Sustainability of India's Growth: An Empirical Analysis

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Abstract

In the context of growth-environment debate, the paper tries to examine the sustainability of India's growth. For ensuring a sustainable development path, the bequest of capital assets (physical capital, human capital, natural capital, social capital) and technology passed on from one generation to the next should be non-declining. In the context of a growing population, this condition for sustainable economic development is restated as 'non-declining comprehensive wealth per capita' (at constant price) at any point in time. The paper attempts to examine whether the sustainability criterion is being met in the Indian economy by computing 'comprehensive wealth per capita' for the period 1993-94 to 2012-13. Various components of comprehensive wealth which are explicitly estimated by the paper are physical capital, human capital and natural capital. Unlike other studies, we follow a methodology which is consistent across estimation of all the three types of capital. We find that the value of 'comprehensive wealth per capita' is increasing in India during the past two decades. The study also estimated 'Comprehensive Investment' which is adjusted for damages from particulate emissions and CO_2 emissions. The adjusted 'Comprehensive Investment' also shows an overall increasing trend. However, it must be noted that the stock of natural capital is declining as shown by declining reserves of subsoil deposits and decline in area under native forests and agricultural land. Hence, the Indian economy is meeting the 'weak sustainability' criterion but we should be cautious about exploitation of natural capital given the uncertainty about the extent to which natural capital is substitutable. Additionally, the study conducted a regression analysis taking income per capita as the dependent variable and various forms of capital wealth as independent variables. We found that various types of capital are statistically significant in explaining per capita income. The results are robust to alternate OLS specifications as well as ARDL modelling approach.

Keywords: Sustainable development, green accounting, comprehensive wealth

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1. Introduction

Indian economy has been experiencing a growth rate of above 7% over the last two decades on an average[1]. At the same time, environmental quality in India is deteriorating with severe hidden health costs particularly from ambient air and water pollution. These issues bring us to the very old growth versus environment debate. Economic activities exert pressure on the environment due to which the natural capital can depreciate in quantity/quality overtime. Worldwide concern over depreciation of natural capital is not contemporary. It dates back to the doomsday predictions by Meadows el al (1972) in its report 'The Limits to Growth'. The authors emphasised the finiteness of natural resources and predicted that humanity will exceed the Earth's carrying capacity in the next 100 years. In the Indian context, the growth versus environment debate raises important questions like: Can we really afford to grow up now and clean up later? Is the Indian economy growing in an environmentally sustainable manner? This paper examines the sustainability of India's growth during the last two decades.

The answer to the growth versus environment debate lies in 'Sustainable Development'. 'Sustainable Development' broadly means "development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs" (WECD 1987, p 43). Conventional indicators such as GDP do not account for the environmental externalities of growth. 'Greening' of national accounts quantifies the extent of natural capital depreciation paving way for better natural resource management. For ensuring a sustainable development path, the bequest of capital assets (physical capital, human capital, natural capital, social capital) and technology passed on from one generation to the next should be non-declining (Pearce and Atkinson 1998). In the context of a growing population, this condition for sustainable economic development is restated as 'non-declining comprehensive wealth per capita' (at constant price) at any point in time (Arrow et al, 2012).

Studies have estimated comprehensive wealth for various countries including India (e.g. World Bank 2006 and 2011, Arrow et al 2012, UNU-IHDP and UNEP 2012). However, these studies have generated wealth estimates for selected time points only. Just like GDP, we need

[1] The annual GDP growth rate increased from 5.3 percent in 1992-93 to 7.3 percent in 1995-96. It has been above 7 per cent from 1995 to 2005 except during the years 1997-2000, 2001 and 2002. From 2005-06 to 2010-11, the annual GDP growth rate was above 8 per cent except during 2008-09. From 2011-12 onwards, the annual GDP growth rate is reported to be below 7 percent (Source: CSO, MOSPI).

the series of wealth estimates for India in order to analyse whether we are growing sustainably. This paper attempts to examine whether the sustainability criterion is being met in the Indian economy by computing 'comprehensive wealth per capita' for the Indian economy for the period 1993 to 2012. CSO has also commissioned various studies on natural resource accounting. But these are sector specific studies confined to select States only. We follow a macro approach by generating wealth estimates for India. Unlike other studies, we follow a methodology which is consistent across estimation of the three major forms of capital, that is, physical capital, human capital and natural capital. Our methodology is based on the basic principle that the value of resource wealth should be taken as the present discounted value of returns flowing from the resource over its life. Having generated wealth estimates, we also test how various types of wealth taken as independent variables explain per capita income. We apply OLS as well as ARDL modelling approach. The paper is divided into two parts. Part A deals with estimation of comprehensive wealth. The theoretical and empirical literature on wealth and the methodology for estimating various wealth components are discussed in Part A along with the wealth estimates results. Part B covers the econometric regression analysis which attempts to explain income as a function of various wealth components using both OLS and ARDL modelling techniques.

Part A

2. Theoretical and Empirical Review

Sustainable development implies a development path which ensures that per capita 'well being' or utility is non–declining over some time horizon (Pearce and Atkinson 1998).The optimal growth problem was cast in the intergenerational utility maximisation problem given below, where the Hamiltonion gives the maximum consumption sustainable forever, provided the underlying initial aggregate capital stock K_0 is maintained by following the Hartwick rule.

Maximise $V(t) = \int_t^{\infty} U\big(C(s)\big)e^{-\delta(s-t)}\ ds;\ \delta \geq 0, s \geq t \geq 0$ such that $K(0) = K_0$ (1)

Intergenerational well-being 'V(t)' is the discounted flow of utilities of present and future generations, which is a function of K(t) and 'δ' is the discount rate. C(s) represents vector of consumption flows at 's'. It includes consumption services provided by nature, apart from marketed consumption goods (Arrow et al 2012). If the existing aggregate capital stock 'K(t)' increases over time (due to increase in human capital or technological progress, for instance), intergenerational utility 'V(t)' also increases. That is, dV/dt ≥ 0 if dK/dt ≥ 0. This brings out the equivalence between wealth and well-being and one can define sustainability in terms of 'non-declining comprehensive wealth' (Arrow et al 2012). That is, in order to ensure a sustainable development path, the "change in the real value of aggregate assets at a point in time, must be at least zero in the aggregate" (Pearce and Atkinson 1998, p 3). Hence, for sustainability, dK/dt ≥ 0, where aggregate capital (K) is the sum of man-made capital (K_M), human capital (K_H), natural capital (K_N) and social capital (K_S)[2].

Apart from the stock of capital assets K(t), intergenerational utility 'V(t)' is also a function of factors which change exogenously with time such as technological changes (changes in knowledge and institutions). That is, V = V(t, K(t)). The change in V is given by:

$$\frac{dV(t)}{dt} = \frac{\partial V}{\partial t} + \sum_i [(\frac{\partial V(t)}{\partial K_i(t)})(\frac{dK_i(t)}{dt})] \qquad (2)$$

Define $p_i(t) = \frac{\partial V(t)}{\partial K_i(t)}$; where $p_i(t)$ is the spot shadow price of 'i'th capital asset[3]. Thus, $p_H(t)$ is the spot shadow price of human capital asset, $p_M(t)$ is the spot shadow price of physical capital asset and $p_N(t)$ is the spot shadow price of natural capital asset. Define $r(t) = \frac{\partial V}{\partial t}$. This term captures the change in intergenerational well-being due to changes in exogenous factors such as knowledge and institutions. Hence, we obtain the following equation:

$$\Delta V(t) = r(t)\Delta t + \sum p_i (t)\Delta K_i(t) \qquad (3)$$

Here, the second term represents 'comprehensive investment' or ***'CI'.***

Comprehensive wealth 'W(t)' is the shadow value of all capital assets in the economy (Arrow et al 2012). It is given by,

$$W(t) = r(t)t + \sum p_i(t)K_i (t) \qquad (4)$$

If population grows at a constant rate, "development is sustained at 't' if and only if, when valued at constant shadow prices, comprehensive wealth per capita is non-decreasing at t" (Arrow et al 2012, p 328).

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[2] Human capital is basically the intangible assets of knowledge, skills and health embodied in humans. Natural capital is the stock of natural assets such as soil, air, water, geology and biodiversity. Social capital basically includes inter and intra relationships between individuals and institutions. Some of the aspects of social capital are good governance, well-defined property rights and efficient judicial system (World Bank 2006).

[3] Shadow prices are the true opportunity cost of a resource. The spot shadow price of goods and services reflect future scarcities of natural capital as well as the extent of substitutability of various assets for each other not only today but in future as well (Arrow et al 2012).

The condition of weak sustainability requires that the aggregate capital stock is non-declining, which implicitly assumes that various forms of capital can be substituted for each other. That natural capital is substitutable by physical capital is a view endorsed by neoclassical economists, whereas ecological economists believe that certain critical natural capital[4] (e.g., ozone layer) is non-substitutable. Solow (1974) contends that exhaustion of natural resources (a part of K_N) is not a problem if substitution of natural resources by other factors of production is very easy. In such a case, introduction of a 'backstop' technology[5] can free economic production from exhaustible resource dependence[6]. The thumb rule for sustainability with respect to exhaustible natural resources is the Hartwick rule, which requires investing of all the resource rents earned from exhaustible natural resource extraction in physical capital (Solow 1986). Economic growth is typically accompanied by accumulation of physical capital at the expense of degradation of natural capital. There is hope for sustainability as the depletion of K_N is accompanied by accumulation of K_M and technological progress. But, one can precisely comment on sustainability only by examining if the value of resource depletion is outweighed by the value of accumulation of other forms of capital, that is, by looking at aggregate capital 'K'.

Leading attempts to estimate comprehensive wealth for various countries including India has been made by the World Bank (2006 and 2011) which estimates 'comprehensive wealth' by finding the present value of future consumption stream. Only man-made capital and natural capital are directly measured, whereas human capital and social capital are derived from the 'intangible capital residual'. However, as pointed out by Arrow et al (2012), such a methodology of computation of comprehensive wealth has an in-built assumption of sustainability as it implicitly assumes a constant and positive growth rate of consumption. Several studies have attempted to directly estimate the various forms of capital which are

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[4] Critical natural resources are for instance, the essential life support services of nature such as carbon cycle, water cycle, climate change, etc. The answer to what exactly constitutes critical resources is provided by the scientific community.

[5] A 'backstop' technology (for instance, breeder reactor using uranium as fuel) substitutes for the natural resource at a relatively high cost (Solow 1974). Such a technology becomes operative as soon as the market price rises high enough to cover its cost of extraction and profit on capital equipment.

[6] But, if a certain minimum amount of natural resource is indispensible for production which creates an upper bound on the average productivity of natural resources, then exhaustion of natural resources will result in a catastrophe (Solow 1974).

summed up to compute comprehensive wealth, some of these being Arrow et al (2012), UNU-IHDP and UNEP (2012 and 2014) and Kumar (2012). A significant finding of Arrow et al (2012) is that the value of health capital is more than twice the combined value of all other forms of capital. However, such high estimate of health capital is the result of imputing a very high shadow price to health capital as pointed out by Solow (2012) and Hamilton (2012). Moreover, Arrow et al (2012) have separately estimated health capital and educational capital. Estimating educational capital stock is based on the presumption that the population whose educational capital is valued is healthy. Both health and education are embodied in humans and there are spill over benefits of health on education. Hence, appropriately disentangling these two components of human capital is difficult. The present study aims to estimate human capital (K_H) as a part of the comprehensive wealth 'W(t)' estimates for India along with physical capital (K_M) and natural capital (K_N), without explicitly estimating 'health capital'. Addressing the basic question as to whether the Indian economy is growing sustainably, we compute 'comprehensive wealth per capita' for the Indian economy and analyse whether it has increased or decreased overtime. In addition, we also analyse what forms a larger part of comprehensive wealth? Is it the physical capital or human capital? Is natural capital being run down and physical capital being accumulated?

3. Methodology and Database

The methodology for estimation of each of the various forms of capital is discussed here. Since the present study estimates three types of capital, viz., physical capital, human capital and natural capital, selecting methods which are theoretically consistent across all three estimations is an appropriate idea. Broadly, we follow the approach of taking the present discounted value of expected returns over resource lifetime for each type of capital. Using Perpetual Inventory Method for estimating physical capital is consistent with applying a variant of Lifetime Income Method for human capital[7]. Firstly, we outline the methodology for estimation of physical capital followed by human capital and natural capital in that order.

[7] Liu (2011) draws out this consistency as explained here. Both human capital and physical capital continue to be used in production from one accounting period to the next. The value of an asset is a stock concept but the value of the service that the asset generates in each accounting period is a flow. The value of the capital stock is a measure of wealth. If the markets are functioning properly, the value of the stock of the capital good equals the present discounted value of the stream of benefits generated by the asset over its life. In case of physical capital, the stock value is observable from the market through market prices, but not the service value. In case of human capital, the service value is observable as earnings or labour compensation accruing to labour during each accounting period, but the stock value is not observable. Thus, in this case, the stock value of human capital is taken to be the present discounted stream of income of individuals over expected working span (Liu 2011).

Physical Capital: Several studies have estimated the value of the physical capital stock (e.g., Nehru and Dhareshwar 1993, Berlemann and Wesselhoft 2014, Larson et al 2000, Erumban and Das 2014, Kumar 2012, Arrow et al 2012, World Bank 2006 and 2011). Estimation of physical capital stock is mainly based on 'gross fixed capital formation' (GFCF) data available from the national accounts. Since the estimation of comprehensive wealth is an accounting exercise, it will be worth looking into the composition of GFCF in order to avoid any possibility of double counting. GFCF is basically investment or additions to the existing stock of physical capital. It covers fixed assets which are produced assets (mostly machinery, equipment, buildings or other structures but also including some intangible assets) that are used repeatedly or continuously in production over several accounting periods (more than one year)" (pp 8, SNA 2008; pp 12, SNA 1993). Various types of fixed assets should be included in GFCF as per SNA 1993 and SNA 2008. These include (but are not limited to) tangible fixed assets such as dwellings, other buildings and structures[8], machinery and equipment, transport equipment, ICT equipments, and cultivated assets[9] such as treestock and livestock which are repeatedly used to produce goods such as milk, breeding stock, dairy cattle, etc. Trees cultivated for fruits, nuts, sap, resin, etc are treated as fixed assets. However, trees grown for timber, cereals or vegetables are not fixed assets. Similarly, animals raised for slaughter such as poultry are not treated as fixed assets (these are treated as inventories). Other fixed assets include weapons systems, mineral exploration and some intangible assets such as 'computer software and databases', and 'entertainment, literary or artistic originals'. The 2008 SNA also included 'research and development' as an intellectual property asset. With respect to land, SNA 1993 as well as SNA 2008 treat land and 'land improvement' differently. Land improvements prevent land deterioration and leads to improvement in the quantity, quality and productivity of land. Construction of dams or sea walls for reclaiming land from the sea, forest clearance to use land for production, construction of irrigation channels, flood barriers, breakwaters, etc. are some examples of land improvements.

Assuming that the capital markets are efficient, the observed stock value of physical capital is the present discounted value of its unobserved service values over lifetime of the capital asset. Whether one observes the service values and derives the stock value (as in case of human capital) or vice-versa (as in case of physical capital) amounts to the same thing in principle. Implicit here is the assumption that the shadow price of physical capital '$p_M(t)$' (or human capital) is equal to the market price.

[8] While consumer durables such as washing machines are not treated as fixed assets, owner occupied dwellings are treated as fixed assets (SNA 2008).

[9] "Cultivated biological resources cover animal resources yielding repeat products and tree, crop and plant resources yielding repeat products whose natural growth and regeneration are under the direct control, responsibility and management of institutional units" (SNA 2008).

Improvements in land are included but land itself is not included in GFCF (land is included under non-produced assets). With respect to valuables such as precious metals, stones and antique or art objects, a separate category as ‘valuables’ is described in the SNA. These are not placed under fixed assets.

Within the broader definition of physical capital, the paper includes buildings, roads, bridges, machinery and equipments, transport equipments, breeding stock, dairy cattle, computer software, etc. In India, NAS, CSO publishes data on GFCF wherein the asset breakdown is as follows: construction (residential buildings, non-residential buildings, and other construction) and ‘machinery and equipment’ (which includes breeding stock, dairy cattle, transport equipment and other machinery and equipment including computer software). ‘Construction’ here includes buildings, highways, streets, bridges, railroads, airports, dams, water and power projects, telephone and telegraph lines, land improvements, planting and cultivating new orchards, installation of wind energy systems, etc. The new series of NAS with base year 2004-05 also includes ‘research and development’ expenditure in capital formation as per the recommendations of SNA 2008 (NAS 2012). The paper also accounts for depreciation of the physical capital stock which occurs as a result of deterioration in the physical condition of the assets or the assets being rendered obsolete. An economists’ notion of depreciation is different from depreciation as recorded in business accounts which is based on the historical cost of the asset. Economic depreciation, on the other hand, is based on the current market value of the asset[10].

Having discussed the scope of physical capital and the meaning of ‘economic depreciation’, we outline the methodology for estimation of the physical capital stock. Taking into account the accumulated depreciation of assets, the stock value of total physical capital is generally measured from directly observed market prices using the Perpetual Inventory Method (PIM). Most studies have employed the PIM or some variant of this method for estimating physical capital (e.g., most OECD countries, Erumban and Das 2014, Berlemann and Wesselhoft 2014, Nehru and Dhareshwar 1993, Larson et al 2000, World Bank 2006 and 2011, Kumar 2012, UNU-IHDP and UNEP 2012, 2014). According to the PIM, the total physical capital

[10] Historical cost depreciation is based on the original cost of the asset and it does not reflect current market valuation. It is equal to initial purchase price of the asset minus the resale value. On the other hand, current cost depreciation is based on the current price of the asset. It is equal to the current purchase price of the asset minus the resale value.

stock of an economy is to be interpreted as an inventory, which increases with investment. Current physical capital stock includes new as well as old assets. The value of current physical capital stock is the sum of current years' investment and the depreciated value of all previous year investments beginning from an initial capital stock estimate. Hence, the capital stock in period 't' is the weighted sum of all previous capital stock investments. Here, the weights are derived from a geometric depreciation function[11]. Assuming that 'I' is the value of investment at constant prices, 'α' is the rate of depreciation (assumed constant overtime), and 'K_{M_0}' is the initial capital stock, the aggregate capital stock value in period 't' is given by 'K_{M_t}' such that:

$$K_{M_t} = (1-\alpha)^{t-1} K_{M_0} + \sum_{j=0}^{t-1} (1-\alpha)^j I_{t-1-j}; \tag{5}$$

The following formulas are used to construct the time series of capital stock:

$$K_{M_{1993}} = (1-\alpha) K_{M_{1992}} + I_{M_{1993}}$$
$$K_{M_{1994}} = (1-\alpha)^2 K_{M_{1992}} + (1-\alpha) I_{M_{1993}} + I_{M_{1994}}$$
$$K_{M_{1995}} = (1-\alpha)^3 K_{M_{1992}} + (1-\alpha)^2 I_{M_{1993}} + (1-\alpha) I_{M_{1994}} + I_{M_{1995}} \text{ and so on.} \tag{6}$$

The first step in estimation of physical capital stock involves computation of the 'initial capital stock'. The study follows Berlemann and Wesselhoft (2014) Unified Approach[12] for estimation of the initial capital stock using the following formula,

$$K_{M_0} \approx \frac{I_{M_t}}{g_I + \alpha} \tag{7}$$

Here, K_{M_0} is the initial capital stock accumulated till the beginning of 1993-94 or end of 1992-93. I_{M_t} is investment for the year 1993-94 or first period investment. The fitted value of

[11] Most studies have employed a geometric pattern of depreciation (e.g., World Bank 2006 and 2011, Nehru and Dhareshwar 1993, Erumban and Das 2014, UNU-IHDP and UNEP 2012 and 2014). Empirical literature widely supports the use of geometric pattern of depreciation (OECD Manual 2009). Empirical evidence based on used asset prices or resale prices show that for most assets, a geometric pattern of depreciation is most appropriate (Fraumeni 1997).

[12] Such an approach is a variant of the Steady State Approach of estimating the initial capital stock. The Steady State Approach is based on neoclassical growth theory and it assumes that the economy is in a steady state. Thus, $g_Y = g_K = \frac{K_{M_t} - K_{M_{t-1}}}{K_{M_{t-1}}} = \frac{I_{M_t}}{K_{M_{t-1}}} - \alpha$. Hence, we get, $K_{M_{t-1}} = \frac{I_{M_t}}{g_Y + \alpha}$. Here, g_Y and g_K are the rates of growth of output and capital respectively, K_{M_t} denotes capital in period 't' and $K_{M_{t-1}}$ denotes capital in period 't-1'.

I_{M_t} is obtained by regressing log investments on time using OLS. The following equation is used:

$$\ln I_{M_t} = \gamma + \beta . t + \epsilon \tag{8}$$

Here, β gives the trend growth rate of investment or 'g_I'. Using this procedure, the fitted value of first period investment and the trend growth rate of investment is obtained. The depreciation rate is assumed to be 5 per cent (time-invariant) and the service life of assets is taken to be 20 years[13]. Thereafter, the initial capital stock is estimated using equation (7). Having obtained the initial capital stock, the PIM is applied to estimate the physical capital stock series for the period 1993-94 to 2012-13. Table A-1 gives the variables and data sources used in estimation of the physical capital stock.

Human Capital**:** In the present system of national accounts, human capital is not included. Education expenditure and staff training costs are treated as final consumption (SNA 1993, 2008). These are not treated as investment in human capital. Few recent attempts at green accounting have estimated the monetary value of the human capital stock (e.g., Arrow et al 2012, UNU-IHDP and UNEP 2012, Kumar 2012). Using a sample of 13 countries, Hamilton and Liu (2014) find that the average share of human capital in total wealth is 62 per cent[14]. This makes a strong case of inclusion of human capital in the national income accounts.

In order to assign a monetary value to the human capital stock, we follow a variant of the method adopted by UNU-IHDP and UNEP (2014 and 2012). However, we consider population in the working age group only unlike UNU-IHDP and UNEP (2014 and 2012) which considers the entire population. It is assumed that education earns a market rate of return equal to 8.5 per cent. Human capital per person is,

$$h = e^{(Edu*\delta)} \tag{9}$$

[13] World Bank (2006 and 2011) assumes a constant rate of depreciation of 5 per cent for all countries overtime so that the heterogeneous basket of assets having different depreciation rates is well represented. Nehru and Dhareshwar (1993) assume a depreciation rate of 4 per cent. UNU-IHDP and UNEP 2014 also assume a depreciation rate of 4 per cent for all countries (including India) across time.

[14] Despite accounting for human capital, an average of 25 per cent of total wealth is still not accounted for in case of selected high income countries. This essentially includes institutional capital and social capital. Hamilton and Liu (2014) call it the 'stock equivalent' of total factor productivity which enhances the capacity of other forms of capital.

Here, δ equals 8.5 per cent and Edu is the average number of years of educational attainment or schooling. We further assume that all individuals (in working age group 15 to 60) have human capital irrespective of their work or employment status. Hence, h is multiplied by the total number of people in the working age group (15 to 60) in the country, that is, $Pop_{\ 15-60}$. In order to estimate the shadow price of a unit of human capital 'P_H', we discount real per capita annual income $'RY'$ (taken as a proxy for earnings in the absence of time series data on wages or earnings) over working years remaining. Here, $'RY'$ is at constant 2004-05 prices. Assuming that an individual retires at the age of 60, there are 45 working years remaining. Hence,

$$P_H = \int_{t=0}^{44} RY.e^{-\delta t}\,dt \tag{10}$$

Here, δ is the discount rate assumed to be 8.5 per cent per annum. Using this method, total human capital is estimated as follows,

$$Human\ Capital = e^{(Edu*\delta)} * Pop_{\ 15-60} * \int_{t=0}^{44} RY.e^{-\delta t}\,dt \tag{11}$$

The first two terms capture the total amount of human capital while the third term represents the shadow price of human capital per unit. Together, these terms attach a monetary value to human capital. Table A-2 presents the variables and data sources used in estimation of human capital.

It is observed that while the physical capital stock is estimated net of depreciation, the human capital stock estimates are gross figures because they do not deduct the "living and human maintenance costs" (p 29 Liu 2011). Conrad (1992) point out that 'health deterioration' and 'knowledge obsolescence' is not accounted for in the gross estimates of human capital but Fraumeni (2011) argues that wage rates may implicitly account for these factors responsible for depreciation of human capital. Human capital appreciates due to investment in education but it depreciates due to deterioration in health. Various studies show that poor environmental quality also negatively affects health (e.g. Nagar et al 2012, Gangadharan and Valenzuela 2001). However, explicit accounting for human capital depreciation is not undertaken due to lack of data.

***Natural Capital*:** Given that the non-renewable resources such as fossil fuels and minerals are depleting and renewable resources such as the forest wealth as degrading, the present study broadly estimates the following natural resources:

1. Subsoil assets (includes fossil fuels and selected minerals)

2. Forests

3. Agricultural Land- Cropland and Pastureland

A brief discussion of the theoretical underpinnings of the methodology used to estimate natural capital will prove to be useful. The theory by Hotelling (1931) forms the foundation of the economics of resource extraction. The objective of the resource owner is to maximise the present value of future profits over the life of the resource or the "social value of the resource" (Hotelling 1931, p 143). Along the optimal extraction path, the resource price per unit rises exponentially (at 'γ' per cent per year, where 'γ' is the real interest rate on investments in the economy which is assumed to be constant overtime) until at a very high price, the resource demand chokes off and the resource supply also reduces to zero at the same time. Hence, quantity extracted falls continuously until the resource exhausts at time 'T' (Khanna 2003). Here, the resource price is the net price, that is, market price minus the marginal extraction cost. Alternatively, it is known as the Hotelling rent or scarcity rent (or user cost). The price the consumer pays or the market price does not necessarily follow the same path as the Hotelling rent. In a situation of falling marginal extraction costs, the market price may fall if the rising scarcity rents are not high enough to outweigh the marginal extraction costs. However, as the resource nears depletion, rapid increase in scarcity rents will cause the market price to rise (Khanna 2003).

The above theory of exhaustible resources rests on restrictive assumptions which may not hold in the real world. For example, resource prices may not follow a rising trend as the Hotelling's theory predicts if new discoveries are made. There can be wasteful exploitation of resources as well, in cases when actual conditions deviate from the ideal, calling for state intervention (Hotelling 1931). For instance, if the private discount rate 'γ' is higher than the social rate of time preference, it will cause the resource to deplete faster as the scarcity rent rises rapidly (Khanna 2003).

In the light of the above theory of resource extraction, we follow the *'constant revenue'* assumption (adopted by World Bank 2006 and 2011) wherein the unit rents[15] are rising overtime and the quantities extracted are falling overtime. This approach has the advantage of being consistent with optimization as resource owners seek stable revenue along the optimal extraction path (Vanoli 2005, World Bank 1997). However, the resource extraction path

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[15] Unit rents are equal to price minus production costs (World Bank 2011).

typically deviates from the optimal due to violation of several restrictive assumptions underlying the theory. Empirically, the quantities of subsoil assets extracted have been observed to increase overtime[16]. This contradicts the assumption of declining quantities extracted along the optimal path although increase in reserves can be a possible explanation for the same. As rightly pointed out by World Bank (1997) "because real mines do not behave like textbook mines, the problem of valuing subsoil assets is inherently one in which there are no good solutions, only less bad ones" (p 33). Since the present study assumes that the economy is in a business-as-usual scenario, we simply take the capitalized value of future total rents in order to estimate the value of fossil fuels (coal, oil and gas) and mineral resources (bauxite, phosphate and iron ore) for the Indian economy[17]. Such a methodology for estimating natural capital is also consistent with the methodologies the study has adopted for estimation of physical and human capital.

The methodology for estimation of various types of natural capital is discussed below. The variables and data sources used in estimating natural capital are given in Tables A-3, A-4 and A-5.

1. Subsoil Assets

The study estimates the stock values of coal, oil, natural gas and minerals (tin, gold, lead, zinc, iron, copper, nickel, silver, bauxite, and phosphate) under the broad category of subsoil assets for the period 1993 to 2012. We take the present discounted value of total resource rents over the resource lifetime 'T' as follows:

$$PDV_t = \sum_{j=t}^{t+T-1} \frac{\pi_j q_j}{(1+\gamma)^{j-t}} \tag{12}$$

Here, $\pi_j q_j$ is total rent at time 'j', π_j is the unit rent and q_j represents extraction or production. The above formula is restated as,

$$PDV_t = \pi_j q_j \left(1 + \frac{1}{\gamma}\right)\left(1 - \frac{1}{(1+\gamma)^T}\right) \tag{13}$$

[16] For instance, if we observe the trend over the period of the study, that is, 1992-93 to 2012-13, production of coal in India has increased (Source: Energy Statistics, Various Issues).

[17] Note that the expenditures incurred on mineral exploration are included in Gross Fixed Capital Formation in the national accounts. Mineral exploration is undertaken to discover new deposits of minerals or fuels that may be exploited commercially (NAS 2012).

Additionally, the study also estimates the reserves for all these subsoil assets for the years 1993 to 2012. Reserves are estimated according to the following equation:

$$Reserves_{t-1} = Reserves_t + Production_t \tag{14}$$

Application of equation (12) necessitates assumptions about the discount rate γ and resource exhaustion time 'T'. The study assumes γ = 8.5 per cent for all resources in order to maintain consistency with estimation of other forms of capital, since this rate has been applied to discount future earnings in the estimation of human capital. For 'T', the study attempted to estimate the reserve-extraction ratio for each resource separately as illustrated in Table A-3 below. The following equation is used to estimate the reserve-extraction ratio at 2013:

$$T = \frac{Reserves\ as\ on\ 1-4-2013}{Extraction\ in\ 2012-13} \tag{15}$$

The above method of estimating 'T' may understate or overstate it. If the economy is on the optimal extraction path, the quantity extracted decreases overtime and T may be understated. But, as we find in the present study, quantity extracted has an increasing trend for various subsoil assets. In such a scenario, 'T' estimated using the above method is biased upwards. To account for overstated T, we assume it to be lower than the estimated values as discussed below. Table A-3 shows that India has abundance of coal and lignite which will last more than 100 years. However, Batra and Chand (2011) point out that coal reserves in India are greatly overstated. "The coal that can be extracted –taking into account geological, technical and economic aspects- is only a small fraction of our total coal inventories, without taking into account no-go areas where coal mining may not be permitted" (p 2, Batra and Chand 2011). Hence, we assume that for coal, T = 25 years at 2012. In this manner, T= 26 years at 2011 and so on. In case of crude petroleum and natural gas, proved reserves are not reported. The data on reserves includes proved and indicated balance recoverable reserves. Hence, the reserve-extraction ratios derived may be biased upwards. For these reasons, the study assumes that the resource exhaustion time for natural gas is 25 years in 2012. For oil, the study assumes T = 15 years at 2012. In case of minerals data on proved reserves are available as per UNFC system[18]. But we take aggregate mineral rents and assume T = 25 years at 2012.

[18] Under the UNFC system, reserves are classified as proved (STD 111), probable (STD 121 and 122), feasibility (STD 211) and pre-feasibility (STD 221 and 222). The 'remaining resources' are further classified as measured, indicated, inferred and reconnaissance.

2. Forests

Forests provide a range of benefits such as timber and non-timber forest products which include rubber, medicinal plants, etc. Apart from these, forests also provide other intangible benefits such as ecosystem services, carbon sequestration, watershed benefits, etc. Several studies have estimated the forest wealth as a part of comprehensive wealth (e.g., World Bank 2006 and 2011, UNU-IHDP and UNEP 2012 and 2014).

Under the classification 'fixed assets', GFCF covers cultivated assets which are mainly treestock and livestock "under the direct control, responsibility and management of institutional units" (p 230, NAS 2012). Hence, orchards, vineyards and other tree plantations providing repeat products such as trees cultivated for nuts, fruits, sap, resin, bark, leaf products, etc. are covered by GFCF. However, trees grown for timber are not considered as fixed assets as they cannot be used repeatedly (NAS 2012). Thus, the present study has estimated timber wealth from forests as timber trees are not taken to be fixed assets in GFCF. Various forest services which the study has accounted for are: economic value of timber, bamboo and fodder production, NWFPs (Non- Wood Forest Products such as bel, neem, sal, harad and others), fuelwood production, carbon sequestration services[19], soil conservation, pollination and seed dispersal services, water recharge and water purification services.

The present study estimates forest wealth by taking capitalized value of total annual forest benefits (all the above types of forest services) assuming 25 years' lifespan of forests and 8.5 per cent discount rate. 10 per cent of the forest area is assumed to be accessible to the population. Therefore,

$$\text{Forest Wealth} = \text{Value of Annual Forest Benefits}\left(1+\frac{1}{\gamma}\right)\left(1-\frac{1}{(1+\gamma)^T}\right) \quad (16)$$

The study assumes a 25 years lifetime of forests following World Bank (2006 and 2011). Studies such as Ravindranath et al (2012) have highlighted the deforestation and forest degradation in India. With this perspective, it seems reasonable to assume a 25 year lifetime for forests. The present study estimates forest wealth as a range. We provide the upper limit for forest wealth had all forest area been covered by 'very dense forest' and the lower limit

[19] Verma et al (2013) has drawn out a distinction between carbon storage and carbon sequestration. While carbon storage is a one-time value which comes from standing timber, carbon sequestration is the services delivered by forests by storing carbon annually. Carbon sequestration comes from potential timber production if the forests are not diverted.

for forest wealth had all forest area been covered by ‘open forests’[20]. The lower limit of forest wealth ‘PDV_{open}’ is estimated by taking the present discounted value of benefits assuming all forests are open forests, that is,

$$PDV_{open} = \mathrm{PHB}_{open} Forest\ Area * 0.1 \left(1 + \frac{1}{\gamma}\right)\left(1 - \frac{1}{(1+\gamma)^T}\right) \tag{17}$$

Here, PHB_{open} is the annual per hectare benefits from open forests. Similarly, forest wealth assuming very dense forest, that is, $PDV_{very\ dense}$ is estimated using the following equation:

$$PDV_{very\ dense} = \mathrm{PHB}_{very\ dense}\ Forest\ Area * 0.1 \left(1 + \frac{1}{\gamma}\right)\left(1 - \frac{1}{(1+\gamma)^T}\right) \tag{18}$$

Here, $\mathrm{PHB}_{very\ dense}$ is the annual per hectare benefits from dense forests.

We have used data on forest cover from World Development Indicators Database. Continuous time series data on area under forests for the period 1993 to 2012 is not available in the State of Forest Reports, Forest Survey of India (FSI), Ministry of Environment and Forests. The Forest Survey of India brings out a biennial publication, State of Forest Reports (SFR) which provides data on ‘actual forest cover’ in India. There has been a change in definition since 2001 Assessment of forest cover, due to which, the data on forest cover before and after 2001 Assessment are not comparable. The SFR 2001 assessed the forest cover of the entire country using digital method whereas previous assessments had used visual interpretation of satellite data. Prior to SFR 2001, the method adopted was that of visual interpretation at 1:250,000 scale and post 2001 assessment, digital interpretation at 1:50,000 scale is being used. Additionally, the Minimum Mappable Unit which was 25 hectares prior to 2001 assessment was changed to 1 hectares since SFR 2001. Due to a change in definition of area under forests, we were unable to use this series.

We find that forest cover in India is expanding. Although increasing forest cover in India is ‘technically accurate’, this masks the decline in native forests as pointed out by Puryavaud et al (2010). Puryavaud et al (2010) has proved that it is the plantations expansion which is contributing to the increase in forest cover. But plantations are not a replacement for native forests as they do not have same ecological significance as native forests. Due to lack of bifurcated data on plantations and native forests, an exercise reflecting the decline in forest

[20] According to the SFRs, ‘very dense forest’ have crown density above 70 per cent whereas open forests have crown density between 10-40 per cent.

wealth due to loss of native forests could not be undertaken. This is an interesting area of future research if such data is available.

Data on annual per hectare benefits from open forests 'PHB_{open}' and very dense forests '$\text{PHB}_{very\ dense}$' are calculated using estimates provided by Verma et al (2013). Verma et al (2013) provides the economic values of forest ecosystem services for 14 forest type groups according to Champion and Seth Classification and 4 density classes. These economic values of forests are used to provide revised NPV rates for forests as per the directions of the Hon'ble Supreme Court of India. Table A-5 provides the total economic value of select forest types and 2 density classes. Included in the TEV of forests are various services mentioned above (viz., economic value of timber, bamboo and fodder production, NWFPs, fuelwood production, carbon sequestration services, soil conservation, pollination and seed dispersal services, water recharge and water purification services). TEV excludes the values of bioprospecting, gene-pool protection and carbon storage which are one-time values. It also adjusts for double counting since several ecosystem services are delivered simultaneously or in a complementary manner. Using the TEV for select forest types as shown in Figure 5, we find the annual per hectare benefits for very dense and open forests by application of weighted average method. Data on forest area by select forest types are obtained from Reddy et al (2015). Together, the select forest types considered by the study account for 85 per cent of total forest area in 2013. Hence, the annual per hectare benefits derived from this area has a representative character. It is assumed that the annual per hectare benefits so derived for the year 2013 are time invariant.

3. Agricultural Land – Cropland and Pasture Land

The present study estimates the agricultural land wealth by adding the wealth values of cropland and pastureland. Cropland wealth is estimated by multiplying the physical cropland area with the shadow price of cropland. In order to obtain the shadow price of cropland, the average rental price per hectare 'RPA' is estimated for 12 crops. The crops taken are: rice, wheat, jowar, bajra, maize, gram, tur/arhar, groundnut, cotton, sugarcane, rapeseed and mustard, and sesamum seed[21]. That is,

$$RPA_y = \frac{1}{A}\sum_{k=1}^{12} Re\, P_{yk}Q_{yk} \tag{19}$$

[21] The crops are chosen on the basis of 'area under crops'. Together, these 12 crops cover more than 70 per cent of the total area under crops.

Here, subscript 'y' denotes year and subscript 'k' denotes crop. Re is the rental rate (assumed to be 30 per cent for all crops following World Bank 2011). P denotes price per amount of crop and Q denotes the amount of the crop produced. Here, 'A' is total area harvested. Using this method, we obtain the rental price per hectare for the years 1993-94 to 2012-13. These rental prices are capitalized using 8.5 per cent discount rate and 25 years' time horizon to obtain the wealth per hectare 'Wha' for each year. That is,

$$Wha_y = RPA_y\left(1+\frac{1}{\gamma}\right)\left(1-\frac{1}{(1+\gamma)^T}\right) \tag{20}$$

These wealth values give the required shadow price. Finally, cropland wealth in any year is obtained by multiplying the wealth value per hectare Wha_y with the physical cropland area in that year. That is,

$$Cropland_y = Wha_y * CLA_y \tag{21}$$

Here, $Cropland_y =$ cropland wealth in year 'y' and CLA_{cy} is physical cropland area in year 'y'. For pastureland, the physical area is multiplied with the wealth value per hectare as obtained for cropland (following UNU-IHDP and UNEP 2012 and 2014). That is, we assume that pasturelands have identical rental prices per hectare and hence, identical wealth per hectare as cropland. The reason behind this assumption is that unlike cropland, rents from products accruing from pastureland cannot be directly linked to the pastureland area used for production (UNU-IHDP and UNEP 2012 and 2014). Hence,

$$Pastureland_y = Wha_y * PLA_y \tag{22}$$

Here, PLA_{cy} is physical pastureland area in year 'y'.

Finally, agricultural land wealth is obtained by summation of cropland wealth and pastureland wealth. The variables and the corresponding data sources for estimation of agricultural land are given in Table A-4.

It must be mentioned that ideally, land should be valued for its fertility. Research shows some evidence of decline in soil fertility. For instance, Pathak (2010) shows that the 'nitrogen fertility index' declined in States of Orissa and Kerala during 1967 to 1997. A priori, decline in soil fertility negatively impacts agricultural production. According to the productivity change method of land valuation, "depletion value of a unit of soil is equal to the capitalized value of future agricultural revenue that is forgone due to loss of that unit" (p 12, Vincent and Castaneda 1997). Such a method implicitly assumes that agricultural land revenue and fertility of land go together. However, under practical scenario, decline in fertility of land does not affect land revenue (or agricultural production) as the soil is compensated by fertilizers. However, in the absence of indicators of soil fertility, the study uses this method to estimate agricultural land wealth.

To avoid any possibility of double counting, we selected the crops by looking at items included in GFCF. GFCF covers cultivated assets which includes treestock and livestock. Livestock for breeding, draught animals, dairy, cattle, etc. which provide products repeatedly every year (e.g., fish, poultry, sheep for wool production, animals used for entertainment and transport) are included in GFCF as fixed assets. Moreover, 'construction activity' under GFCF includes planting and cultivating new orchards (tea, coffee, rubber, mango, cashew nuts, areca nut, coconut, citrus fruits, grapes, apple, banana, guava, papaya, litchi, pomegranates, pineapple, and Sapota planatations) (NAS 2012). Fruits bearing trees are considered as fixed assets but 'cereals and vegetables' are not considered as fixed assets as they yield a finished product only once when they are harvested. In the light of these observations, the present study does not consider 'fruits' while estimating cropland rental price per hectare. Moreover, livestock is accounted in GFCF. Hence, the present study does not estimate the per hectare rental price of pastureland using data on milk, beef, lamb and wool.

Adjustments to Comprehensive Investment

We adjusted the comprehensive investment estimates for two types of pollution damages: particulate emission damages and carbon emissions damages.

a) Particulate Emission Damages: These damages are deducted from comprehensive investment 'CI'. The damages are converted to 2004 prices using the implicit GDP deflator derived from GDP at market prices.

b) Carbon Emission Damages: The procedure for estimating carbon emission damage is as follows. We first obtain the global carbon emissions for the period 1993 to 2012. This includes carbon emissions from fossil fuel consumption, cement production, and gas flaring. It also includes carbon emissions attributed to deforestation. Change is world forest area is multiplied by the average carbon release per hectare which is assumed to be 100 tonnes of carbon (based on Lampietti and Dixon 1995). Global carbon emissions are multiplied by damage per tonne of carbon which is estimated at 50 U.S. $ (see Tol 2009). Having obtained the global damages from carbon, we apportion the damage to India. Following Arrow et al (2012), we assume that India bears 5 per cent of the global loss.

4. Empirical Results

Physical Capital: The study estimates the physical capital stock for the Indian economy for the period 1993-94 to 2012-13 at constant 2004-05 prices. In order to obtain the initial capital stock 'K_{1992}', we regress the logarithm of investments '$\ln I$' on time 't' (equation 8) in order to obtain the fitted value of first period investment 'I_{1992}', and the trend growth rate of investment, β. Applying OLS to equation 8 shows the presence of first order positive autocorrelation. Hence, we apply Heteroscedasticity and Autocorrelation (HAC) Standard Errors. We get β equal to 0.095118 (significant at 1 per cent level). We also obtain the fitted values of $\ln I$. We take the antilog of the first period fitted value of $\ln I$ and obtain I_{1992}. The depreciation rate is assumed to be 5 per cent. Now, initial capital stock is obtained applying the formula:

$$K_{1992} = \frac{I_{1992}}{\beta+\alpha}$$

We get an estimate of 23, 41, 468 Rupees Crores for 'K_{1992}'. Assuming a geometric pattern of depreciation, PIM is applied to get the stock values of capital for the years 1993-94 to 2012-13 as presented in Table A-6. The results indicate that there is an increasing trend in the value of physical capital stock in the Indian economy. However, it must be noted that the increase in the value of physical capital stock is driven by both price and quantity effects. The data on quantity of physical capital stock is not available due to which it is not possible to separate the price and quantity effects. The shadow prices are implicit in the investment figures.

Human Capital: Over the time period 1993-94 to 2011-12, the value of human capital in India has increased. Here again, it must be noted that such an increase in human capital stock estimates is driven by both the price and quantity effects. Increase in real annual incomes, average years of schooling and increase in population are driving the increase in the value of human capital stock.

Natural Capital:

1. Subsoil Assets

This section shows the wealth estimates for coal, oil, natural gas and minerals along with the reserves of these subsoil assets for various years across the period 1993-94 to 2012-13. In all cases, we find that the reserves are declining (see Table A-7), but the value of wealth of the respective resource has an increasing trend (see Table A- 6). This is because total rents have an upward trend during the period 1993-2012. Such a rising trend can be attributable to rising unit rents or rising extraction of the respective resource. Some intermittent fluctuations in wealth are noticed which are mainly attributable to the fluctuations in rents. The volatility in intermittent years is mainly due to fluctuations in prices, production and unit costs. Since the rents are valued at the prevailing international market prices, they are influenced by the wide fluctuations in fossil fuels' prices.

The period 1993-94 to 2012-13 also witnessed an increasing trend in resource extraction. Here, we observe that empirically, the economy is not extracting resources optimally. Along the optimal extraction path, the quantity extracted should decline overtime. On the contrary, in case of various subsoil assets, we observe that quantity extracted has an increasing trend. The reasons for the deviation of resource extraction from the optimal path can be traced to the underlying imperfect market structure. For instance, coal production in India is largely carried out by Coal India, a public sector organisation which also sets the coal prices. Although crude oil prices are market determined, natural gas prices are administered. These prices do not reflect the true scarcity cost of the resource. Since the market signals are poor, over-exploitation of resources is typically observed. An implication of rising production or extraction of resources is that the rents are observed to be rising overtime in contrast to the 'constant revenue' assumption as discussed earlier. Another implication of this can be seen from the data on reserves of various assets as generated by the study. It is seen that the reserves of coal, oil, natural gas, bauxite, iron ore and rock phosphate are shrinking over time.

2. Forests

Using equation 16, 17 and 18 forest wealth is estimated. Table A-6 presents the upper and lower limits for forest wealth. Since the area under forests is increasing, forest wealth is also seen to increase overtime.

3. Agricultural Land- Cropland and Pastureland

Using the methodology as described above, the study estimates the wealth value of cropland and pastureland for the years 1993-94 to 2012-13. We find that area under cropland and pastureland is declining even though value of land is rising due to rise in rental prices.

Comprehensive Wealth- Results and Discussion

Having estimated the physical capital (K_M), human capital (K_H) and natural capital (K_N) stock values for the Indian economy for the period 1993-94 to 2012-13, we estimate Comprehensive wealth 'W(t)' by simple summation of the values of various forms of capital. We also estimate Comprehensive Wealth per capita for the Indian economy for the same period. The results are presented in Tables A-6, A-7 and A-9 (see Appendix) and also shown graphically in Figures 1 and 2 below. We find that the value of comprehensive wealth as well as comprehensive wealth per capita is increasing in India during 1993 to 2012. We find that the rate of growth of 'comprehensive wealth per capita' is increasing overtime. The study also estimated 'Comprehensive Investment' as shown in Table A-9 (also see Figure 3). Comprehensive Investment is adjusted for damages from particulate emissions and CO_2 emissions. The adjusted 'Comprehensive Investment' also shows an overall increasing trend.

Theoretically, comprehensive wealth should be estimated at constant shadow price in order to trace out the increase or decline in the stock of capital. But, due to data limitations, this has not been possible. Shadow prices are implicit in the physical capital stock values. Even in case of subsoil assets rents and forests rents, the shadow prices are implicit. Hence, estimating the value of physical capital stock and natural capital stock at constant shadow price has not been possible.

Given the above observation, our wealth estimates subsume both the price and quantity effects. In case of natural capital, it is evident that the quantity or stock is declining (see Table A-7). Area under native forests is declining as reported by Puryavaud et al (2010). The reserves of fossil fuels and minerals are declining. And the area under cropland and pastureland is also declining. Increasing scarcity of natural resources is driving up resource rents and hence exerting an upward pressure of natural capital values. We can thus conclude that 'comprehensive wealth' is increasing even though the stock of natural capital is declining. Other studies have also reported similar findings. Kumar (2012) finds that the Indian economy is on a sustainable growth path since 1991, but the scale of resource depletion is high. The results of UNU-IHDP and UNEP (2014) indicate that inclusive wealth is increasing over the period 1990 to 2010 but fossil fuels and subsoil wealth are declining. Arrow et al (2012) finds that comprehensive investment in India is positive over the period 1995 to 2000, although the change in the value of natural capital is negative. These findings lead us to conclude that even though the comprehensive wealth in India is increasing, much of the increase is due to investments in physical capital. That our natural resources are declining raises questions about the sustainability of our growth.

A glance at Tables A-6 shows that human capital forms the largest component of wealth followed by physical capital. The value of natural capital is the least among all forms of capital. This clearly indicates that natural capital has been declining (see Table A-7) and other forms of capital are accumulating. That is, the Indian economy is meeting the weak sustainability criterion. However, we should adopt a cautious approach to conservation of natural capital given the uncertainty about the extent to which natural capital is substitutable (Pearce and Atkinson 1998). At the very least, the critical natural capital such as ozone layer should be preserved.

For comparability purposes, our estimates are converted into dollars using average annual exchange rate for the year 2004-05. A comparison with the results of selected studies as presented in Table A-8 shows that our estimates are on the conservative side. This is largely because we have chosen a higher discount rate. Use of a higher discount rate is justified because the stakeholders are myopic. This is reflected in the large scale exploitation of natural capital which we are witness to. We also chose a narrow range of human capital by taking only the working age population. In a country like India, the entire population is not skilled or embodied with human capital. Hence, our human capital estimates are more realistic as opposed to the higher estimates reported by UNU-IHDP and UNEP (2014) as UNU-IHDP and UNEP (2014) includes the entire population[22]. Our physical capital stock estimates are lower than that of UNU-IHDP and UNEP (2014) as we use a higher depreciation rate of 5 per cent as opposed to a 4 per cent depreciation rate employed by UNU-IHDP and UNEP (2014). Our physical capital stock estimates are also lower than that of World Bank (2011) since the latter study also includes urban land in physical capital. Urban land is generally unproductive and they act as complementary to the existing infrastructure. It derives utility from being attached to the existing physical capital infrastructure and has no independent utility value. Hence, the present study does not account for 'urban land' separately and explicitly. In case of natural capital, UNU-IHDP and UNEP (2014) wealth estimates for fossil fuels are higher compared to the corresponding wealth estimates obtained by the present study. This is because UNU-IHDP and UNEP (2014)

[22] Towards the recent years, our human capital estimates exceed that of UNU-IHDP and UNEP (2014) due to increase in earnings or real per capita annual income.

directly employs the stock in the ground figures for estimation. India does not follow the UNFC (United Nations Framework Classification) system for estimation of reserves for fossil fuels. Hence, the coal, oil and natural gas reserves data used for India may be grossly overvalued. Hence, we chose to refrain from using direct reserves data. In case of agricultural land, World Bank (2011) has employed world prices for estimation of cropland and pasture land; this results in very high estimates of World Bank (2011) whereas the present study employs 'farm harvest prices' which does away with chances of overvaluation. UNU-IHDP and UNEP (2014) has assumed infinite time horizon due to which its agricultural wealth estimates are higher. The present study uses a reasonable time frame of 25 years.

Figure1: Various Wealth Estimates

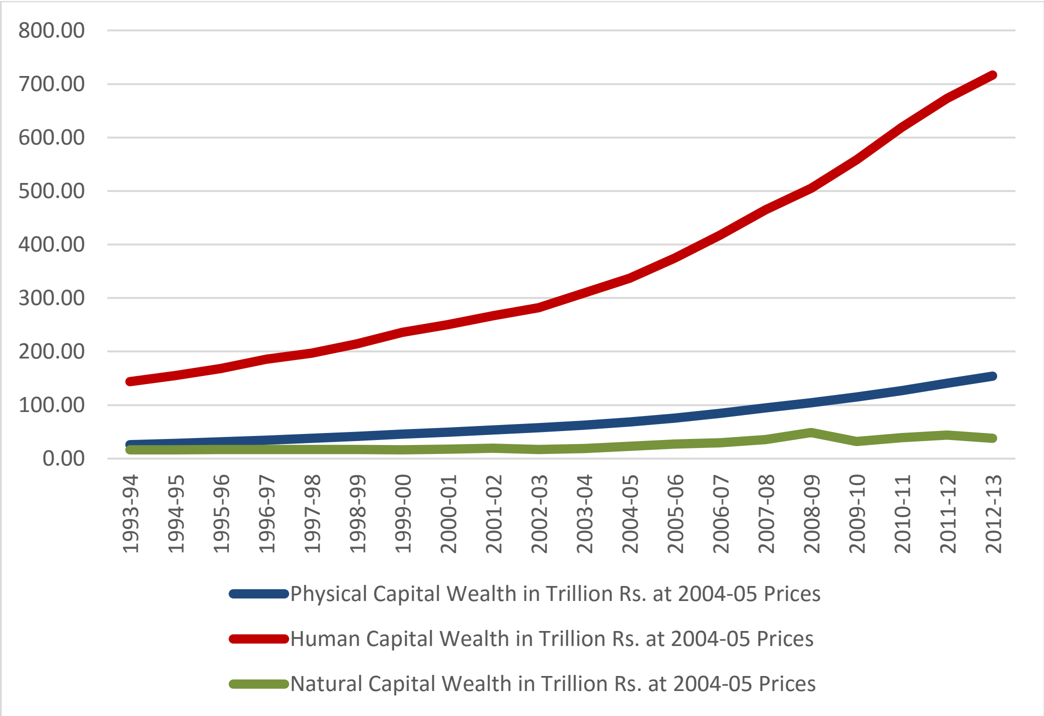


Figure 2: Comprehensive Wealth Estimates

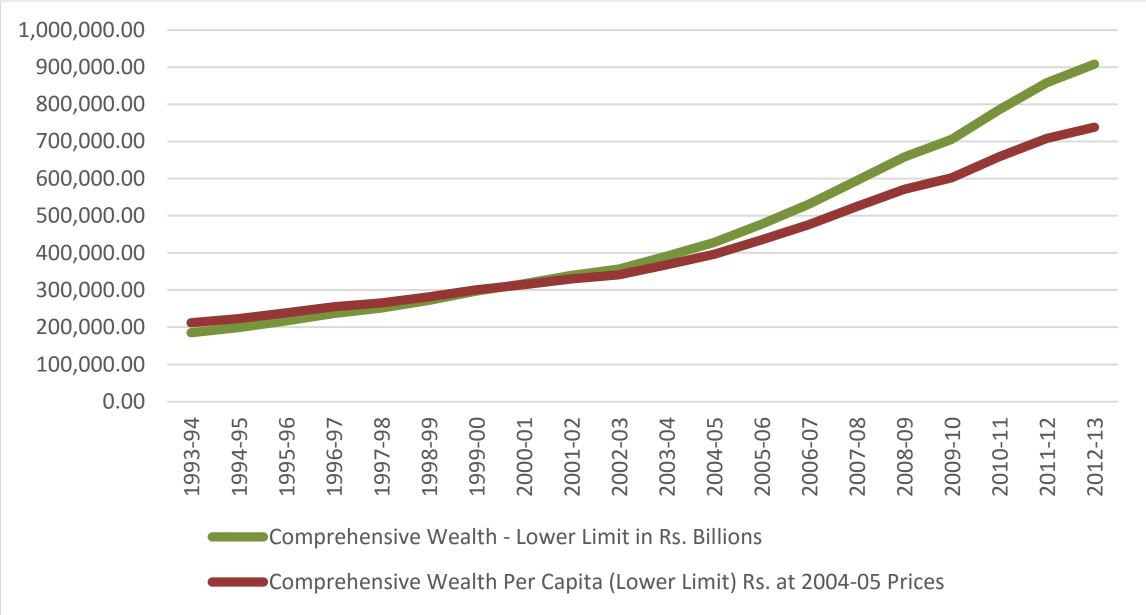
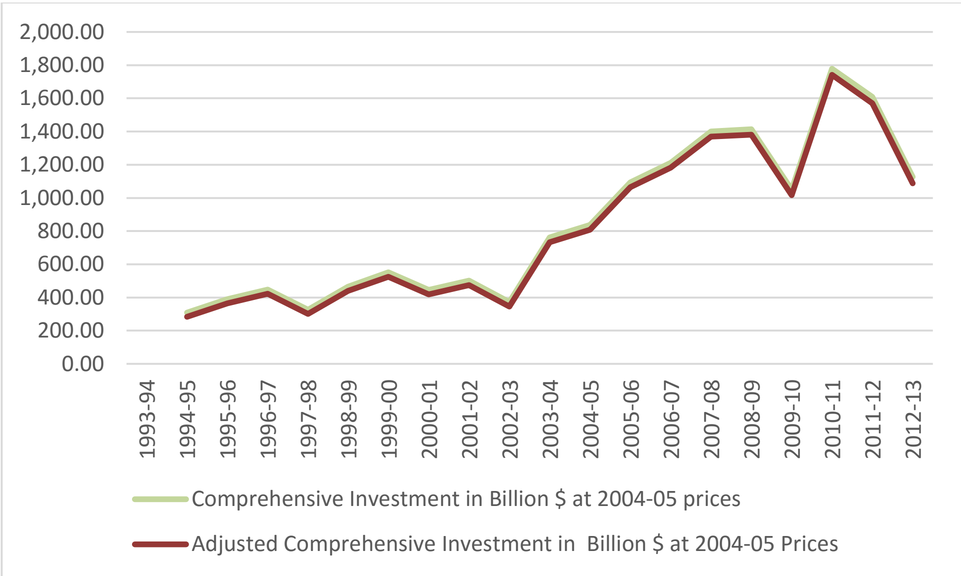


Figure 3: Comprehensive Investment Estimates



Part B

5. Regression Analysis

Here, the study aims to analyse to what extent wealth estimates of physical, human and natural capital explain the income or GDP. Table A-6 shows the various wealth estimates obtained by the study. The natural capital wealth estimates are also given in disaggregated form as subsoil wealth, forest wealth and agricultural land wealth. We use these series as our variables for econometric analysis. All the variables are described in Table 1.

Table 1: Description of Variables

Variables	**Description**	**Units**
$pc\ GDP$	Per Capita GDP (obtained by dividing GDP at Factor Cost by population)	Rs. Trillions at 2004-05 prices
$pc\ K_M$	Per Capita Physical Capital Wealth	Rs. Trillions at 2004-05 prices
$pc\ K_H$	Per Capita Human Capital Wealth	Rs. Trillions at 2004-05 prices
$pc\ K_N$	Per Capita Natural Capital Wealth	Rs. Trillions at 2004-05 prices
K_M_GDP	Ratio of Physical Capital Wealth to GDP at Factor Cost	Ratio
K_H_GDP	Ratio of Human Capital Wealth to GDP at Factor Cost	Ratio
K_N_GDP	Ratio of Natural Capital Wealth to GDP at Factor Cost	Ratio
$'W'$	Comprehensive Wealth - Lower Limit. It is obtained by adding Physical Capital Wealth, Human Capital Wealth and Natural Capital Wealth (based on lower limit of Forest Wealth).	Rs. Trillions at 2004-05 prices
K_M_W	Ratio of Physical Capital Wealth to Comprehensive Wealth	Ratio
K_H_W	Ratio of Human Capital Wealth to Comprehensive Wealth	Ratio
K_N_W	Ratio of Natural Capital Wealth to Comprehensive Wealth	Ratio
$trade\_GDP$	Sum of exports and imports of goods and services measured as a percentage of GDP (obtained from World Development Indicators Database)	Percentage
$credit\_GDP$	Domestic credit to private sector as a percentage of GDP (obtained from World Development Indicators Database)	Percentage
$pc\ AGRILAND$	Per Capita Agricultural Land	Thousand Hectares
$pc\ ENERGY$	Per Capita Energy (Total production of coal, lignite, oil and natural gas expressed in energy equivalent terms)	Million Gigajoules
$pc\ AGRIwealth$	Per Capita Agricultural Land Wealth	Rs. Millions at 2004-05 prices
$pc\ SUBSOILwealth$	Per Capita Subsoil Assets Wealth	Rs. Millions at 2004-05 prices
$pc\ FORESTwealth$	Per Capita Forests Wealth (Lower Limit)	Rs. Millions at 2004-05 prices

We tried various OLS model specifications. In all these regressions, per capita GDP (in log terms) is taken as the dependent variable. Basically, the aim is to test for the following model,

$$ln\, pc\, GDP = f(ln\, pc\, K_M, ln\, pc\, K_H, ln\, pc\, K_N) \quad (23)$$

But, the correlation between $ln\, pc\, K_M$ and $ln\, pc\, K_H$ is found to be very high. Hence, we estimated OLS using $ln\, pc\, K_M$ and $ln\, pc\, K_N$ in one set of specifications (see models 1 to 6 in Table 2) and $ln\, pc\, K_H$ and $ln\, pc\, K_N$ in another set of specification (see models 7 to 13 in Table 3). Model 1 takes $ln\, pc\, K_M$ and $ln\, pc\, K_N$ as independent variables and both are found to be significantly positive in explaining income. Model 1 does not have multicollinearity as the VIF of both the explanatory variables are less than 10. In Model 2, we add two additional control variables ($trade_{GDP}$ and $credit\_GDP$). Despite these controls, $ln\, pc\, K_M$ and $ln\, pc\, K_N$ are found to be highly significant in explaining income. Model 3 takes lagged independent variables and finds that both physical and natural capital per capita when taken with one period lag have a significant impact on income per capita. Model 4 takes $ln\, pc\, K_M$ but its takes per capita agricultural land and per capita energy in quantity rather than monetary terms for natural capital. Both per capita agricultural land and per capita energy are found to be significant and positive determinants of income per capita, apart from physical capital. Model 5 adds two additional control variables ($trade_{GDP}$ and $credit\_GDP$) to Model 4. Land is still significant, but energy loses its significance. In model 6, we take physical capital, but natural capital wealth is taken in disaggregated form as subsoil wealth, forest wealth and agricultural land wealth. We find that forest wealth and agricultural land wealth are significant and positive as expected. Hence, we find that across all specifications, physical capital is significant and positive. Natural capital is found to be significant in both quantity terms and monetary terms.

Table 2: Various OLS Model Specifications and Results

Dependent Variable $\boldsymbol{ln\,pc\,GDP}$	Model (1)	Model (2)	Model (3)	Model (4)	Model (5)	Model (6)
Explanatory Variables						
$\boldsymbol{ln\,pc\,K_M}$	0.623*** (0.024)	0.683*** (0.038)		0.902*** (0.096)	0.901*** (0.080)	0.821*** (0.047)
$\boldsymbol{ln\,pc\,K_M}$ **(-1)**			0.627*** (0.026)			
$\boldsymbol{ln\,pc\,K_N}$	0.088** (0.038)	0.118*** (0.038)				
$\boldsymbol{ln\,pc\,K_N}$**(-1)**			0.099** (0.037)			
$\boldsymbol{ln\,trade\_GDP}$		−0.126 (0.084)			0.008 (0.032)	
$\boldsymbol{ln\,credit\_GDP}$		0.037 (0.070)			0.061* (0.033)	
$\boldsymbol{ln\,pc\,AGRILAND}$				1.149*** (0.286)	1.266*** (0.214)	
$\boldsymbol{ln\,pc\,ENERGY}$				0.187* (0.094)	0.129 (0.094)	
$\boldsymbol{ln\,pc\,AGRIwealth}$						0.066* (0.037)
$\boldsymbol{ln\,pc\,SUBSOILwealth}$						0.006 (0.009)
$\boldsymbol{ln\,pc\,FORESTwealth}$						0.922*** (0.222)
Constant	−5.501*** (0.348)	−3.670*** (0.916)	−5.191*** (0.276)	9.573*** (3.261)	9.666*** (2.459)	2.271 (1.986)

HAC (robust) Standard errors are in parentheses. *** Significant at 1 per cent level. **Significant at 5 per cent level. *Significant at 10 per cent level.

In another set of specification (models 7 to 13 in Table 3), we take $ln\,pc\,K_H$ and $ln\,pc\,K_N$. Model 7 takes $ln\,pc\,K_H$ and $ln\,pc\,K_N$ as independent variables and both are found to be significantly positive in explaining income. Model 8 takes lagged independent variables and finds that both human and natural capital per capita when taken with one period lag have a significant impact on income per capita. In Model 9, we add two additional control variables ($trade_{GDP}$ and $credit\_GDP$). Despite these controls, $ln\,pc\,K_H$ and $ln\,pc\,K_N$ are found to be highly significant in explaining income. Model 10 takes $ln\,pc\,K_H$ but its takes per capita agricultural land and per capita energy in quantity rather than monetary terms for natural capital. Both per capita agricultural land and per capita energy are found to be significant and positive determinants of income per capita, apart from human capital. Even with addition of controls ($trade_{GDP}$ and $credit\_GDP$) to Model 10 (see Model 11), the variables $ln\,pc\,K_H$, $ln\,pc\,AGRILAND$ and $ln\,pc\,ENERGY$ do not lose their significance. In model 12, we take human capital, but natural capital wealth is taken in disaggregated form as subsoil wealth, forest wealth and agricultural land wealth. We find that human capital, forest wealth and agricultural land wealth are significant and positive as expected. However, subsoil wealth is found to be insignificant. With addition of controls ($trade_{GDP}$ and $credit\_GDP$), subsoil wealth becomes significant and agricultural land wealth loses its significance. Hence, we find that across all specifications, human capital is significant and positive. Natural capital is found to be significant in both quantity terms and monetary terms.

Table 3: Various OLS Model Specifications and Results

Dependent Variable $\boldsymbol{ln\,pc\,GDP}$	Model (7)	Model (8)	Model (9)	Model (10)	Model (11)	Model (12)	Model (13)
Explanatory Variables							
$\boldsymbol{ln\,pc\,K_N}$	0.039** (0.0172)		0.058*** (0.013)				
$\boldsymbol{ln\,pc\,K_N}$**(-1)**		0.051** (0.022)					
$\boldsymbol{ln\,pc\,K_H}$	0.723*** (0.0125)		0.773*** (0.017)	0.860*** (0.025)	0.859*** (0.024)	0.821*** (0.016)	0.852*** (0.019)
$\boldsymbol{ln\,pc\,K_H}$**(-1)**		0.727*** (0.017)					
$\boldsymbol{ln\,trade\_GDP}$			−0.053 (0.032)		0.018** (0.006)		−0.0018 (0.013)
$\boldsymbol{ln\,credit\_GDP}$			−0.02 (0.026)		−0.013 (0.010)		−0.036* (0.017)
$\boldsymbol{ln\,pc\,AGRILAND}$				0.488*** (0.059)	0.502*** (0.055)		
$\boldsymbol{ln\,pc\,ENERGY}$				0.067** (0.0272)	0.064** (0.0253)		
$\boldsymbol{ln\,pc\,AGRIwealth}$						0.025*** (0.008)	0.008 (0.009)
$\boldsymbol{ln\,pc\,SUBSOILwealth}$						0.0004 (0.003)	0.008* (0.004)
$\boldsymbol{ln\,pc\,FORESTwealth}$						0.395*** (0.090)	0.466*** (0.062)
Constant	−5.875*** (0.154)	−5.556*** (0.20887)	−4.525*** (0.301)	0.435 (0.631)	0.496 (0.587)	−2.527*** (0.766)	−1.536** (0.643)

HAC (robust) Standard errors are in parentheses. *** Significant at 1 per cent level. **Significant at 5 per cent level. *Significant at 10 per cent level.

Because of the high correlation between physical and human capital, we could not include these together in the above model specifications. However, we tried all three in one specification by taking ratios (see Table 4). Since, physical, human and natural wealth add up to comprehensive wealth 'W', we could not include all three as ratio of wealth in one specification. In that case, one of these was taken as ratio of GDP. In Model 14, physical capital and natural capital are taken as ratio of GDP whereas human capital is taken as a ratio of wealth. All three ratios are found to be significant and positive as expected. In Model 15, natural capital is taken as ratio of GDP, whereas physical capital and human capital are taken as ratio of wealth. All three ratios are found to be significant and positive as expected. In Model 16, physical capital is taken as ratio of GDP, whereas natural capital and human capital are taken as ratio of wealth. All three ratios are found to be significant and positive as expected. Model 17 is formed by adding other control variables to Model 14. The significance and signs of the ratios do not change. Hence, our results are robust as many alternative specifications give consistently significant coefficients.

Table 4: Some More OLS Model Specifications and Results

Dependent Variable $\boldsymbol{ln\,pc\,GDP}$	Model (14)	Model (15)	Model (16)	Model (17)
Explanatory Variables				
$\boldsymbol{ln\,trade\_GDP}$				−0.0837 (0.308)
$\boldsymbol{ln\,credit\_GDP}$				0.242 (0.175)
$\boldsymbol{ln\,K_M\_GDP}$	2.142*** (0.096)		2.899*** (0.345)	1.814*** (0.579)
$\boldsymbol{ln\,K_N\_GDP}$	1.144*** (0.283)	2.507*** (0.618)		0.983** (0.375)
$\boldsymbol{ln\,K_M\_W}$		7.055*** (0.666)		
$\boldsymbol{ln\,K_H\_W}$	16.403*** (5.164)	30.431** (11.025)	13.976* (7.097)	14.679** (5.591)
$\boldsymbol{ln\,K_N\_W}$			1.095** (0.431)	
Constant	−14.908*** (1.304)	3.570 (3.275)	−13.205*** (2.661)	−15.661*** (1.501)

HAC (robust) Standard errors are in parentheses. *** Significant at 1 per cent level. **Significant at 5 per cent level. *Significant at 10 per cent level.

In all the above regression models, we find that the residuals are stationary. This suggests that the regressions are not spurious. It also points to the existence of a long run relationship between the variables. Hence, we also estimated the ARDL model using few of the above variables listed in Table 1. ARDL model is chosen because we have a small sample size- only 20 observations. Although testing of variables for the presence of a unit root is not a prerequisite of ARDL models, yet we conducted unit root tests to see if the variables are I(0), I(1) or a mixture of the two. Table 5 shows the results of two unit root tests for few selected variables which are used in ARDL models.

Table 5: Unit Root Tests Results

Variables	Augmented Dickey-Fuller (ADF) test statistic			Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test statistic		
	Level	1st Difference	2nd Difference	Level	1st Difference	2nd Difference
$\boldsymbol{ln\ pc\ GDP}$	−	−	−5.426***	0.147***	0.104*	−
$\boldsymbol{ln\ pc\ K_M}$	−	−	− 3.633*	0.142**	−	−
$\boldsymbol{ln\ pc\ K_H}$	−	−	− 5.115***	0.149***	0.096*	−
$\boldsymbol{ln\ pc\ K_N}$	−	−5.139***	−	0.146**	−	−
$\boldsymbol{ln\ pc\ AGRILAND}$	−	−	−5.114***	−	0.094*	−
$\boldsymbol{ln\ pc\ ENERGY}$	−	−	−5.425***	0.131**	−	−
$\boldsymbol{ln\ pc\ AGRIwealth}$	−	− 6.121***	−	0.155*	−	−
$\boldsymbol{ln\ pc\ SUBSOILwealth}$	−	−4.791***	−	0.111*	−	−
$\boldsymbol{ln\ pc\ FORESTwealth}$	−	−	−2.822	−	0.146***	0.141**

From Table 5, we can see that the two unit root tests show conflicting results. While the series are mostly I(0) or I(1) when we apply KPSS test, they are mostly I(2) when ADF test is used. Since our sample size is very small, the test results may not be accurate. Hence, we proceed to apply ARDL modelling approach assuming that our series are mostly I(0) or I(1).

We estimated 4 ARDL models the results of which are displayed in Table 6 below. In all the models, the error correction term is negative and significant which proves that the series converge to the long run equilibrium. The F-statistic from Bounds test is also significant showing the existence of a long run relationship. In Model 1, physical capital is positively significant but natural capital is found to be insignificant. In Model 2, physical capital and agricultural land are found to be significant but energy is found to be insignificant. In Model 3, both human capital and natural capital are found to be positive and significant. In Model 4, human capital and agricultural land wealth are found to be positive and significant whereas forest and subsoil wealth are found to be insignificant. Thus, we see that the results of ARDL models also prove that physical, human and natural capital wealth are significant determinants of income. Our results are very robust as we have used various specifications and we find persistently significant coefficients. Even though our sample size is small (which is one of the limitations of our analysis), our results are consistently same across many model specifications.

Table 6: Estimated Long-Run Coefficients using ARDL Method

Dependent Variable	ARDL Model 1 (1, 1, 0) Auto Selection based on AIC	ARDL Model 2 (1,1,0,0) Auto Selection based on AIC	ARDL Model 3 (1,1,1) Auto Selection based on AIC	ARDL Model 4 (1,1,0,1,0) Auto Selection based on AIC
$\boldsymbol{ln\,pc\,GDP}$				
Independent Variables				
$\boldsymbol{ln\,pc\,K_M}$	1.151*** (0.098)	0.901*** (0.080)		
$\boldsymbol{ln\,pc\,K_H}$			0.930*** (0.035)	0.988*** (0.031)
$\boldsymbol{ln\,pc\,K_N}$	−0.0008 (0.031)		0.017* (0.009)	
$\boldsymbol{ln\,pc\,ENERGY}$		0.105 (0.080)		
$\boldsymbol{ln\,pc\,AGRILAND}$		1.061*** (0.241)		
$\boldsymbol{ln\,pc\,AGRIwealth}$				0.020* (0.011)
$\boldsymbol{ln\,pc\,FORESTwealth}$				0.058 (0.113)
$\boldsymbol{ln\,pc\,SUBSOILwealth}$				0.002 (0.0016)
$\boldsymbol{CointEq(-1)}$	−0.928** (0.324)	−1.039*** (0.254)	−0.0762*** (0.099)	−0.0664*** (0.112)
$\boldsymbol{Bounds\,Test\,F - statistic}$	4.819	5.306	6.552	5.238
$\boldsymbol{Significance\,Level}$	10%	2.5%	5%	2.5%
$\boldsymbol{I(0)bound}$	4.19	3.69	4.87	3.89
$\boldsymbol{I(1)bound}$	5.06	4.89	5.85	5.07
Fixed Regressors	Constant and Trend	Constant	Constant and Trend	Constant and Trend

HAC (robust) Standard errors are in parentheses. *** Significant at 1 per cent level. **Significant at 5 per cent level. *Significant at 10 per cent level.

6. Conclusion and Policy Implications

Several important observations follow from the paper. The value of 'comprehensive wealth per capita' is increasing in India during 1993-2012 even though the stock of natural capital is declining, a finding which is corroborated by other studies. That natural capital is declining and other forms of capital is rising shows that we are meeting the weak sustainability criterion. Since we are uncertain about the extent of substitutability of natural capital, a rather cautious approach should be adopted and policies encouraging conservation of natural capital should be implemented. At the very least, the critical natural capital such as ozone layer should be preserved. This brings us to an important limitation of the present study. Although the study has adjusted the wealth estimates for particulate emission damages and carbon emission damages, several other types of environmental degradation such as ground water depletion are not accounted for. A reasonable decline in the figures can be expected when an attempt is made to incorporate the negative impact of various types of environmental degradation in wealth accounting. In conclusion, it can be said that although the Indian economy is growing sustainably as per the 'weak sustainability' criterion, decline in the stock of natural capital may put such sustainability at risk in the near future. This is further supported by the results of our OLS and ARDL models wherein we find that natural capital wealth is a significant determinant of income. Whether we take natural capital is monetary terms in aggregate or disaggregated as subsoil, forest and agricultural land wealth or we take natural capital in volume terms as energy or agricultural land, we see that these variables have a significant and positive impact on income.

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Appendix

Table A-1: Variables and Data Sources used in measuring Physical Capital

Variables	***Data Sources***
Gross Fixed Capital Formation or GFCF	National Accounts Statistics Back Series 1950-51 to 2012-13 (base year 2004-05)
Depreciation Rate 'α'	Assumed to be 5 per cent
Average annual exchange rate of Rupee vis-a-vis U.S. dollar for the year 2004-05	RBI Handbook of Statistics on Indian Economy, 2015

Table A-2: Variables and Data Sources used in measuring Human Capital

Variables	***Data Sources***	***Adjustments***
'Edu'- average number of years of schooling	Barro-Lee Educational Attainment Dataset available at www.barrolee.com	Data on average years of schooling are obtained at 5 year intervals for the years 1990, 1995, 2000, 2005 and 2010. Linear interpolations are used to obtain the required data for the intervening years. For the later years, linear extrapolation is used.
'Pop_{15-60}'- population in the age group 15-60	Census of India	Population data by age is available for the years 1991, 2001 and 2011. The mid-year population estimates for the age-group 15-60 is obtained by interpolation using exponential growth rate method.
'RY'- Per Capita Gross Domestic Product at Factor Cost at constant 2004-05 prices	EPWRF website	
Gross Domestic Product at Factor Cost at constant 2004-05 prices	National Accounts Statistics, CSO, MOSPI	
'δ' - Discount Rate	Assumed to be 8.5 per cent	

Table A-3 – Resource Exhaustion Time for Various Resources

Category	*Reserve-Extraction Ratio or Resource Exhaustion time in years at 2013*	*Source*
Proved Recoverable Reserves of Coal (including Lignite)	>100	World Energy Resources 2013 Survey, World Energy Council.
Proved and Indicated Balance Recoverable Reserves of Crude Petroleum	20	Authors' Calculations
Proved and Indicated Balance Recoverable Reserves of Natural Gas	34	Authors' Calculations
Proved Reserves of Bauxite (STD 111) As Per UNFC System	17	Authors' Calculations
Proved Reserves of Copper Ore (STD 111) As Per UNFC System	34	Authors' Calculations
Proved and Probable Reserves of Lead and Zinc Ore As Per UNFC System[1]	10	Authors' Calculations
Proved Reserves of Rock Phosphate As Per UNFC System	7	Authors' Calculations
Proved Reserves of Silver Metal As Per UNFC System[2]	2	Authors' Calculations
Proved Reserves of Gold Ore (Primary) As Per UNFC System	29	Authors' Calculations
Proved Reserves of Tin metal As Per UNFC System[3]	62	Authors' Calculations
Proved Reserves of Nickel Ore As Per UNFC System[4]	NA	Authors' Calculations
Proved Reserves of Iron Ore (Haematite and Magnetite) As Per UNFC System	44	Authors' Calculations

Source: Authors' Calculations. Notes: [1]Considering only proved reserves of lead and zinc ore as on 1-4-2010 and accounting for the extraction of lead and zinc ore in 2010-11, 2011-12 and 2012-13, we get negative reserves as on 1-4-2013. For this reason, we consider both proved and probable reserves for lead and zinc ore. [2]Data on production of Silver Ore is not available. [3]Data on production of tin ore is not available. [4]There is no data on proved reserves of nickel ore or metal. Data on production of nickel is not available.

Table A-4: Variables and Data Sources used in measuring Natural Capital

Subsoil Assets		
Variables	***Data Sources***	***Notes***
Total Rents[23] '$\pi_j q_j$' for coal[24], oil, natural gas and minerals (bauxite, phosphate and iron ore) for the years 1993 to 2008	World Bank's World Development Indicators Database[25]	The database gives rents as % of GDP. Using GDP at constant 2004-05 prices, we obtain total rents for various subsoil assets
Implicit GDP deflator (2004 base year)	World Development Indicators (WDI) Database	The implicit GDP deflator is derived using GDP at market prices (current prices and constant prices) as obtained from the WDI Database (Base year 2005 is converted to 2004).
Production of coal, lignite, crude petroleum and natural gas for the years 1993-94 to 2012-13	Energy Statistics 2007, 2015 and 2016.	
Production for various minerals (bauxite, iron ore and rock phosphate) for the years 1993-94 to 2012-13	Indian Minerals Yearbook, Indian Bureau of Mines, Various Issues.	

[23] Few studies such as Kunte et al (1998), Bolt et al (2002) and Hamilton and Clemens (1998) provide a description on estimation of total rents.

[24] Coal rents include rents from coal as well as lignite. Coal is classified as hard coal (bituminous and anthracite) and soft coal (lignite and sub-bituminous).

[25] Total Rents = Unit Rents * Production, where, Unit Rents = Unit Price - Unit Cost. Hence, total rents are derived by multiplying unit rents from extraction of the respective resource with the quantity produced. However, these total rents figures are derived using world prices for various countries including India. Such an approach tends to introduce an upward bias in the wealth estimates since world prices are generally higher than local prices. See WDI database for a detailed description.

Coal Reserves	World Energy Resources 2013 Survey, World Energy Council.	According to this report, proved recoverable reserves of coal at end 2011 is 60600 million tonnes (bituminous and anthracite – 56100 million tonnes and lignite- 4500 million tonnes). Taking the reserves of coal as on 2012, we find the reserves in the previous years (1993 to 2011) by using equation (14).
Reserves of Crude Petroleum and Natural Gas	Energy Statistics 2015.	The report gives data on 'proved and indicated balance recoverable reserves' as on 1-4-2013. We set the end of year reserves at 2013 and estimate the reserves for all preceding years starting 1993 using equation (14).
Reserves of various minerals (bauxite, iron ore and rock phosphate).	Indian Minerals Yearbook 2012 (Indian Bureau of Mines).	The latest data on proved reserves of various minerals as per the UNFC system are available for 1-4-2010. The data on proved reserves (of various minerals) as on 1-4-2013 is estimated by subtracting the total extraction in the years 2010-11, 2011-12 and 2012-13 from the reserves as on 1-4-2010. Using equation (14), the reserves for the period 1993-2012 is estimated for each of these minerals.
Forests		
Forest Area (sq. kms)	World Bank's World Development Indicators' Database (which has sourced from FAO, electronic files and website).	Forest area is land under natural or planted stands of trees of at least 5 meters in situ, whether productive or not, and excludes tree stands in agricultural production systems (for

		example, in fruit plantations and agroforestry systems) and trees in urban parks and gardens.
Implicit GDP deflator (2004 base year)	RBI Handbook of Statistics on Indian Economy 2015	The implicit GDP deflator is derived using GDP at market prices (current prices and constant prices) as obtained from the RBI Handbook of Statistics on Indian Economy, 2015 (Base year 2004-2005).
Agricultural Land- Cropland and Pastureland		
Agricultural Land- Cropland 'PLA_y' and Pastureland 'PLA_y'	Data on land use classification for the years 1993-94 to 2012-13 are obtained from 'Land Use Statistics' available on the website of Directorate of Economics and Statistics, Department of Agriculture, Cooperation and Farmers' Welfare, Ministry of Agriculture and Farmers' Welfare (http://eands.dacnet.nic.in/LUS_1999_2004.htm). Total area harvested or sum of areas under different crops is obtained from the same source. Please note that data on land use statistics for 2008-09 onwards are provisional figures as actual figures are not available.	Cropland area is taken to be the sum of: 1. Land under miscellaneous tree crops and groves 2. Culturable waste land 3. Current fallows 4. Fallow land other than current fallows 5. Net area sown Pastureland area is taken as the area under 'permanent pastures and other grazing land'. Data shows that area under cropland and pastureland is declining overtime. This is mainly due to diversion of land to non-agricultural uses.

Representative Farm Harvest Prices of Various Crops 'P_{yk}'[26]	Data on farm harvest prices are obtained from 'Farm Harvest Prices of Principal Crops in India,' Various Issues from 1993-94 to 2012-13[27]. These are available on the website of Directorate of Economics and Statistics, Department of Agriculture, Cooperation and Farmers' Welfare, Ministry of Agriculture and Farmers' Welfare.	In order to find the representative price of each crop, we first find the largest producing State and take its farm harvest price as the 'representative price'. These current farm harvest prices are corrected for inflation (converted to 2004-05 base) using data on wholesale price index of the representative agricultural commodity.
Production of Various Crops 'Q_{yk}'	'Agricultural Statistics at a Glance, Various Issues' (Source: Directorate of Economics and Statistics, Ministry of Agriculture).	
WPI for selected agricultural commodities	Website of Office of the Economic Adviser, Ministry of Commerce and Industry, Department of Industrial Policy and Promotion (DIPP).	
Comprehensive Wealth Per Capita		
Population	Census of India	The mid-year population estimates for the age-group 15-60 is obtained by interpolation using exponential growth rate method.
Adjustments to Comprehensive Investment		
Particulate Emissions Damages	World Development Indicators Database	Particulate emissions damage is the damage due to exposure of a country's population to ambient concentrations of particulates measuring less than 2.5 microns in diameter (PM2.5), ambient ozone pollution, and indoor

[26] Farm harvest prices are prices received by the farmer at first point of sale. By using these prices, we do away with the cascading effect which would occur if wholesale or retail prices are used. Hence, our estimates are not inflated.

[27] In case of rice, the farm harvest prices are taken to be the average of winter, autumn and summer prices.

		concentrations of PM2.5 in households cooking with solid fuels. Damages are calculated as foregone labour income due to premature death. Estimates of health impacts from the Global Burden of Disease Study 2013 (Institute for Health Metrics and Evaluation, University of Washington) are for 1990, 1995, 2000, 2005, 2010, and 2013. Data for other years have been extrapolated from trends in mortality rates (Source: WDI Database)
Implicit GDP deflator (2004 base year)	World Development Indicators (WDI) Database	The implicit GDP deflator is derived using GDP at market prices (current prices and constant prices) as obtained from the WDI Database (Base year 2005 is converted to 2004).
Global CO_2 Emissions from Fossil Fuel (Solid, Gas, and Liquid) Consumption, Cement Production and Gas Flaring in million metric tonnes of carbon	Boden, T., Marland, G. & and Res, R. (2011). Global, regional, and national fossil-fuel CO2 emissions. Carbon Dioxide Information Analysis Center	
World Forest Area (sq. kms)	World Bank's World Development Indicators' Database (which has sourced from FAO, electronic files and website).	Forest area is land under natural or planted stands of trees of at least 5 meters in situ, whether productive or not, and excludes tree stands in agricultural production systems (for example, in fruit plantations and agroforestry systems) and trees in urban parks and gardens (Source: WDI Database).

Table A-5: Total Economic Value of forests

Type of Forests	Total Economic Value - Rs./ha/year for Very Dense Forest[1]	Total Economic Value - Rs./ha/year for Open Forest[2]	Forest Area in Hectares[3] for 2013
Tropical Wet Evergreen Forests -North East	1,78,772	81,716	14,71,400
Tropical Wet Evergreen Forests -Western Ghats	1,97,052	53,832	18,82,100
Tropical Semi Evergreen Forests -North East	1,02,971	42,447	13,92,100
Tropical Semi Evergreen Forests -Western Ghats	1,59,497	63,064	21,67,800
Tropical Moist Deciduous Forests	1,47,493	57,112	2,07,64,900
Littoral & Swamp Forests	2,40,606	92,650	3,94,000
Tropical Dry Deciduous Forests	1,07,810	46,804	2,17,71,300
Tropical Thorn Forests	61,365	43,238	8,16,600
Tropical & Subtropical Dry Evergreen Forests	1,26,952	51,781	73,200
Subtropical Pine/Broadleaved Hill Forests	1,08,322	47,420	43,50,300
Montane & Moist Temperate Forest	1,65,691	63,635	34,96,700
Sub Alpine & Dry Temperate Forest	1,39,036	54,901	13,40,800
TOTAL			5,99,21,200
Total Forest Area in 2013			7,03,25,200
Per cent of Area Covered			0.85
Annual Per Hectare Benefits for Very Dense Forest '$\mathrm{PHB}_{very\ dense}$' -Nominal Value for 2013 (Rs. Per year)			**1,32,241.81**
Annual Per Hectare Benefits for Open Forest 'PHB_{open}' - Nominal Value for 2013 (Rs. Per year)			**53,408.16**
Annual Per Hectare Benefits for Very Dense Forest '$\mathrm{PHB}_{very\ dense}$' -Real Value for 2013 at 2004 -05 prices			**72,156.83**
Annual Per Hectare Benefits for Open Forest 'PHB_{open}' - Real Value for 2013 at 2004 -05 prices			**29,141.79**

Source: Authors' Calculations

[3] Source: Reddy, C. Sudhakar; Jha, C. S.; Diwakar, P. G. and V. K. Dadhwal (2015), "Nationwide classification of forest types of India using remote sensing and GIS," *Environ Monit Assess* (2015) 187: 777, DOI 10.1007/s10661-015-4990-8

[1,2] Source: Verma M, Negandhi D, Wahal A K, Kumar R (2013), "Revision of rates of NPV applicable for different class/category of forests". *Indian Institute of Forest Management. Bhopal, India. June 2013.*

Table A-6: Wealth in Million Rs. at 2004-05 Prices

Year	Physical Capital Wealth $'K_M'$	Human Capital Wealth $'K_H'$	Coal Wealth	Oil Wealth	Natural Gas Wealth	Minerals Wealth	Subsoil Assets Wealth	Agricultural Land Wealth
1993-94	25,792,425.73	143,592,258.26	1,107,757.53	1,557,843.97	62,359.26	484,448.26	3,212,409.02	10,788,702.79
1994-95	28,386,904.44	154,879,782.47	1,086,858.50	1,594,318.50	54,041.13	381,914.41	3,117,132.53	10,875,178.29
1995-96	31,483,519.22	168,526,979.00	1,765,028.48	1,936,871.89	75,169.99	405,682.52	4,182,752.89	10,606,059.15
1996-97	34,562,893.26	185,366,794.73	1,685,222.98	2,206,216.45	129,461.64	473,344.51	4,494,245.58	10,485,484.12
1997-98	37,901,808.59	197,031,778.52	1,511,176.81	2,042,562.15	141,731.03	494,071.31	4,189,541.29	10,462,549.76
1998-99	41,565,848.16	214,067,198.79	1,244,371.00	1,236,674.08	44,946.10	870,554.69	3,396,545.87	11,450,211.90
1999-00	45,487,285.76	235,785,250.84	926,223.35	1,884,511.96	55,856.58	701,066.86	3,567,658.75	10,386,675.19
2000-01	49,129,021.47	250,509,899.44	1,343,783.31	3,328,143.42	368,682.43	839,207.44	5,879,816.59	9,709,938.60
2001-02	53,494,000.39	267,214,137.00	2,448,297.35	2,643,763.91	393,252.47	967,932.25	6,453,245.98	10,552,022.03
2002-03	57,611,000.37	282,144,649.03	1,740,255.40	2,728,840.62	331,258.76	993,019.08	5,793,373.86	8,861,651.87
2003-04	62,239,850.36	309,707,556.40	1,985,757.43	2,830,659.81	342,559.45	1,133,774.87	6,292,751.56	10,345,052.71
2004-05	68,438,137.84	336,848,435.74	4,853,146.61	3,440,294.17	384,869.68	1,587,105.36	10,265,415.82	10,603,151.15
2005-06	75,834,150.95	374,765,162.53	4,223,542.87	4,345,978.08	668,152.61	3,761,930.61	12,999,604.18	11,663,531.07
2006-07	84,355,093.40	417,838,854.36	4,528,986.32	5,306,744.92	905,975.97	4,974,925.68	15,716,632.89	11,787,343.82
2007-08	94,444,978.73	464,905,244.86	5,315,003.96	4,914,848.02	704,332.93	9,165,672.99	20,099,857.91	13,189,850.53
2008-09	104,532,159.79	505,086,422.19	13,515,836.27	6,733,315.95	865,682.80	12,596,936.16	33,711,771.18	12,789,509.80
2009-10	115,250,301.80	558,460,133.20	6,784,221.16	3,347,760.71	653,974.96	5,838,152.31	16,624,109.14	12,919,872.78
2010-11	127,185,706.71	619,398,515.44	8,448,434.19	4,301,691.44	775,637.92	9,534,288.82	23,060,052.36	13,479,685.50
2011-12	140,692,871.38	673,082,233.35	11,289,589.82	6,260,422.68	1,038,238.43	8,698,690.28	27,286,941.23	14,314,294.02
2012-13	153,678,707.81	716,918,073.16	8,505,684.17	6,372,135.89	891,416.91	5,449,734.60	21,218,971.58	14,138,748.58

Year	Forest Wealth Lower Limit	Forest Wealth Upper Limit	Natural Capital Wealth (based on lower limit of Forest Wealth) $'K_N'$	Comprehensive Wealth - Lower Limit $'W'$	Comprehensive Wealth - Lower Limit in Million $	Comprehensive Wealth - Upper Limit	Comprehensive Wealth Per Capita (Lower Limit) Rs. at 2004-05 Prices	Growth Rate of Comprehensive Wealth Per Capita (Based on Lower Wealth Estimates)
1993-94	2,082,341.20	5,156,001.62	16,083,453.01	185,468,137.00	4,127,797.58	188,541,797.42	212,318.84	
1994-95	2,087,034.81	5,167,623.27	16,079,345.62	199,346,032.53	4,436,665.42	202,426,620.99	223,591.64	0.05
1995-96	2,091,728.42	5,179,244.92	16,880,540.45	216,891,038.67	4,827,148.85	219,978,555.18	238,351.73	0.07
1996-97	2,096,422.03	5,190,866.58	17,076,151.72	237,005,839.71	5,274,825.90	240,100,284.27	255,190.49	0.07
1997-98	2,101,115.63	5,202,488.23	16,753,206.69	251,686,793.80	5,601,566.69	254,788,166.40	265,518.39	0.04
1998-99	2,105,809.24	5,214,109.89	16,952,567.01	272,585,613.97	6,066,692.94	275,693,914.61	281,751.24	0.06
1999-00	2,110,502.85	5,225,731.54	16,064,836.79	297,337,373.39	6,617,570.60	300,452,602.09	301,121.07	0.07
2000-01	2,115,196.46	5,237,353.19	17,704,951.64	317,343,872.56	7,062,837.26	320,466,029.29	314,883.93	0.05
2001-02	2,130,199.18	5,274,500.84	19,135,467.19	339,843,604.58	7,563,593.57	342,987,906.24	330,391.01	0.05
2002-03	2,145,201.90	5,311,648.48	16,800,227.64	356,555,877.04	7,935,543.60	359,722,323.62	341,030.01	0.03
2003-04	2,160,204.63	5,348,796.13	18,798,008.90	390,745,415.65	8,696,469.42	393,934,007.15	367,684.02	0.08
2004-05	2,175,207.35	5,385,943.77	23,043,774.33	428,330,347.91	9,532,963.46	431,541,084.33	396,529.58	0.08
2005-06	2,190,210.08	5,423,091.41	26,853,345.33	477,452,658.81	10,626,234.58	480,685,540.14	434,853.47	0.10
2006-07	2,203,673.06	5,456,426.58	29,707,649.77	531,901,597.53	11,838,055.65	535,154,351.04	476,606.31	0.10
2007-08	2,217,136.05	5,489,761.74	35,506,844.50	594,857,068.08	13,239,198.96	598,129,693.77	524,393.13	0.10
2008-09	2,230,599.04	5,523,096.91	48,731,880.01	658,350,462.00	14,652,314.35	661,642,959.87	570,975.39	0.09
2009-10	2,244,062.03	5,556,432.07	31,788,043.95	705,498,478.95	15,701,645.37	708,810,848.99	601,966.33	0.05
2010-11	2,257,525.01	5,589,767.23	38,797,262.88	785,381,485.03	17,479,529.62	788,713,727.25	659,284.18	0.10
2011-12	2,263,295.79	5,604,056.02	43,864,531.03	857,639,635.76	19,087,714.32	860,980,395.99	708,292.61	0.07
2012-13	2,269,066.57	5,618,344.81	37,626,786.73	908,223,567.70	20,213,515.41	911,572,845.94	737,932.28	0.04

Source: Authors' Calculations.

Table A-7: Reserves of Various Subsoil Assets (Author's Calculations)

Year	Proved Recoverable Reserves of Coal in Million Tonnes	Proved and Indicated Balance Recoverable Reserves of Crude Petroleum in Million Tonnes	Proved and Indicated Balance Recoverable Reserves of Natural Gas in Billion Cubic Meters	Proved Reserves of Bauxite in tonnes	Proved Reserves of Rock Phosphate/Phosphorite in Million tonnes	Proved Reserves of Iron Ore in Million tonnes
1993	68,199.35	1,430.29	1,991.37	493.10	45.00	8,527.50
1994	67,932.57	1,403.26	1,973.04	487.56	43.96	8,467.86
1995	67,655.49	1,371.02	1,953.57	482.65	42.87	8,403.35
1996	67,359.93	1,335.86	1,930.93	477.09	41.56	8,335.93
1997	67,051.21	1,302.96	1,907.67	471.01	40.22	8,267.77
1998	66,730.99	1,269.10	1,881.27	464.90	39.00	8,192.05
1999	66,415.30	1,236.38	1,853.84	458.29	37.73	8,119.82
2000	66,093.13	1,204.43	1,825.40	451.23	36.54	8,042.21
2001	65,756.49	1,172.00	1,795.92	443.24	35.19	7,961.63
2002	65,403.89	1,139.97	1,766.20	434.55	33.95	7,875.40
2003	65,036.60	1,106.92	1,734.82	424.69	32.75	7,776.33
2004	64,647.39	1,073.55	1,702.85	413.76	31.31	7,653.49
2005	64,234.44	1,039.57	1,671.09	401.80	29.59	7,507.55
2006	63,797.17	1,007.38	1,638.89	389.20	27.54	7,342.32
2007	63,335.05	973.39	1,607.14	373.47	25.96	7,154.62
2008	62,843.99	939.27	1,574.72	350.84	24.11	6,941.37
2009	62,318.81	905.76	1,541.87	335.38	22.30	6,728.41
2010	61,752.70	872.07	1,494.37	321.26	20.70	6,509.86
2011	61,182.28	834.39	1,442.15	308.54	18.60	6,302.70
2012	60,600.00	796.30	1,394.59	294.94	16.34	6,134.12

Table A-8: Wealth Estimates of Selected Studies

Year	UNU-IHDP and UNEP (2014) Inclusive wealth in millions of constant 2005 US$	UNU-IHDP and UNEP (2014) Inclusive wealth per capita in millions of constant 2005 US$	World Bank (2011) Wealth Estimates in 2005 US $	World Bank (2011) Wealth Per Capita in 2005 US $
1990	92,87,027.00	10,628.00		
1995	101,95,737.00	10,571.00	68,94,358.64	7,395.95
2000	115,02,578.00	10,914.00	91,70,188.88	9,026.46
2005	129,96,926.00	11,400.00	115,35,972.38	10,539.15
2010	150,88,491.00	12,321.00		

Table A-9: Adjusted Comprehensive Investment

Year	Comprehensive Investment in Million $ at 2004-05 prices (estimated from Lower Limit of Wealth)[28]	Particulate Emission Damage (Constant US Million $) 2004 base	Carbon Damages in Million $	Adjusted Comprehensive Investment in Million $ at 2004-05 Prices
1993-94	-	7,924.99	-	-
1994-95	308,867.84	7,901.87	17,336.68	283,629.29
1995-96	390,483.43	7,939.41	17,676.68	364,867.34
1996-97	447,677.04	7,910.24	18,044.18	421,722.62
1997-98	326,740.80	7,915.43	18,289.18	300,536.19
1998-99	465,126.25	7,897.76	18,244.18	438,984.31
1999-00	550,877.66	7,958.96	18,214.18	524,704.52
2000-01	445,266.67	7,945.09	18,634.18	418,687.40
2001-02	500,756.31	8,102.99	18,357.98	474,295.34
2002-03	371,950.02	8,181.23	18,507.98	345,260.81
2003-04	760,925.82	8,246.77	19,560.48	733,118.57
2004-05	836,494.05	8,252.29	20,480.48	807,761.28
2005-06	1,093,271.11	8,279.48	21,205.48	1,063,786.15
2006-07	1,211,821.08	8,639.68	21,620.99	1,181,560.41
2007-08	1,401,143.31	9,138.64	22,073.49	1,369,931.18
2008-09	1,413,115.38	9,826.17	22,698.49	1,380,590.72
2009-10	1,049,331.03	10,756.36	22,455.99	1,016,118.68
2010-11	1,777,884.25	11,870.58	23,695.99	1,742,317.68
2011-12	1,608,184.70	12,819.57	24,596.97	1,570,768.16
2012-13	1,125,801.10	13,711.60	25,004.47	1,087,085.03

Source: Authors' Calculations

[28] Lower value of comprehensive wealth are more reliable as very dense forests account for only 7-12 per cent of the total forest area over the period 2003 to 2015 (Source: Estimated from State of Forest Reports, Various Issues). Hence, we use the lower value of comprehensive wealth for estimation of rate of growth of comprehensive wealth per capita as well as comprehensive investment.