aquifers, and causing enormous damages to the economy. The water quality of surface and ground water has deteriorated significantly over the last two decades. The water quality of most of the rivers in India is not even fit for bathing, recreation and other social uses that Indians have been using for thousands of years.

Murty and Kumar (2004) estimate shadow cost of untreated industrial water pollution using distance function approach. They estimate marginal abatement cost for three major water pollutants: BOD, COD and SS for the 17 major polluting industries for the years 1995-96 and 1996-97. They find that these costs are about 2.47 percent of the value added in the industrial sector. Note that these abatement costs relate to the water pollution that is above the MINAS (minimum national standards) and remains untreated. Water pollution abatement cost borne by the industry is already accounted in the national accounts. The study uses these cost estimates of water pollution for producing the estimates of genuine investment.

(d) Valuation of Accumulation in Human Capital

Measuring human capital formation is a complex issue as there are complementarities between expenditures made on different sectors. For example, there are strong complementarities between the expenses made for primary health care, nutrition and primary education. It is very difficult to locate which expenses are towards the maintenance of human capital or formation of new human capital. Arrow et al (2003) suggest using estimates of expenditures on health and education as expenditure towards human capital formation. However, in a developing country like India, most of the expenses in the health sector are curative; therefore the study instead concentrates only on the education sector and takes the view that net investment in human capital can be approximated up to a point by expenditure on formal education. Arrow et al. (2004) indicate that using expenditure on education as a proxy for increases in human capital neglects depreciation of human capital due to morbidity, mortality and retirement form the workforce, and overstates the increase in human capital.

In the literature some attempts have been made for estimating depreciation of human capital. Rosen (1976) is, perhaps, the first attempt towards this direction. Recently, Groot (1998) estimates the rate of depreciation of education for Great Britain and the Netherlands and it ranges between 11 to 17 percent.[13] Following Groot, it is assumed that the rate of depreciation of educational expenditure for India is 17 percent and accordingly the public expenditure on formal education is adjusted for estimating per capita genuine wealth.

(e) Accounting for Change in Knowledge Base and Institutions

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[13] Arrazola and De Hevia (2004) found the depreciation of educational expenditure vary between 10-30% for Spain using the Groot model.

Growth accounting literature shows that the growth rate of income or output is generally higher than the growth rate of inputs, i.e., there is some residual which Solow terms as total factor productivity (TFP). Dasgupta (2007a) argues that the growth rate in TFP occurs due to improvements in the existing body of knowledge and the working of institutions. Alternatively it can be said that the growth in TFP occurs due to technological- innovations and diffusions.[14]

Arrow et al. (2004) demonstrate how changes in TFP alter the assessment of social welfare function. They show that if TFP growth rate is γ and output elasticity of capital is α, it raises the growth rate of intertemporal social welfare function in terms of genuine wealth by γ/α.[15] Following Arrow et al. (2007), it is assumed that the elasticity of output with respect to all forms of capital is one. Adjustment in the growth rate of per capita genuine wealth is made by adding the Hicks-neutral technological progress to the rate of growth of the aggregate of all forms of capital.

The conventional productivity studies consider the production of marketed output as a function of manufactured capital and labor (sometimes adjusted for education). In these studies the estimates of TFP are biased since they do not account for the contribution of natural capital in the production of marketed commodities. Murty and Kumar (2006) using data for Indian industry observe that the marginal productivity of natural capital is positive. Kumar and Managi (2008) estimate TFP for a large number of countries using three inputs, viz. labor, manufactured capital and energy use, for producing GDP and the emissions of CO_2 and SO_2. Kumar and Managi observe significant difference in the estimates of TFP when natural capital is taken into account.

4. EMPIRICAL APPLICATION

The application proceeds in two steps. First, it estimates change in the natural capital by estimating the Hotelling rent for exhaustible and renewable natural resources. It also estimates value of environmental degradation for soil, air and water pollution. It then adjusts for changes in net investment in human capital formation. In the second step, it considers the changes in genuine wealth on per capita basis and makes adjustment for changes in TFP growth.

Table 1 places the economic significance of total minerals, energy and roundwood rents in net domestic saving/investment and GDP.[16] It shows that natural resource extraction was about 4 percent of GDP in 1970s which increased to 5 percent in 1980s, though in 1990s a declining trend was observed, but soon it reversed. In 2006, the share of total rent earned from the extraction of natural resource was 6 percent of GDP. This table also shows that the total rent amounted to two-fifth of net domestic investment in the 1970s and increased to about 47 percent in 1980s.

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[14] In the efficiency and productivity literature these terms are known as technological change and efficiency change respectively and these are analogous to innovation and diffusion (Kumar, 2006). Acquiring new knowledge and making its use is known as innovation and better or more use of what people already know is termed as diffusion of knowledge.

[15] Elasticity of output with respect to capital can be obtained from the production function estimates. For example if the production function is Cobb-Douglus form: $Y = AK^{\alpha}$, then α is the elasticity of output with respect to capital.

[16] Note that in India capital formation is to a large extent financed by the domestic savings, therefore there is no major difference between the figures of genuine saving and genuine investment (Mohan, 2008).

Thereafter, the share of natural resource earning in investment has declined, it was about 27 percent in 2006. It shows that though total rents are small in absolute term and small relative to GDP, they provide a significant source of net domestic investment. Regarding energy and minerals, the depletion relative to GDP is increasing suggesting that the resource use intensity of the economy is increasing. It is interesting to note that the depletion in forest resources relative to GDP is declining and it gets momentum in 1990s. Per se, this may be attributed to judicial intervention and subsequent governmental alertness and institutional developments.

Table 2 shows the ratio of Hotelling rent to total rent for energy, minerals and roundwood. As predicted by theory, the ratio is increasing at increasing rate over time. It was about one percent in the 1970s and increased to about 28 percent by 2006. These trends suggest that the need for investing to offset resource depletion is increasing. It appears that the country is entering into a period when the economic depreciation of natural resources is likely to escalate rapidly.

Table 3 provides the estimates of environmental damages relative to net domestic investment. Column 1 of the table shows that the ratio of Hotelling rent to net domestic investment overtime; it is about 8 percent in 2006 indicating that the net investment has been much more than adequate to offset natural resource depletion. But as damages from environmental degradation (soil, air and water pollution) are included, it is found that in 1970s the net investment was just equal to total environmental damages. Overtime, a declining trend in economic depreciation of the environmental assets relative to net investment is observed, per se indicating that the net investment is enough to offset the environmental damages.

The most important cause of economic depreciation of environmental resources appears to have been soil degradation. In Table 4, column 4 shows that agricultural soil losses relative to GDP were more than 8 percent in 1970s and declining onwards. The relative decline in the soil losses occurs due to structural changes in the economy; share of agriculture in GDP is continuously declining. It was more than 42 percent in 1970 and has declined to 17.5 percent by 2006. Nevertheless, the soil degradation is a serious problem in India. The ratio of water pollution damages relative to GDP is increasing, but the ratio for air pollution damages was increasing till 2002 and is declining in recent years. Similar trend are observed with respect to the damages from CO_2 emissions.

Table 4 shows the various estimates of investment in India since 1970. Gross investment in the 1970s was about 17.5 percent of GDP and the estimates of genuine investment were only about 2 percent. Though, there is an increasing trend in both gross and genuine investment, genuine investment was far below the gross investment. By 2006 gross investment reached at the level of 31 percent of GDP and genuine investment was just about its half. Downward trend in the difference in gross and genuine investment rates could be attributed to various factors such as structural changes, change in the development strategy in 1991, increase in education expenditure, complete ban on green felling in 1996 by the Supreme Court of India, declining carbon intensity of the economy, improvements in environmental regulatory performance and increasing environmental awareness. But the issue of concern is the increasing resource and energy use intensity of the economy. Ayres (2008) calls for a radical change in the development trajectory. He says that nations should concentrate on increasing resource productivity; "…goods must be converted as much possible into services, and services must be delivered with the minimum possible requirement for material and energy inputs" (p11).

Figure 1 scatters genuine investment against growth rate of per capita GDP. First point to note it that India never observed negative genuine investment. Second, there is a clear upward trend in the scatter; as the economy's health improves genuine investment increases. This result is very striking given the fact that many countries under US$ 1000 per capita income have negative genuine saving/investment rates (Hamilton and Hassan, 2003).

Growth rate of unadjusted genuine wealth is computed by dividing the figures of genuine investment by the incremental capital output ratio (ICOR). Increasing populations are considered as a major reason for the destruction and depletion of natural resources, and thereby introduce the Malthusian aspect to the environmental accounting. If populations are increasing at higher rate than aggregate genuine wealth, the wealth is shared between more people. To compute the figures at per capita level, from the figure of growth rate of unadjusted genuine wealth the growth rate of population is subtracted. The figures of per capita growth rate of unadjusted genuine wealth are adjusted for the growth rate in total factor productivity (TFP).

In India, except for the decade of 1970s, the ICOR has been hovered around 4.[17] This measure of capital intensity does include only manufactured capital, and to account for human and natural capital, therefore, the observed ICOR is increased by one. The estimates of TFP growth rate are available until 2000; therefore, it is assumed that in the later years TFP growth rate is constant and equal to the growth rate of 2000. This assumption may bias the estimates of growth rate of per capita genuine wealth downward for the corresponding period. TFP growth accounts for about 48 and 40 percent of per capita GDP in 1980s and 1990s, respectively.

Table 5 presents the trend in the growth rate of per capita genuine wealth and per capita GDP. These figures provide some important insights on the question of sustainability of Indian growth trajectory. First, both per capita- GDP and genuine wealth are continuously increasing since 1970. Second, in the growth rate of per capita- GDP and genuine wealth, the contribution of technological changes is substantial. During 1981-2000, it is the TFP growth rate that converted per capita genuine wealth rate into positive figures. TFP growth accounts for about two-third of the estimated 3.14 percent growth rate of comprehensive wealth in later years.[18]

Third, during the study period of 37 years, per capita GDP increased at the rate of 3.1% per year and the growth rate of per capita genuine wealth was virtually near zero, it was only 0.15% per year. For the period 1970 to 2000, the growth rates of per capita GDP and genuine wealth were 2.58% and -0.42% per year respectively, however, Arrow et al. (2004) observed that the growth rate in per capita genuine wealth was 0.34% per year. The difference in these two estimates may be attributed to the comprehensiveness of genuine investment and use of different parameters for manufactured capital intensity and TFP growth rate. The growth rate of per capita genuine wealth reveals that during the period of 1970-2000, economic development was not sustainable. These figures reveal that an assessment of long term economic performance of Indian economy would be significantly off the mark if it were to look at growth rate of per capita GDP.

Fourth, the growth rate of genuine wealth was negative till 1983 (Figure 2). It was also negative in 1991. These estimates reveal that the development trajectory followed by the country before mid-1980s was not sustainable. Though the country observed positive growth rate in GDP, the growth rate of decline in natural assets was more than enough to offset the positive growth rate of manufactured and human capital. During the second half of 1980s and in 1990s, economic development in the country was barely sustainable. Only in recent years the productive base of the economy is improving.

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[17] ICOR figures are generated using the formula, $g = s/c$ where g is the growth rate of GDP, s is the gross saving rate measured a ratio of GDP and c is the incremental capital output ratio.
[18] Average of per capita genuine wealth for the period of 2001-2006.

Preceding discussion on the sustainability of income or welfare should be read with some utter caution. In the estimates of genuine investment all the natural resources are not accounted for. For example, these estimates do not account for biodiversity losses. India is recognized as one of the 17 "Mega Diversity Regions" of the world, which accounts for 67 percent of the world biodiversity. A large number of species are either endangered or on the verge of extinction. According to SACEP, India has about 12 percent of the recorded world's flora.[19] Similarly, as indicated, the analysis focused on onsite- and ignored offsite- impacts of land degradation such as sedimentation of reservoirs which might be economically more important. The analysis also does not account for depletion in water resource and waste generation.[20]

In the estimation of growth rate of per capita genuine wealth, it is assumed that there is substitutability between different forms of assets. These estimates miss critical bottlenecks that limit the substitution possibilities; substitution possibilities are constrained by space and time. For example, in rural India for the people it is often not possible to find an appropriate substitute if their water holes vanish and the local woodlands recede (Dasgupta, 1993).

Though environmental degradation is taking place throughout the country; the regional distribution of natural resources and the level economic development is skewed across states. The poverty distribution is coincidently linked with the distribution of ecosystems and their health in the country (ESPASSA, 2008). Regional disparities in the post liberalization regime are increasing. Most of the manufactured capital formation is taking place in those states which are economically in a better situation than those states that are poor and houses most of the natural resources.

5. CONCLUSIONS

This paper has tried to examine the question whether India's development has been sustainable over a period of time using the sustainability criterion. Sustainability is defined in terms of productive base of the economy which includes manufactured, human, and natural capital, knowledge base and institutions. The criterion of sustainability is satisfied if productive base is increasing on a per capita basis.

Though the paper follows Arrow et al. (2004) framework, it offers further methodological improvements and provides more comprehensive estimates of the growth rate of per capita genuine wealth for the Indian economy by considering soil losses and water pollution along with energy, minerals and forests depletion and air pollutants. To measure the value and composition of investment in natural capital, it estimates resource depreciation allowances on the basis of the Hotelling rents, not total rents; it adjusts education expenditure for depreciation in human capital; and uses the estimates of TFP that takes into account natural capital in the production of commodities and services.

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[19] http://www.sacep.org/html/mem_india.htm as accessed on July 14, 2008

[20] The availability of fresh water is going to be the most pressing problem in India over the coming decades. India receives an average annual rainfall equivalent of about 4,000 billion cubic meters (BCM). This only source of water is unevenly distributed both spatially as well as temporally. Similarly, increasing amounts of untreated hazardous waste is becoming a serious environmental issue in India. Daily waste generation in India vary between 0.45 - 0.89 kg/capita.

It is observed that the deprecation of natural resources is a significant source of net domestic investment. Though carbon intensity of GDP is declining but the issue of concern is the increasing resource and energy use intensity of the economy. The ratios of Hotelling rent to total rent are increasing exponentially overtime suggesting the need for investing more in human and manufactured capital to offset the increasing resource depletion. Though overtime both gross investment and genuine investment are increasing, genuine investment was far below the gross investment. In 2006, genuine investment was just half of the gross domestic investment. However, note that India never observed negative genuine investment and there is positive association between the per capita GDP growth rate and genuine investment rate.

The empirical application suggests that Indian economy is barely sustainable. Both per capita-GDP and genuine wealth are continuously increasing since 1970; over the study period, former increased at the rate of 3.1 percent per year and the growth rate of later was virtually near zero, it was only 0.15 percent. The growth rate of per capita genuine wealth was negative till 1983. Thereafter it became positive; it was about 0.5 percent during the 1980s and about one percent during the 1990s. In recent years, the growth rate was about 4 percent. This reveals that long term assessment of economic performance of Indian economy would be significantly off the mark if it were to look at growth rate of per capita GDP only.

These results must be viewed as preliminary and tentative. During the study period, the life expectancy at birth has increased; under-5 mortality has declined significantly. Ignoring improvements in the health sector biases our estimates downward. Many significant natural resources damages such as biodiversity losses, depletion of water resources, offsite losses of land degradation, which may bias the estimates in opposite direction, are ignored. Note that the estimates are based on the assumption that market prices are equal to the shadow prices of natural assets. Market prices don’t reflect social costs of the consumption of natural capital, the use of market prices could bias the estimates of genuine investment in the upward direction. It is also, implicitly, assumed that damages from carbon emissions are linked to the emissions generated within the economy, whereas in fact the damages are linked to global level of CO_2 emissions.

The substitutability between different forms of capital is based on their relative shadow prices which signal social scarcity of different forms of capitals. The shadow prices are surrounded by many uncertainties regarding non-linearities in ecosystem dynamics, technological changes etc. Despite these limitations, the study underscores for the need for vigorous public policies that help in bringing efficiency in consumption and production and reducing distortions, and thereby preventing excessive resource depletion and promoting higher genuine investment.

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Table 1: Role of Natural Resources in GDP and Investment (%)

Year	Total Rent to Net Domestic Investment	Total Rent to Gross Domestic Product
1970-1980	40.33	4.00
1981-1990	46.59	5.02
1991-2000	33.88	4.14
2001	32.18	4.45
2002	25.26	3.81
2003	21.72	3.70
2004	25.62	5.24
2005	26.06	5.60
2006	27.22	6.00

Table 2: Ratio of Hotelling Rent to Total Rent (%)

Year	Energy (1)	Minerals (2)	Forests (3)	Resource Depletion (1+2+3)
1970-1980	1.00	0.97	0.87	0.94
1981-1990	3.13	3.14	2.82	3.04
1991-2000	9.62	9.45	8.61	9.31
2001	16.82	16.47	15.02	16.47
2002	18.47	18.34	16.75	18.05
2003	20.48	20.39	18.66	20.10
2004	23.15	22.65	20.78	22.80
2005	25.37	25.12	23.13	25.10
2006	28.04	27.85	25.72	27.80

Table 3: Ratio of Environmental Damages to Net Domestic Investment (%)

Year	Hotelling Rent (Resource Depletion) (1)	Environmental Degradation (2)	Total Environmental Damage (3) = (1) + (2)
1970-1980	0.41	99.93	100.34
1981-1990	1.30	80.12	81.42
1991-2000	2.94	69.10	72.04
2001	5.30	56.40	61.70
2002	4.56	48.86	53.42
2003	4.37	42.17	46.54
2004	5.84	32.97	38.81
2005	6.54	30.52	37.06
2006	7.57	29.02	36.59

Table 4: Genuine Investment and Components (% of GDP)

				Environmental Degradation (4)				Natural Resource Depletion (5)			
Year	Gross Investment (1)	Net Domestic Investment (2)	Human Capital Formation (3)	Damages from CO_2 Emissions	Damages from Particulates	Damages from Water Pollution	Soil Losses	Energy Depletion	Mineral Depletion	Net forest Depletion	Genuine Investment (6)
1970-1980	17.48	10.07	2.23	0.57	0.80	0.56	8.12	0.02	0.004	0.02	2.15
1981-1990	20.65	11.12	2.85	0.87	0.80	0.65	6.59	0.10	0.01	0.04	4.77
1991-2000	22.74	12.53	2.99	1.45	0.86	0.65	5.69	0.25	0.02	0.10	6.12
2001	23.56	13.83	3.28	1.48	0.82	0.63	4.88	0.56	0.05	0.12	7.84
2002	24.58	15.08	3.28	1.49	0.83	0.65	4.39	0.47	0.06	0.15	9.61
2003	26.16	17.06	3.28	1.33	0.81	0.65	4.40	0.53	0.07	0.14	11.65
2004	29.16	20.46	3.28	1.33	0.78	0.68	3.95	0.95	0.11	0.14	14.60
2005	30.39	21.50	3.28	1.29	0.74	0.68	3.85	1.03	0.25	0.13	15.40
2006	31.06	22.03	3.28	1.28	0.74	0.69	3.69	1.20	0.33	0.14	15.58

Table 5: Growth Rate of Per Capita Genuine Wealth

Year	Genuine Investment	Observed ICOR	Growth Rate of Unadjusted Genuine Wealth	Growth Rate of Population	Growth Rate of Unadjusted Per Capita Genuine Wealth	Growth Rate of TFP	Growth Rate of Per Capita Genuine Wealth	Growth Rate of Per Capita GDP
1970-1980	2.15	8.28	0.30	2.28	-1.97	-0.35	-2.32	0.95
1981-1990	4.77	4.24	0.94	2.12	-1.18	1.62	0.44	3.35
1991-2000	6.12	5.08	1.14	1.79	-0.65	1.45	0.81	3.61
2001	7.84	4.24	1.50	1.62	-0.12	2.14	2.02	3.52
2002	9.61	5.89	1.40	1.55	-0.16	2.14	1.98	2.13
2003	11.65	4.06	2.30	1.49	0.81	2.14	2.95	6.79
2004	14.60	3.83	3.03	1.43	1.60	2.14	3.73	6.79
2005	15.40	3.69	3.28	1.37	1.92	2.14	4.06	7.75
2006	15.58	3.69	3.32	1.38	1.94	2.14	4.08	7.70

Figure 1: Genuine Investment Vs Growth Rate of Per Capita GDP

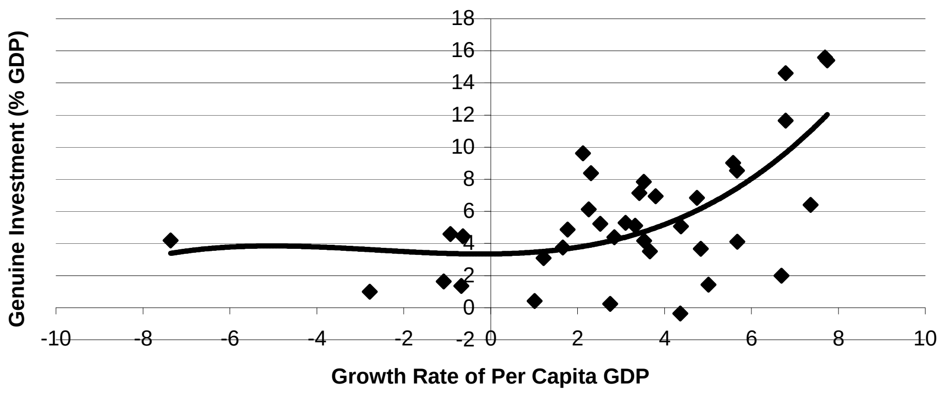
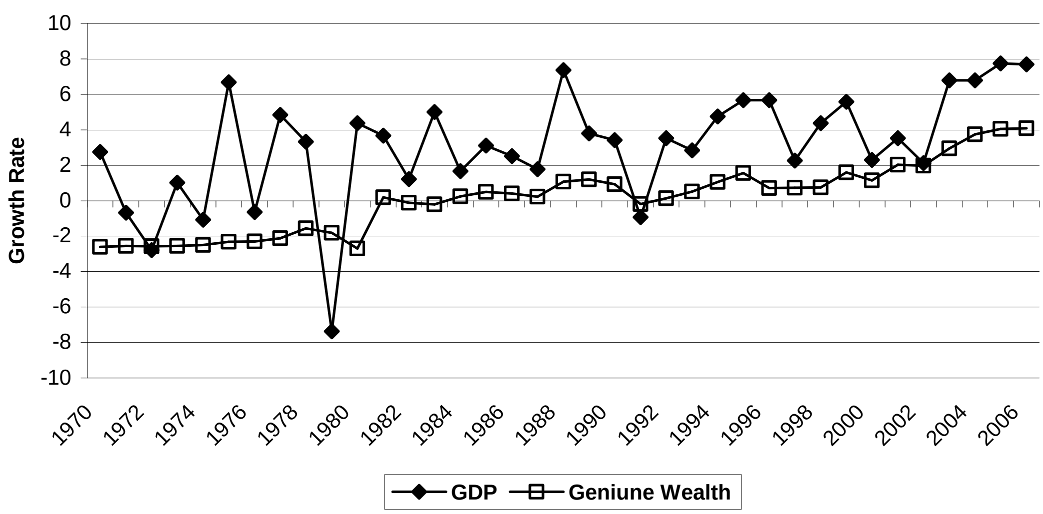


Figure 2: Growth rate of Per Capita- GDP and Genuine Wealth in India



Appendix

Table A1: Marginal Cost Elasticities of Natural Resource Extraction

Resource	Intercept (a)	Elasticity (b)	Adj R^2
Oil	-28.21 (1.59)	2.83 (0.09)	0.96
Natural Gas	-3.72 (0.88)	1.79 (0.07)	0.95
Hard Coal	-7.75 (2.17)	1.55 (0.11)	0.84
Soft Coal	0.75 (0.63	1.04 (0.04)	0.96
Bauxite	-14.96 (2.19)	2.08 (0.15)	0.85
Copper	-12.80 (2.57)	2.92 (0.25)	0.79
Lead	-6.13 (1.09)	2.17 (0.11)	0.92
Phosphate	-15.01 (2.37)	2.35 (0.18)	0.83
Zink	-4.70 (0.94)	1.99 (0.08)	0.94
Gold	15.31 (4.58)	-0.34 (0.58)	-0.02
Silver	-0.42 (0.20)	1.94 (0.06)	0.96
Iron Ore	-15.36 (4.46)	1.99 (0.26)	0.63
Round wood	-33.78 (2.75)	2.89 (0.14)	0.92

Note: $C = aY^{b}e^{u}$ where C: total cost of extraction, Y: quantity extracted, a: intercept term, b: marginal cost elasticity, and u: error term. Figures in parentheses are standard error.