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Environmental Sustainability and the Account
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Abstract: In order to gauge the sustainability of the economic growth of nations, genuine savings rates are used as a ready comparable measure. Essentially it provides a measure of the sum of the change in various forms of capital, including manufactured, ecological (natural resource and pollution), human and knowledge capital. The depreciation in manufactured and natural capital during the economic growth process is deducted from the conventional national savings to measure genuine wealth. With increasing attention to global warming, the loss due to the increase in stock pollution of carbon emissions has also entered into the accounting exercise. However the damage from local flow and stock pollutants to human capital productivity has not got the same attention. This paper argues that in a developing country like India, where adverse human health impacts are known to be significant from local pollution and defensive expenditure is not forthcoming from the population at large, ignoring human productivity losses introduces a serious upward bias in the genuine wealth and savings measure especially with an increasing trend in emission of hazardous wastes. To this effect, it considers human capital as a function of both education and the stock pollutant in the Hamilton model that further raises the cost of pollutants. The paper suggests that, the depreciation in human capital may be taken as an increasing function of the local pollution generated in the system (following the current logic of using education expenditure as a proxy for enhancement in human capital). The attention to the local pollutants in the genuine wealth and savings measure would help focus developing country government policy on local pollution concurrently with their focus on global pollutants. The paper observes that current development of green accounting system in India is a step in the right direction, since it has attempted to account for health costs of pollution in some of the states.

Environmental Sustainability and the Account of Genuine Wealth in India

***Aparna Sawhney*[1]**

1. Introduction

Sustainable development is broadly understood as development that meets the needs of the present without compromising the ability of the future generations to meet their own needs. In economic growth literature it is interpreted as a condition where the present path of economic growth allows future generations to have economic opportunities at least as large as that of the present generation in the form of capacity to produce and consume. The efficiency in the transmission of productive capacity across time is intrinsically linked to intergenerational equity aspect. Sustainability of economic growth thus encompasses both dynamic efficiency as well as intergenerational equity (assuming that intra-generational equity is taken care of within each time period), where the economy moves along a Pareto frontier consumption path such that the discounted stream of intergenerational welfare is non-decreasing over time (Stavins et al, 2003).

The capacity to produce and consume goods and services depends on forms of productive capital - natural and anthropogenic capital assets of the economy, namely, ecological, manufactured and intellectual capital; with the help of enabling capital of institutions and social norms. Natural/ ecological capital pertains to the biosphere that support all life forms, so natural capital includes air, water, soil, minerals, fuel, habitat and biological diversity. Manufactured capital consists of machines and infrastructures, while intellectual capital includes human skills, knowledge and technology –together these different forms of capital build on natural capital.[2] The measure of sustainability of an economy is then reduced to accounting for the capital bequeathed each period for future consumption.

Genuine saving is one of the most widely used measures that is estimated from traditional net savings less of the value of resource depletion and environmental degradation plus the value of investment in human capital. Considering sustainability as a non-declining welfare path, allows for exhaustible natural capital/ resources to be transformed into man-made reproducible capital or productive capacity as an intergenerational transfer (Solow 1986).[3]

Economic growth models and associated estimates of genuine savings thus inherently assume the substitutability between different forms of capital in the production function, as well as

[1] I would like to thank in particular Professor Ramprasad Sengupta, Dr. Purnamita Dasgupta, Dr Mausumi Das for their comments and observations from other participants at the CIGI-JNU-NIPFP conference on *Economic Theory, Markets and Institutions for Governance*, New Delhi, 22-24 March, 2010; and CITD seminar 23-24 April 2010.

[2] The institutional capital, including markets, regulations, and government policies, plays a critical role in determining the returns to capital and hence their rate of investment or disinvestment. Finally, social capital including norms guiding the behaviour of people determines the final demand and pattern of use of the different forms of capital.

[3] The Hartwick rule requires investment of all rents from exhaustible resources in reproducible capital for sustainability (Hartwick 1977).

substitutability between natural resource services and anthropogenic goods/ services in consumption.[4] Essentially in the process of economic growth, natural capital typically decreases while the other forms of capital increase. Accordingly, Pearce et al (1989) defined two sustainability criteria on the maintenance of the capital assets: *weak* and *strong* sustainability. Weak sustainability requires the aggregate wealth of the three heterogeneous capital assets be maintained for future generations; while strong sustainability requires that the stock of critical natural capital be maintained since certain natural resources are non-substitutable. For example, ecological services flowing from natural resources, including biodiversity, water cycle, climate change, etc, are irreplaceable, and cannot be substituted with other forms of anthropogenic capital.

The genuine savings would be non-negative so long as investment in produced assets and human capital is greater than the value of natural resources depletion and of pollution accumulation. It is important note however that negative genuine savings imply decline in future utility, however the reverse is not always true since positive genuine savings does not ensure all future utility is non-declining (Pezzey 2004).

An important source of high growth in India is found in the output growth per worker: during 1993-2004 output per worker grew at about 4.6% per annum compared to 2.4% during 1978-93 (Bosworth and Collins 2008). The labour productivity increased remarkably in the industrial and services sectors, compared to the agricultural sector. The growth in output per worker is estimated to have been driven by higher physical and education capital per worker, and more significantly higher total factor productivity (the residual productivity of the Solow growth model, after taking into account physical capital's contribution to productivity increase). I.e. while both manufactured and intellectual capital per worker increased, their contribution to growth of output per worker was less than that contributable to sheer increase in factor productivity.

However, as Sawhney (2009) observed that the enhanced industrial growth in India during 1980-2006, has been dominated by the performance of selected industries (including textiles, basic chemicals, pharmaceuticals, electronics and information technology, etc) some of which are highly polluting.[5] For instance, among the fastest growing service-oriented sectors in India, in recent years, is the electronics and information technology hardware industry The remarkable growth of this industry has been driven by software services, communication services, entertainment services, household consumer appliances, etc., which are responsible for the fastest stream of hazardous e-waste, including personal computers, mobile handsets, audio video devices, printers, scanners, and the like. Electronic waste consists of heavy metals and toxins such as lead, cadmium, beryllium, brominated flame retardants, which are generated both at the production stage and at the end of the life of the equipments. The improper disposal of e-waste in landfills or incineration leads to extensive dispersion of toxins in land, groundwater through

[4] While the utility function in some growth models may differentiate between the consumption of anthropogenic goods/ services and natural environmental services – in Hamilton, Pezzey, etc (as opposed to consumption of a homogenous good), the underlying substitutability remains. Economists, however, do acknowledge that such consumption substitutability may not be feasible in case of direct consumption of certain environmental resources like pristine forest, natural beauty, etc.

[5] The Central Pollution Control Board classifies these industries among others (metals, fertilizer, pesticide, petrochemicals, etc) under the "red category" of pollution-intensive activities.

leaching, and air.[6] Thus the impetus to growth from the industrial sector in the past three decades has continued to come from severely polluting segments, and whose environmental costs are not reflected in our growth accounts due to incomplete markets and lack of information among the population.[7]

An early exercise to gauge the environmental cost on human health in India, measured in terms of mortality and morbidity rates, had indicated that health cost from water pollution was in the range of US$ 3076-8344 billion (World Bank 1995). The estimation of health production functions across Indian cities and villages due to water borne diseases, air pollution etc. have pointed out that health impacts are indeed significant. Thus when the working population is considered to be a form of capital, just the way we account for appreciation in human capital due following education and experience, any depreciation in this form of capital due to environmental degradation also ought to be accounted for in the true wealth estimation of the nation.

The rest of the paper is organized as follows: Section 2 provides a brief on the concept of genuine wealth and savings as an index of sustainability, and the World Bank's estimates based on the Solow-Hamilton model. Section 3 highlights the special features of developing countries as distinct from developed countries, and outlines the significance of defining human capital as a function of pollution for a developing country, followed by an augmented Hamilton model with such a function. Section 4 comments on the measure of genuine saving that incorporate adverse environmental health impact and the current green accounting exercise in India. Section 5 concludes.

2. The criterion of non-declining intertemporal social welfare and measurement of genuine wealth and savings

The criterion for sustainability of an economy typically used in the growth models is that of non-declining total welfare path. This conditionality allows for appropriate intergenerational transfers over time - analogous to potential Pareto improvements - to achieve sustainability according to the definition. Defining sustainability as a non-declining welfare path, allows for exhaustible natural capital/ resources to be transformed into man-made reproducible capital or productive capacity as an intergenerational transfer (Solow 1986).

The distinction between consumption of economic goods and direct consumption of environmental amenities features in the Hamilton model (2000 and 2003) that has been used in recent measurement approach to sustainability of economic growth. In maximizing the

[6] The waste from electrical and electronic waste in India is estimated to be about 0.15 million tonnes per year. The recycling of e-wastes for the extraction of valuable metals (like copper, gold, lead, mercury, etc) is also hazardous when done in the improper facilities – as mostly done in the informal sector in India. The low cost of recycling in the country has also led to illegal importing of e-waste into India, particularly after the implementation of stringent regulations on producer responsibility of e-waste in the Europe Union and United States. (Toxics Link 2007).

[7] The most stark example of this is to be found in the national capital city of New Delhi, where following inadvertent exposure of some workers to radioactive wastes in the scrap market, cordoning off and closure of the entire Mayapuri scrap market, some daily wage workers were concerned for the loss in wages. The scrap dealers too were completely unaware of the risk and harm from the unmarked scrap material. "They deal in crores, but live off scrap", by Vijaita Singh, *Hindustan Times,* 9th April 2010.

discounted stream of intergenerational utility at every time period, subject to various constraints, the sustainability condition in the Hamilton model is reduced to non-negative *genuine saving* or investment at every time period.[8]

The genuine wealth of a nation is measured through the valuation of the different asset components of manufactured capital, natural resources, and human capital. While valuation of physical capital is relatively easy through market prices, natural resource valuation is challenging since natural assets are often under-priced in the market, and Hotelling rent imputations have typically been used. Similarly, in the real world, pollution levels are typically more than the

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[8] Utility of consumers is considered to be a function of consumption of the produced composite good (C), and environmental services (B), in a model with constant population. Based on the Solow model, the economy is assumed to produce a homogeneous good that may be either consumed (C) or invested as capital (K). The economic goal is to maximize the discounted stream of intergenerational utility (U) subject to the various constraints including production, capital accumulation, natural resource stock, and environmental pollution. Utility of consumers is considered to be a function of consumption of the produced composite good (C), and environmental services (B). The intertemporal optimization problem for the planner is to maximize the discounted stream of welfare at every point in time:

$$MaxV_t = \int_t^{\infty} U[C(\tau), B(\tau)]e^{-r(\tau-t)}d\tau$$

$$s.t.$$

$$\dot{K} = F - C - a - m;$$

$$\dot{X} = e(F, a) - d;$$

$$\dot{S} = -R + g;$$

$$\dot{N} = q(m)$$

Where the first constraint shows that the production of the composite good (*F*) at any point in time is invested in manufactured capital (*K*), consumed (*C*), used in pollution abatement (*a*) and invested in education (*m*). Pollution, which is determined by production and abatement at every period, accumulates as a stock to the extent that it is not naturally dissipated. Thus the second constraint gives the change in pollution stock (*X*) as equal to total emissions (*e*) less of the natural dissipation (*d*). The flow of environmental services (*B* in the utility function), is negatively related to this stock of pollution. The third constraint indicates that growth in natural resource (*S*) is equal to its natural growth rate (*g*) less of the extraction (*R*). The last constraint represents the change in human capital (*N*) as an increasing function (*q*) of education expenditure (*m*).
Using the sustainability criterion of non-declining intergenerational welfare V at any point in time, is equivalent to genuine saving being non-negative at any period

$$\dot{V} = U_C G = rV - U \geq 0$$

The genuine saving G is equal to investment in manufactured capital $\dot{K}$, plus change in real value of environmental resources (change in stock *R* – *g*, valued at resource rental rate F_R net of the effective pollution tax be_F), plus change in pollution accumulation *e-d* valued at the marginal damage of pollution *b*, plus change in human capital *q* times the marginal cost of creating a unit of human capital *1/q´*.

$$G = \dot{K} - (1 - be_F)F_R(R - g) - b(e - d) + \frac{q}{q'}$$

It may be noted here, that the above optimization exercise (maximization of the intertemporal social welfare flow subject to the constraints on various capital forms) neither implies sustainability as defined by the criterion of non-declining welfare, nor does sustainability imply maximization of intertemporal social welfare (Arrow et al 2004). The exercise, however, does help to indicate the optimal prices of the various capital forms and their time path.

optimal levels and the associated marginal abatement cost are lower than the marginal damage cost from pollution – hence use of marginal abatement costs to value depreciation would be biased downwards (valuation of pollutants thus need marginal damage costs). The human capital has typically been measured through education expenditure (or adjustments thereof), and knowledge / technological improvements have been often proxied through factor productivity improvements (Arrow et al 2004).

Genuine saving is estimated from traditional net savings less of the value of resource depletion and environmental degradation plus the value of investment in human capital. In order to estimate genuine savings rate of various countries, the standard approach currently followed by the World Bank (Hamilton model) has been to obtain the traditional savings from the national accounts, which are then adjusted for manufactured capital disinvestment, intellectual investment and natural capital use and depreciation. Four types of adjustments are made: deduction of capital consumption to obtain net national savings rate; addition of current education expenditure in lieu of human capital investment; deduction of natural resource depletion (imputed values of selected minerals, based on estimated resource rents); and pollution damage from atmospheric particulate matter and global warming.

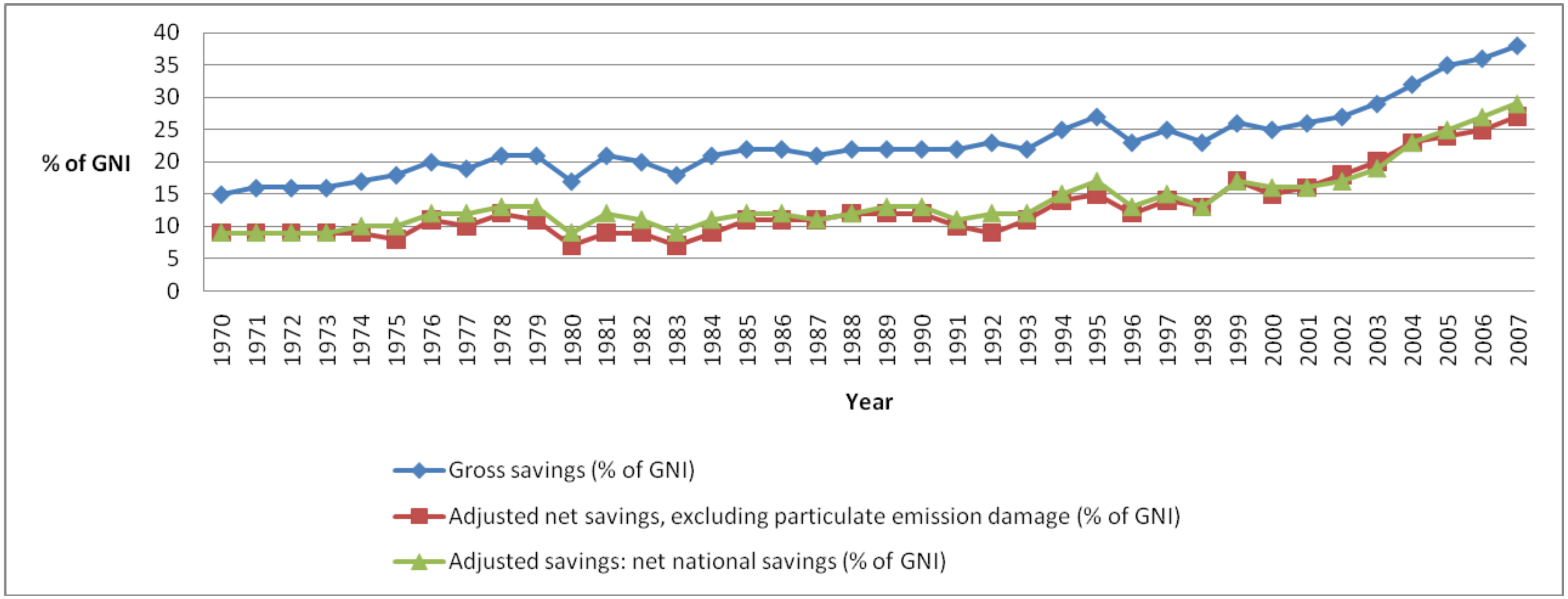
2.1 The World Bank estimates of genuine savings for India

Following the Hamilton model, the World Bank has generated a time series on genuine savings as well as point wealth estimates for most countries. Starting with the national accounts data, adjustments are made to the national savings rate for deforestation, energy depletion, damage from particulate pollution and global warming and enhancement in human capital (public expenditure on education). The genuine savings or investment rate as a proportion of gross national income in India has been estimated to be steadily increasing in the period 1970 through 2007. During the 1970s and 1980s, the rate was between 9-12%, and rose to 11-17% in the 1990s, and since has rapidly increased to 29% in 2007 (see figure below).

By definition, genuine saving is given as

$$GS = \frac{GDS - D - \sum_i S_i - CO_2 damage - PM_{10} damage + Educn.}{GNI}$$

where GDS is the gross domestic savings of a country, D is the standard depreciation of capital, S_i is the extraction of natural resources, CO_2 damage is the damage from carbon dioxide emissions, PM_{10} damage is the damage from respirable particulate matter, Educn is the current expenditure on education to signify the investment in human capital, and GNI is the gross national income.



Genuine Savings of India, 1970-2007

Source: World Bank time series:
http://web.worldbank.org/WBSITE/EXTERNAL/TOPICS/ENVIRONMENT/EXTDATASTA/0,,contentMDK:21061847~menuPK:2935543~pagePK:64168445~piPK:64168309~theSitePK:2875751,00.html

2.2 Other estimates of genuine savings for India

Arrow et al (2004), following a similar methodology, estimated the annual average genuine investment rate of 9.47% for India during the period of 1970 through 2001, which was close to the World Bank estimate. However, as the authors observed, these estimates of genuine savings tend to overstate the savings/ investment in productive capacity since several natural resources cannot be included due to absence of environmental data like carbon sequestration, pollution, biodiversity, etc; and the valuation of natural assets through market prices. The estimate of 9.5% of genuine investment for India over the 30-year period is also misleading since it does not reflect the change in per capita terms, especially since population increased significantly during the period. When Arrow et al (2004) adjusted for population growth, the wealth per capita in India was found to have *declined* during the 1970-2001 at an annual average rate of 0.57% , i.e. growth was not sustainable during the three decades.[9] Since factor productivity is considered to have increased in India during the same time, Arrow et al made another adjustment in terms of technological improvement or enhanced factor productivity changed the estimate further. The rate of dissavings per capita due to population growth was found to be more than offset by the projected increase in factor productivity such that per capita wealth was estimated to have grown at 0.54% in India during 1970-2001.

Among the recent estimate of genuine savings for India, Dasgupta and Gupta (2008) augmented the human capital valuation by including both public and private spending education and weighing it with the social return to schooling. Moreover, valuing natural capital depletion (wood, five minerals, and two fossil fuels) with marginal Hotelling rents (instead of average rents), their genuine investment estimates for India are higher than that of World Bank as well as Arrow et al (2004), due to the enhanced estimates of intellectual investment. Kumar (2008) has also re-estimated genuine savings by incorporating certain damages from environmental degradation of soil and water (besides air as done in the other studies). The exercise shows that the cost of soil degradation in India is strong enough to reverse the genuine wealth estimates obtained in the other studies: re-calibrated growth rate of genuine wealth per capita was found to be negative during the period 1970 through 1983, and positive since the mid-eighties (biodiversity losses, among several other natural resources/ services, not been accounted for in the study).

Evidently that the empirics of genuine savings and wealth per capita are less optimistic as economists incorporate the environmental damage costs in the estimation of natural capital valuation. Considering the lack of data coverage on the status of several environmental resources, estimated genuine savings are obviously overstated. For instance, if due to an increase in acid rain, the cars in the country are subjected to more corrosion and need to be replaced more rapidly, this is also depreciation which should be included but are currently not included (Sterner 2003, World Bank 1997).

[9] Arrow et al (2004) observe that since developing countries suffer from low level of consumption, greater investment could cause misery by reducing consumption per capita in the present. Since poverty alleviation of the present generation is a foremost goal, there arises a conflict between saving for tomorrow versus consuming more today given the abysmally low consumption in some of the poorer developing countries.

In particular with regard to the impact of growth induced environmental degradation on human capital, accounting exercises have left it while acknowledging its significance, due to difficulty to isolate its measurement. For example, Dasgupta and Gupta (2008) when measuring the enhancement of human capital through education acknowledge that “there are strong complementarities between primary health care, nutrition and education expenses for children. However measuring net investment in health or nutrition is problematic since it is difficult to isolate what part of total expenditure is for maintaining the stock of human capital and is therefore not new investment. We therefore leave out health human capital from our model for the present and concentrate instead on educational human capital.”

Yet, it is hard to ignore the increasing burden of local pollution on human health and productivity in the measure of genuine wealth and savings of a nation in the face of rising evidence of morbidity and mortality in developing countries. A recent OECD report (OECD 2008) reiterated the WHO finding that that in non-OECD countries, 1.7 million deaths and 4.4% of the burden of disease (e.g. reduced years of healthy life) have been attributed to unsafe water supply, sanitation and hygiene. The salination of groundwater affects agricultural productivity on 22 million ha of land, particularly in China, India, Pakistan, and the cost of inaction in developing countries from salination and resource exhaustion are significant (for example, 0.3% of annual GDP in China).

2.3 Other measures gauging environmental costs of India’s growth

It is interesting to note that while the genuine savings rate for India have been estimated to be positive and growing through the years, increase from about 9% in 1970 to about 29% in 2007, due to the substitution of natural capital with manufactured/ human and technological capital, it has been a cause of alarm for ecological economists who strongly recognize the restrictions on the non-substitutability of natural capital (especially those providing ecological services of the water cycle, etc) with the latter forms of capital.

In contrast to the enumeration of wealth or investment in terms of manufactured capital as done above, the focus is on natural capital accounting, like bio-capacity and land. So considering the economic cost of an economy in terms of equivalent land area, ecological footprint estimates indicate how much land is required by a nation to support its current consumption. Given the bio-capacity, any difference between the capacity and consumption costs indicates a surplus (or deficit) for the economy. The table below gives a glimpse of the ecological costs of India’s average per capita consumption in terms of land as opposed to the available per capita bio-capacity. It indicates that while the per capita footprint has fallen in recent years compared to the decade of the sixties (due to greater efficiency/ productivity, etc), the bio-capacity available per capita has reduced due to population growth, and thus the ecological deficit has been mounting through the years.

Per Capita Ecological Footprint Estimates for India (*global hectares per capita)*, 1960-2006

Year	*Ecological footprint of consumption*	*Bio-capacity*	*Ecological deficit*
1960-69	0.85	0.72	- 0.13
2003	0.75	0.39	- 0.36
2006	0.77	0.37	- 0.40

Source: GFN-CII (2008) and *National Footprint Accounts 2009* edition: November 25, 2009

The concept of ecological footprint highlights the constraint associated with natural capital, and importance of threshold levels of ecological capital base to prevent a collapse of the entire economic system (since humanity's consumption cannot run a deficit on global ecological system in perpetuity even if trade allows for a nation to run an ecological deficit beyond its sovereign borders). However, the impact of environmentally-costly consumption on human capital is not directly reflected in the footprint measure, and to the extent present generation is myopic it may pay little attention to the increasing deficit bequeathed to future generations. Direct losses to current generation human capital in such a case would move the society to a more environmentally benign consumption path.

3. Special features of developing countries and non-monetized adverse health effects

The estimation exercise of genuine savings assumes that the adverse impact of pollution on health to be reflected through medical and defensive expenditure made in the market. Indeed Hamilton (1996) model[10] with defensive expenditure demonstrated that, defensive expenditure does not need to be subtracted out from the genuine wealth computation to avoid double counting; while for local stock pollutants which impact consumers directly the adjustment will be reflected in the genuine wealth computation through the consumers' monetized value of environmental services. As Hamilton (1996) noted, the latter is an "adjustment to utility" and does not reflect market production, and in effect is the consumers' monetized valuation of the level of environmental quality. It is important to note here that incurred pollution abatement expenditure and defensive expenditure (for local pollutants) would be taken care of in the savings data from developed countries, but for developing countries to the extent it is not incurred, these would not feature in the accounts.

The approach of valuing environmental services directly in the welfare function is appealing in case of well-informed consumers and where markets are complete and efficient. It, however, does not fit the situation existing in developing countries where information and markets are incomplete. Consequently the defensive expenditure would be negligible, and incurred medical expenditure to after the incidence of diseases would fail to enumerate the adverse impact on human health and productivity.

A market oriented phenomenon of defensive expenditure is critically dependent on the level of information and education of consumers. Indeed, recent literature in India indicates that the lack of awareness about adverse health effects from environmental pollution is a significant factor in explaining the low demand for home water-purification in urban India (Jalan et al 2009).[11] In the face of incomplete information of the population on the pollution health hazards in developing

[10] Hamilton (1996) provided a set of alternative models wherein stock pollutants, defensive expenditure, carbon emissions, etc were individually incorporated in the optimization exercise, which provided accounting lessons for measuring welfare. Here the reference is to the one incorporating defensive expenditure.

[11] The low demand for environmental quality in developing countries is widely presumed to be due to low income and high incidence of poverty, however, information plays a significant role in perpetuating the low demand for environmental quality. Jalan, Jyotsna, E. Somanathan and Saraswata Chaudhuri (2009) "Awareness and demand for environmental quality: survey evidence on drinking water in urban India", *Environment and Development Economics*, Volume (14): 665-92.

countries, a human capital depreciation function seems more appealing compared to the direct demand for environmental quality/ defensive expenditure.

It is also noteworthy that the damages from local pollution (like PM_{10}) as included in the genuine savings measure at present is insufficient and ignores direct harm to human capital from other hazardous local stock and flow pollutants, especially given the lack of pollution treatment and disposal capital infrastructure for sewage and industrial waste-water. Indeed the human capital erosion from local pollution prevalent in developing countries is the fallout of the deficiency in environmental services infrastructure (part of the physical infrastructure or manufactured capital in the assorted capital portfolio valued as genuine wealth).

In developing countries, during the transformation process of one capital form into another, especially of natural capital (providing ecological/ environmental services) towards manufactured/ infrastructural capital, there is a major gap in physical infrastructure which provides basic environmental services of hygiene, sanitation, water treatment, waste treatment, etc. Consequently, the incidence of diarrhoeal diseases, respiratory infections, tuberculosis, etc, continue to be high in developing country. The incidence of these local-pollution induced diseases is high even in the working-age group of the human capital (apart from infants and children), for which education expenditure is counted as human capital enhancement. For example, the estimated disability adjusted life years (DALY) for three selected parasitic diseases, among persons aged 15-59 years, in five countries are highlighted below.[12] The distinct profiles of the burden of the three preventable respiratory and water-borne diseases for developed countries of Japan and US versus that of emerging countries of Brazil, China and India, reflects the underlying structural difference of manufactured environmental infrastructure (with severe deficiencies in access to clean water and sanitation).

Estimated DALY ('000) for Age Group 15-59 years in selected parasitic diseases, 2004

Disease	*Brazil*	*China*	*India*	*Japan*	*US*
Tuberculosis	204	2,676	6,177	13	6
Diarrhoeal diseases	90	1,257	848	16	40
Malaria	17	12	225	-	0

Source WHO (2009)

3.1 Incorporating decay of human capital from stock pollutant in present value maximization criterion

In developing countries, a human capital depreciation function seems more appealing compared to the direct demand for environmental quality or even defensive expenditure. The high incidence of preventable respiratory diseases, water-borne diseases, etc. in developing countries like India is an indication of high morbidity and associated loss of human capital productivity. However, none of the models so far provide an adjustment for the depreciation in human health capital due to environmental degradation the way one does for the other forms of capital.

[12] DALY is a widely used summary measure of burden of diseases, incorporating both mortality and morbidity, in terms of number of healthy years lost. Thus 1 DALY signifies the loss of one year of healthy life. Based on data from: http://www.who.int/healthinfo/global_burden_disease/estimates_country/en/index.html

Here we augment the Solow-Hamilton model to incorporate the adverse effects of a stock pollutant on the natural resource as well as the human capital. In the augmented model the shadow cost of the stock pollutant increases, and more importantly in the accounting exercise the change in human capital needs to reflect the impact of stock pollution besides that of productivity enhancing education.

Utility of consumers is considered to be a function of consumption of the produced composite good (C), in a model. Based on the Solow model, the economy is assumed to produce a homogeneous good that may be either consumed (C) or invested as capital (K). The economic goal is to maximize the discounted stream of intergenerational utility (U) subject to the various constraints including production, capital accumulation, natural resource stock *S*, environmental pollution *X*, and human capital *N*. The control variables are *C*, consumption; *R*, resource extraction; *a*, pollution abatement; and *m*, education.

F is the composite output production function of the forms *F(K, R,N)* where R is the rate at which the natural resource is costlessly extracted. Emissions *e* is a function of production *F* (with $e_F>0$) and abatement *a* ($e_a<0$). Emissions at each period add to the stock pollution *X*, and the latter adversely affects human capital investment captured through $q_X < 0$. The natural resource stock *S*, like ground water, soil, etc, is also adversely affected through a increasing decay function of emissions $\delta(e)$. Apart from the stock pollution, the change in human capital stock, *q* is a function of education *m* ($q_m>0$).

Consider the intertemporal optimization problem:

$$Max\ V = \int_0^\infty U(C)e^{-rt}\,dt$$

subject to

$$\dot{K} = F(K,R,N) - C - a - m$$

$$\dot{S} = -R - \delta(e)$$

$$\dot{X} = e(F,a)$$

$$\dot{N} = q(m,X);\ \ where\ q_m > 0\ and\ q_X < 0$$

The corresponding current value Hamiltonian is obtained as:

$$H = U + \mu_k\{F(K,R,N) - C - a - m\} + \mu_s\{-R - \delta(e)\} + \mu_X\{e(F,a)\} + \mu_N\{q(m,X)\}$$

The first order conditions with respect to the control variables give:

$$\frac{\partial H}{\partial C} = U_c - \mu_k = 0 \qquad (1)$$

$$\frac{\partial H}{\partial R} = \mu_k F_R - \mu_s - \mu_s \delta' e_F F_R + \mu_X e_F F_R = 0 \tag{2}$$

$$\frac{\partial H}{\partial a} = -\mu_k - \mu_s \delta' e_a + \mu_X e_a = 0 \tag{3}$$

$$\frac{\partial H}{\partial m} = -\mu_k - \mu_N q_m = 0 \tag{4}$$

This gives:

$$\mu_k = U_c$$

$$\mu_s = U_c F_R \left(1 + \frac{e_F}{e_a}\right)$$

$$\mu_X = \frac{U_c}{e_a}(1 + \delta' F_R \{e_a + e_F\})$$

$$\mu_N = \frac{U_c}{q_m}$$

The shadow prices of capital, natural resource and human capital in terms of marginal utility of consumption remain the same as in the Hamilton (2003), and only the shadow price of the stock pollutant, μ_X is enhanced with an extra component $\frac{U_c \delta' F_R}{e_a}(e_a + e_F)$. This component increases the absolute magnitude of μ_X i.e. shadow cost of the stock pollutant increases by the value of the marginal decay of natural resources times the shadow value of the natural resource.
The first order conditions with respect to the stock variables are:

$$\frac{\partial H}{\partial K} = \mu_k F_K - \mu_s \delta' e_F F_K + \mu_X e_F F_K = r\mu_k - \dot{\mu_k}$$

Using equation 3 and substituting the value of μ_s, this gives

$$\frac{\dot{\mu_K}}{\mu_K} = r - F_K \left(1 + \frac{e_F}{e_a}\right) \tag{5}$$

$$\frac{\partial H}{\partial S} = 0 = r\mu_S - \dot{\mu_S}$$

$$\frac{\dot{\mu_S}}{\mu_S} = r \tag{6}$$

$$\frac{\partial H}{\partial X} = \mu_N q_X = r\mu_X - \dot{\mu_X}$$

$$\frac{\dot{\mu}_X}{\mu_X} = r - \frac{\mu_N q_X}{\mu_X} \tag{7}$$

$$\frac{\partial H}{\partial N} = 0 = r\mu_N - \dot{\mu}_N$$

$$\frac{\dot{\mu}_N}{\mu_N} = r \tag{8}$$

The above conditions give the same time paths of the stock prices (shadow values) as in the Hamilton (2003) model, except for the rates of change in the price of manufactured capital and stock pollutant. Here the rates have, since here more manufactured capital is used to compensate for the decay of natural capital, and cost of stock pollutant is also increasing more due to the adverse impact on human capital.

The genuine saving or investment here can be represented as:

$$G = \dot{K} + \frac{\mu_s}{\mu_K}\dot{S} + \frac{\mu_X}{\mu_K}\dot{X} + \frac{\mu_N}{\mu_K}\dot{N}$$

$$= Y - C - a - m - F_R\left(1 + \frac{\varepsilon_F}{\varepsilon_a}\right)(R + \delta) + e\left[\frac{1}{\varepsilon_a} + \delta' F_R\left(1 + \frac{\varepsilon_F}{\varepsilon_a}\right)\right] + \frac{q}{q_m} \tag{10}$$

Now the last term of human capital component of genuine savings *q* is a positive function of the education expenditure and a negative function of the stock pollutant. Thus is an accounting exercise needs to use both variables to impute the value of *q*, and not just education expenditure *m*. For simplicity if q has a linear form $\alpha(m) + \beta(X)$, where $\alpha' > 0$ and $\beta' < 0$, then *q* would be less than the computed values currently used with the proxy of education expenditure.

To incorporate the effect of technology and the associated impact on overall factor productivity, Arrow et al (2004) had an additional term in accounting equation of genuine investment or incremental social welfare expressed in terms of the value of one type of capital (here $p_K K$ as opposed to just the shadow value of the capital K as done 10 above), so that expression 10 gets modified to read as:

$$\frac{\dot{V}}{p_K K} = G = \frac{1}{K}\dot{K} + \frac{p_s S}{p_K K}\dot{S} + \frac{p_X X}{p_K K}\dot{X} + \frac{p_N N}{p_K K}\dot{N} + \frac{\gamma}{\alpha^*} \tag{10'}$$

where γ is the growth rate of total factor productivity and $\alpha^*$is the elasticity of output with respect to capital. Note that the prices of various forms of capital are the shadow values μ of each of the associated capital forms. So the middle terms in the expression are the rates of change in the capital $(\dot{S}, \dot{X}, \dot{N})$ multiplied by the elasticity of manufactured capital with respect to the corresponding capital form.

So here the growth in overall factor productivity due to technology would raise the genuine saving/ investment, but depreciation in human capital due to pollution would depress the estimate. It of course remains an accounting exercise to impute this cost, but it is important not to ignore it, especially in developing countries for reasons invoked earlier.

3.2 Incorporating adverse environmental health impact in national accounting

Incurred pollution abatement expenditure and defensive expenditure (for local pollutants) are taken care of in the savings data for developed countries, but for developing countries to the extent it is not incurred, these would not feature in the accounts. The model in the previous section demonstrates that non-internalized or, non-accounted damage costs would feedback into the system through the adverse health impact on human capital, which in turn affects national income.

The current WB valuation of damages from local pollution like PM10 is insufficient and ignores direct harm to human capital from other hazardous local pollutants, given the lack of pollution treatment and disposal capital infrastructure. The national accounting system should incorporate the erosion of the human capital in the true valuation of national wealth. This may be done in either of the following simple manner:

(i) Since the adverse health effects of pollution in developing countries emanate from the severe under-capacity in environmental services infrastructure in their manufactured capital, one way to incorporate this in the measure of genuine wealth (and hence genuine savings/ investment) is to give weight to the proportion of population having access to improved water and sanitation across the different countries. This is crude but easy since the latter data is annually published by the World Bank.

(ii) Alternatively, the widely used measure of burden of preventable (i.e. requiring defensive expenditure) diseases like DALY for selected local pollution-induced diseases among working-age population, for all countries can be appropriately weighed to provide a more accurate measure of human capital in each country.

The above rough and ready approach is simple enough to be extended for all countries since data-series on infrastructure as well as DALY are available readily. A more accurate means of gauging true ecological wealth and income of a country would need to reflect the state of underlying natural resources and flow of ecological services. The above methods offer quick means of gauging the value of portfolio national assets including human capital.

Green accounting is another alternative national accounting system, which allows for representing the true income-consumption growth net of all the depreciation and leakages of the economic system. In a bid to estimate the overall environmental damage, the Indian Ministry of Statistics launched a programme on Natural Resource Accounting. The exercise has begun for various states, covering depreciation in natural capita, especially forests, water quality, fisheries, coastal ecosystem, etc along with human health costs (for West Bengal, Goa, Karnataka, etc). For instance, heavy metal contamination of drinking water (like arsenic in West Bengal) can cause bladder, lung, kidney, liver and skin cancer, and also affect the central nervous system. Similarly, contamination of waterways with pesticides and fertilizers can be quite significant, although accounting for the actual human health cost remains a challenge (due to lack of data on the extent of contamination, Gudimeda 2008).

4. Concluding Remarks

Adverse health impact from poor environmental condition of a country would be reflected in its national accounts through the healthcare expenditure. Thus, to the extent health expenditure is made to maintain human capital, it does not need to be deducted out of the national accounts. Such a market oriented phenomenon of defensive expenditure, however, is critically dependent on the level of information and education of consumers. A consumer valuation-oriented approach is not appealing for developing countries like India since consumer willingness to pay for environmental services is not evident. Instead, for India (and developing countries in general), a human capital depreciation function seems more appealing compared to the direct demand for environmental quality/ defensive expenditure

The measurement of genuine wealth of nations today incorporates the adverse effect of carbon emissions (valued at $20 per tonne of carbon dioxide by the World Bank, which according to some economists is rather low), besides the depreciation of non-renewable resources. While the literature does recognize that under-pricing (distorted market prices) of natural resources can lead to incorrect positive genuine wealth and investment estimation, which gives a false indication of the measure of sustainability, less attention has been paid to the valuation of human capital investment and depreciation. Attention to the latter is critically important for developing countries especially at a time when national action policies are being implemented to address the global pollution externalities.

The paper here argued that since working population is considered as a form of capital, just the way we account for appreciation in human capital through education, any depreciation in this form of capital due to environmental degradation also ought to be accounted for in the true wealth estimation of the nation.

An attempt to enumerate human capital depreciation due to local flow and stock pollution, the latter seen to be increasing rapidly with the emerging structure of manufacturing and consumption streams, apart from depreciation of natural resource stock in a developing country like India, would help to focus attention and policy towards imminent local pollution problems. The purpose of the augmented Hamilton-model here was to draw attention to exactly this aspect. The estimations of exact social cost of such pollution emissions are rather challenging, as evident from the recent attempts in green accounting for Indian states, but it will help to bring attention to the issue by putting a monetized dollar value (the way it has been done for a greenhouse gas) and signify the special feature of developing countries. To the extent the current exercise in green accounting has attempted to estimate the health costs of pollution, it promises to provide a more realistic assessment of our genuine national wealth.

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