Green National Accounts in India
A Framework

A Report by an Expert Group Convened
by the National Statistical Organization
Ministry of Statistics and Programme Implementation
Government of India

March 2013

Contents

Preface

This Report - on Green National Accounting for India - was commissioned by the Government of India under the direction of the Prime Minister. I was approached by Minister Jairam Ramesh, then at the Ministry of Environment and Forests, to Chair an Expert Group he was in the process of assembling with a mandate to produce the Report. The Expert Group was constituted on August 4, 2011. The Group met in New Delhi on three occasions (23 August 2011, 16-17 April 2012, and 6-7 December 2012), but from the beginning Members have maintained regular correspondence. The *Report's* form and structure evolved as we discussed the underlying issues; indeed a number of the technical appendices grew from a written response to a simple query, through many revisions and expansions, into their final shape. And in one case a chapter was formed and included on the basis of a Member's brief observations over a practical matter. In order to make the Report self-contained, we have developed the theoretical arguments both informally and by the aid of formal models.The text has been written in as non- technical a manner as is possible without obfuscating the analysis. The technical arguments that accompany the text are provided in the Appendices.It perhaps helped that Members of the Group have known one another for some time; if not personally, certainly by reputation, but it is a pleasure to record that our meetings and correspondences have invariably been conducted with intellectual curiosity and zest, and in good humour.

For our second meeting we invited a number of relevant organizations to make presentations. They included the Indian Council of Agricultural Research, the Forest Survey of India, the Central Pollution Control Board, the Ministry of Earth Sciences, the Geological Survey of India, the Indian Bureau of Mines, the Central Water Commission, the Botanical and Zoological Survey of India, and the Social Statistics Division of CSO. In addition, Professor Janakarajan and Dr. Manoj Panda made presentations in their personal capacity. The Ministry of Environment and Forests also participated in all the meetings and the Group had the benefit of their contribution. I am grateful to the officers and staff of the Central Statistics Office, in particular Mr. S.K. Das, Smt. S. Jeyalakshmi, Mr. Ashish Kumar, Dr. N. Eagambaram, Mr. James Mathew, Mr. S. Suresh Kumar, and P. Sai Manohar, who had been associated with the work of this Report.

Throughout, our Group has had the benefit of guidance from Mr. V. Parameswaran, Deputy Director General of the CSO. For nearly two years now, he and I have maintained a regular and frequent correspondence (sometimes three-to-four e-mails a day) not only over the shaping of our *Report*, but also on such practical matters as creating the Agenda for our meetings. He agreed to prepare a chapter describing India's system of national accounts (Chapter 3) against whose backdrop we were develop our recommendations, and he agreed too to prepare the final set of recommendations (Chapter 6). This Report could not have been prepared but for his engagement.

For me personally, involvement with the *Report* has been revelatory. I am an economic theorist by training and inclination and have led a most sheltered life in academia. So, the ease and warmth with which real experts in specialized fields distant from my own welcomed me into their midst and advised me on matters in their subjects of specialization was something I had not expected. The *Report's* theme is close to my own research engagement, so I was naturally attracted to the task of Chairing the Expert Group, but it is the personal involvement among experts in diverse disciplines, with widely differing experiences, that have been the most memorable. For all that I am grateful.

Partha Dasgupta (Chairman)
St John's College
Cambridge
March 22, 2013

Expert Group Members

Dr. T.C.A. Anant (Convenor), Secretary and Chief Statistician of India, M/o Statistics and Programme Implementation, New Delhi

Dr. Kaushik Basu, Former Chief Economic Advisor, Government of India and presently Senior Vice President and Chief Economist, Development Economics, World Bank, Washington DC

Dr. Kanchan Chopra, Former Director and Professor, Institute of Economic Growth, Delhi and Presently Visiting Professor, TERI University, New Delhi.

Prof. Sir Partha Dasgupta (Chairman), Frank Ramsey Professor Emeritus of Economics, University of Cambridge, and Professorial Research Fellow, Sustainable Consumption Institute.

Dr. Nitin Desai, Former Chief Economic Advisor, Government of India.

Prof. Haripriya Gundimeda, Associate Professor, Department of Humanities and Social Sciences, Indian Institute of Technology Bombay, Powai, Mumbai

Dr. Vijay Kelkar, Chairman, India Development Foundation, New Delhi

Mr. Ramesh Kolli, Ex-Additional Director General, National Accounts Division, Central Statistics Office, New Delhi

Dr. Kirit Parikh, Former Member, Planning Commission, and presently Director, Integrated Research and Action for Development (IRADe), New Delhi

Dr. Pronab Sen, Former Chief Statistician of India, Secretary, Ministry of Statistics and Programme Implementation, and Principal Advisor, Planning Commission, and presently Chairman, National Statistical Commission, Government of India, Delhi.

Dr. Priya Shyamsundar, Program Director, South Asian Network for Development and Environmental Economics (SANDEE), c/o ICIMOD, Khumaltar, Lalitpur, Nepal

Dr. E. Somanathan, Professor, Indian Statistical Institute, New Delhi

Prof. K. Sundaram, Former Professor, Delhi School of Economics and Presently Chairman, Advisory Committee on National Accounts Statistics of Government of India

Chapter 1

Executive Summary

Executive Summary

National accounts are descriptors. They describe the state of an economy and form the raw material for both *assessing performance* and prescribing policy. National accounts are meant to contain the kinds of information that are essential for economic evaluation.

The system of national accounts currently in use throughout the world, however, suffers from extreme narrowness. Vast quantities of information relevant for economic evaluation do not appear in them. Some don't because the appropriate data are hard, even impossible, to collect; but others don't because until recently the theory and practice of economic evaluation didn't ask for them. The demand for *green national* accounts has arisen because of a growing recognition that contemporary national accounts are an unsatisfactory basis for economic evaluation. The qualifier "green" signals that we should be especially concerned about the absence of information on society's use of the natural environment.

In this study - henceforth, the *Report* - we provide an outline of what would ideally be needed for a comprehensive set of national accounts. We show that national governments and international agencies ought to go beyond even green national accounts, by reclassifying certain classes of goods and services and adding others that are currently missing. For the present the ideal can be approximated at best very crudely. Data on many items that ought to be included will of necessity appear only in physical terms for some time, while many other items of significance will continue to remain missing. If the recommendations of the *Report* were accepted, economic evaluation would continue to involve cutting corners. But it is essential for good practice to know where the corners that are being cut happen to be. That is why in this *Report* we dive extensively into the conceptual foundations of economic evaluation. In any event, data are collected only when there is demand for them, and the point remains that improvements to the framework for national accounts can be made even now. The ideal, which is what we construct here, should not be an enemy of good practice. Such improvements as are feasible today would be partial but would nevertheless be an advance. The Report suggests a number of ways in which that can be achieved.

The system of national accounts *(SNA)* that are still being developed by the United Nations and their affiliated international agencies contain very few of the additions and reclassifications we suggest here. A number of our recommendations do appear in the satellite system of environmental and economic accounts *(SEEA)*. There are, however, serious shortcomings with the classification scheme favoured even in the *SEEA*. The *Report* suggests ways in which the *SEEA* can more readily serve the purposes of economic evaluation. Given our remit, we say little on the income side of the ledger. The focus of the Report is instead on (the parallel) systems of production and expenditure accounts. We will see though that several of the Propositions that are derived in Chapter 2 and its Appendices are best expressed as a mixture of aspects of production and expenditure accounts.

1.1 National Accounts and the Idea of the Good

It wouldn't do to suggest improvements to national accounts on an ad hoc basis. Readers of the Report would expect us to offer reasons in support of our recommendations. Fortunately, it isn't hard to provide those reasons. It isn't hard, because as we go about our daily lives, we citizens carry with us a conception of the good that includes not only ourselves and our contemporaries, but also the well-being of future generations. We approve of some aspects of our society but deplore others, and at times we even subscribe to the idea of the "common good". National accounts should ideally be so constructed that they permit citizens in their private capacity and as government officials to sift evidence in ways that inform their ethical perspectives. Economic evaluation requires data, to be sure, but it also requires a conception of the good. More tellingly, without a conception of the good we wouldn't know what data we should seek to study. The conceptual foundations of national accounts are constructed in Chapter 2 of the Report. The Appendix to Chapter 2 contains proofs of propositions that form the foundations. Chapter 3 provides outlines of the production and expenditure systems currently in place in the system of national accounts (SNA) in India and salient features of SEEA Central Framework adopted by UNSD.

Readers will wish to compare and contrast the recommendations of this Report with the way data are collated in India's SNA and requirements as per SEEA. They will confirm that it isn't self-evident how the recommendations are to be framed in ways consistent with contemporary national accounts.

Chapter 4 is transitional. It identifies the moves that will need to be undertaken if the existing system of national accounts in India is to adapt to the ideas developed in Chapter 2. Chapter 5 illustrates the problems, and the possibilities that exist, with the help of a partial set of data from the Indian states, pertaining to forests, minerals, and various categories of land. Finally, Chapter 6 provides a map of the steps that will be required if the Report's recommendations are to be adapted to India's national accounts.

1.2 Economic Growth as Growth in Wealth

The Report's central conclusion is that adjusting for population, the coin on the basis of which economic evaluation should be conducted is a comprehensive notion of wealth (adjusted for the distribution of wealth in the economy), not gross domestic product (GDP)[1] , nor the many other ad hoc indicators of human well-being that have been advanced in recent years, such as the United Nations' Human Development Index (HDI). By wealth we mean the social value of an economy's stock of capital assets, comprising (i) reproducible capital (commonly known as "manufactured capital": roads, ports, cables, buildings, machinery, equipment, and so forth), (ii) human capital (population size and

[1]Here we do not distinguish between gross domestic product and gross national product, because the distinction has no bearing on the points we wish to highlight here.

composition, education, health), and (iii) natural capital (ecosystems, land, sub-soil resources, and so on)[2]. We show in particular that changes in the circumstances of an economy should be judged on the basis of their effect on the economy's wealth per capita, adjusted for the distribution of wealth.[3] We are able to so argue because we show that wealth per capita is the mirror image of intergenerational well-being averaged across the generations. To put it in other words, wealth per capita tracks intergenerational well-being averaged across the generations exactly: the former increases over a period of time if and only if the latter increases over that same period of time. This equivalence forms the basis for what may be called sustainability analysis.

The Report also shows that the coin on the basis of which we should judge policy changes - such as changes in taxes, trade, and the undertaking of investment projects - is also wealth. It is well known of course that the criterion that ought ideally to be used to evaluate, say, an investment project is the Present Discounted Value (PDV) of the flow of social profits arising from it. What is perhaps not commonly known is that the PDV in question is the change in wealth brought about by the project. That means the PDV of the flow of social profits arising from an investment project is positive if and only if the project gives rise to an increase in wealth.

The Report argues that the pair of equivalence ("if and only if") relationships just mentioned should serve as the conceptual foundation of national accounts and influence the way data are collected and arranged. The equivalence relationships do not pre-suppose any particular conception of intergenerational well-being; they are valid under as general a set of circumstances as can be. What the ethical conception adopted by a government or the citizen does influence are the (social) values to be imputed to capital assets. So, although the centrality of wealth in economic evaluation is value-neutral, estimates of wealth are inevitably value-laden. If the latter feature should seem overly unpractical for the purposes of hard-headed national accounting, we should remind ourselves that to rely on market prices in economic evaluation, as is the norm when the SNA is put to use, is to adopt the viewpoint that market prices reflect the social values of goods and services.

The Report shows that by "economic growth" we should mean growth in wealth per capita, not growth in per capita GDP; and by "inclusive economic growth" we should mean "inclusive growth in wealth". It can easily be that a society enjoys growth in GDP per capita and/or an improvement in its HDI even while experiencing a decline in its per capita wealth. Of course, the reverse can happen too. That said, the aim of a society should not be to maximize the rate of growth of wealth per capita, but rather to identify a desirable rate.[4]

1.3 The Idea of Investment

Wealth is a stock, whereas the rate of change in wealth over time is a flow. Changes in wealth are brought about by investment. Wealth increases if and only if aggregate net investment is

---

[2]What we are calling "wealth" has been named "comprehensive wealth" by Arrow et al. (2012) and "inclusive wealth" by UNU-IHDP/UNEP (2012).

[3]For ease of exposition we drop the qualifier "corrected for the distribution of wealth" in what follows.

[4]An early, incisive treatise on the idea of optimum economic development was Chakravarty (1969). Understandably, he didn't characterise that development in terms of wealth. The two equivalence relationships just mentioned in the text were discovered many years later.

positive. So investment is a flow. That much is obvious. In common parlance though, the word "investment" has a remarkably limited range. The concept embodies a sense of robust activism. When the government invests in roads, for example, the picture that's drawn is one of bulldozers levelling the ground and tarmac being laid. But that is because national income statisticians have traditionally limited the term's use to the accumulation of reproducible capital.[5] As the Report finds it necessary to extend the notion of capital beyond reproducible assets to include human capital and natural capital, it recommends that we stretch the notion of "investment". To leave a forest unmolested so as to enable it to grow would be to invest in it. To allow a fishery to restock under natural conditions would be to invest in the fishery. And so on. That suggests investment amounts to deferred consumption. But the matter is subtler. To provide food to the undernourished not only increases their current well-being, but also enables them to be more productive in the future. The latter feature makes even consumption among the poorest of people, at least in part, an investment. Estimating aggregate investment is a formidable, even an impossible task. Corners will have to be cut ruthlessly. In this Report we explain why and offer leads on how.

By investment we mean net investment. Formally, net investment in an asset is any increase in the flow of services it can provide over its lifetime. Net investment is therefore the value of the rate at which the asset's stock changes. Aggregate net investment over a brief period of time (e.g., a year) equals the change in the economy's wealth over the period.

What about institutions, knowledge, culture, religion, and norms and practices. In common parlance today the notion of "capital assets" extends even to those durable objects. And yet we have not included them on the list of assets that comprise wealth. The Report explains why and argues that it is more appropriate to view them rather as the social infrastructure within which the more grounded assets (categories (i)-(iii), listed above) get allocated and are put to use. What we are calling an economy's "social infrastructure" should be seen as comprising enabling assets.

All this has further implications.

1.4 Green GDP is a Misnomer

Define net domestic product (NDP) as GDP minus the depreciation of capital assets. By "depreciation" we mean not only the wear and tear of buildings and equipment, we mean also the loss of human capital (the onset of physical and mental disabilities; death) and physical depletion and quality degradation of natural capital. The Report shows that aggregate net investment, as defined above, would be positive if and only if aggregate consumption was not to exceed NDP. Making use of the finding that the coin with which economic evaluation should be conducted is wealth per capita, we obtain an operational notion of "sustainable development": Development would be sustained over a period of time if and only if aggregate net investment per capita was positive. We should stress that by "aggregate net investment per capita" we don't mean aggregate net investment divided by population size, we mean instead the social value of the change in per capita stocks of assets. Estimating stocks is

[5]The term “gross capital formation” is even more restrictive. It doesn’t reflect the depreciation of reproducible capital.

no doubt hard work, but the Report insists it should not be avoided. The term "green GDP" is thus an utter misnomer.

To illustrate, consider a closed economy with constant population. Suppose in a given year it invests 40 billion dollars in reproducible capital, spends 20 billion dollars on education, and depletes and degrades its natural capital by 70 billion dollars. The economy's SNA would record the 40 billion dollars as investment ("gross capital formation"), the 20 billion dollars as a component of aggregate consumption, and remain silent on the 70 billion dollars of loss in stocks of natural capital. The accounting methods advocated by our Report, in contrast, would reclassify the 20 billion dollars as expenditure in the formation of human capital ("investing in the young", as the saying goes) and the 70 billion dollars as disinvestment in natural capital. Aggregating over them and assuming that expenditure on education is a reasonable approximation of gross human-capital formation (which would be to cut a corner in every economy we know!), the methods advocated here would conclude that owing to the disinvestment, the economy's wealth will have declined over the year by 10 billion dollars (and that's before taking note of the depreciation of reproducible and human capital). Aggregate consumption during the year would, equivalently, be found to have exceeded NDP. We should conclude that development was unsustainable that year.

1.5 Pollution is the Reverse of Conservation

Because the Report is on "greening" national accounts, much attention is paid here to discussing ways of measuring the value of environmental resources (Annexe to Chapter 2). The Report offers a unified view of "conservation" and "pollution". We argue that "pollutants" are best seen as the reverse side of "natural capital". The way to conceptualise "pollution" is to turn one's mind to the depreciation of capital assets pollution brings in its wake. Acid rains damage forests; industrial seepage and discharge reduce water quality in streams and underground reservoirs, killing fisheries and damaging human health; sulfur emissions corrode buildings and structures and harm human health; and so on. The damage inflicted on each type of asset (forests, fisheries, human health, and buildings, respectively) should be interpreted as a depreciation of that asset. The Report advances practical methods for estimating depreciation (Appendices 7-10 to Chapter 2).

1.6 The Salience of GDP

GDP routinely gets a bad press these days. But it has a tenacious hold on our economic sensibilities. It isn't hard to see why. Among the reasons for studying the economic performance in terms of GDP is that the index serves to estimate the gap between potential and actual outputs. Moreover time series of GDP enable one to study household and corporate behaviour. A further reason is that Finance Ministers need to know their respective economies' tax base, and GDP provides a foot-hold for that. At the international sphere, a growing GDP wins a country prestige and possibly leverage in negotiations over economic and political matters. Each is a compelling reason. But we should note that the race to improve one's position in the GDP league table resembles the proverbial "problem of the commons" (in the present example, a "rat race"), so all countries lose.

Our Report is on national accounts and we assume that the international race in question will continue in the foreseeable future. In any event, we don't recommend that national accountants should abandon GDP. We argue nevertheless that to ignore depreciation of reproducible capital and the degradation of natural capital is indefensible practice in economic evaluation concerning the long run. As noted above, it can be that GDP per capita grows for a while even as wealth per capita declines. What would be impossible is for wealth per capita to decline indefinitely while GDP per capita increases ceaselessly. That's impossible because in due course the productive base of the economy, which is what wealth measures, would have little left to further degrade and depreciate.

The simplest illustration of that truth is a small economy of constant population whose income is based solely on the export of an exhaustible resource. Imagine that the export price is expected to remain constant, say, because the rest of the world is able to manufacture a perfect substitute for the resource at a constant unit price. Imagine also that owing to bad governance all export revenues are consumed. It would follow that the country's GDP equals aggregate consumption. NDP, however, would be zero at all times because consumption would always equal depreciation of the economy's sole asset. Wealth meanwhile would be declining, at a rate equal to the export revenue. So, intergenerational well-being would be declining. Imagine now that the national policy is to raise exports annually. In that case GDP (aggregate consumption) would increase annually. But it would not be possible to persist with the policy indefinitely. In due course GDP would have to decline because of the ever dwindling resource stock.

Measuring depreciation is hard. So it is frequently suggested that to estimate depreciation and obsolescence, as would be required if aggregate net investment is to be estimated, would be to introduce errors. It should be borne in mind though that 60 years ago estimates of national incomes were subject to uncertainties of a magnitude people are minded to think no longer exists in current estimates. In any event, contemporary estimates of national income are taken too much at face value. Official estimates are silent on the proportion of incomes that are unrecorded. National accountants may have suspicions of how much goes unrecorded, but those very suspicions would be subject to substantial errors.

1.7 Shadow Prices as Social Values

To estimate wealth one needs ideally to impute a social value to every capital asset, multiply each asset's stock (measured in terms of either quantity or quality) by its social value, and add across all the assets. The social value of an asset is called its shadow price. Shadow prices are the link between a society's well-being and its capital assets.

That ideal can't be expected to be attained. One should doubt that it is possible to put a price on natural capital of cultural or religious significance such as sacred groves. Societies usually "ring fence" them against encroachment. They are taken to be of unbounded value and are not to be defiled. The use of shadow prices in national accounts would be perfectly consistent with that practice.

Shadow prices assumed prominence in the 1970s in a literature that codified methods for evaluating public investment projects. But the concept proved to be controversial. The reason is that market prices are out there and can be observed, which makes them "hard" objects. In contrast shadow prices have to be estimated, involving both value judgments and an all too uncertain knowledge of socio-economic processes that are needed to be uncovered if we are to peer into the economy's future. That makes shadow prices "soft".[6] There is then an understandable temptation to identify shadow prices with market prices and avoid talking about the former altogether. But to justify that particular move requires of us to imagine that markets on their own are able to implement the allocation of resources on the basis of an exercise in economic evaluation that concerned citizens and public officials would subscribe to. Among other things it would require of us to imagine that markets are able to aggregate current uncertainties about future possibilities in an adequate manner.

To someone interested in greening national accounts, the assumption doesn't make the cut. Market prices of environmental resources are usually very poor approximations of their shadow prices. The reason lies in the ubiquity of externalities, which are the unaccounted for consequences for other (including future generations) of decisions made by each of us on consumption, production, and use of the natural environment. Consider that in the case of resources to which there is open access, such as the oceans and the atmosphere as sinks for waste products, the market price is zero even while the shadow price is significantly positive. That's known as the "tragedy of the commons." To be sure, it is an extreme case, but in humanity's use of the natural environment, externalities are the rule, not the exception. More generally, externalities reflect institutional weakness, involving weak property rights, ambiguous rules of engagement, the exercise of raw power, and so forth.

A resource's shadow price is the sum of its market price and the externalities that are associated with its use. The Annexe to Chapter 2 reviews techniques that have been developed for estimating shadow prices. Most such techniques are confined to what may be called consumption "amenities", such as recreation.[7] The problem is, the bulk of what comprise natural capital are factors of production; they are not amenities. Natural capital enables humanity to obtain food, fibres, and clean water; protects us against natural hazards such as storms; and is crucial in such processes as the nutrient, water, and carbon cycles, and soil formation. Appendices 7-10 to Chapter 2 provide outlines of ways to estimate the shadow price of non-amenities.

There is unfortunately a dearth of good empirical work on shadow prices of natural capital as factors of production. The Report finds, for example, that there have been woefully few empirical estimates of the value of natural ecosystems in India.[8] The lacuna is in urgent need of repair. For the foreseeable future we expect stocks and flows of ecological resources to continue to appear in SEEA without their attendant shadow prices (Chapters 3-4 and 6). In Chapter 5 we describe how that can be done, by constructing a framework for presenting assets accounts for forests and for various categories of land.

There is a further problem in estimating the shadow price of natural capital:

---

[6]For reflections on the controversy over the use of shadow prices in project evaluation, see Little and Mirrlees (1991).
[7]Freeman (2002) is the recognised treatise on the subject.
[8]This is confirmed by Government of India Report (2012) on expanding the basis of national accounts in India.

The physicist Steven Weinberg once wrote that when you have seen one electron, you have seen them all. The same cannot be said of natural capital, which is inevitably site specific. A village pond in West Bengal isn't the same as a seemingly identical pond in Kerala. The collection and maintenance of micro-level data is of the utmost importance. The lives of people are tied to their local environmental resource-base, which means shadow prices of natural capital are site specific. No doubt aggregation is a necessity in the preparation of national accounts, but the spatial heterogeneity of ecosystems should always be kept in mind. We noted earlier that "inclusive growth" should mean inclusive growth in wealth. The Report argues that to implement inclusive growth requires that policy makers pay particular attention to the processes that connect rural poverty to the state of the local environmental resource-base.

1.8 Illustrative Rules

As wealth is a stock, particular attention is paid in this Report to capital accounts. Under ideal circumstances (viz, an optimizing economy) the (shadow) value of expenditure on the accumulation of an asset would equal the (shadow) value of the resulting accumulation. That way the accumulation of one type of asset would exactly match the prevention of the accumulation of another (the expenditure) - which is the classic rule for asset management. In those circumstances the expenditure in terms of one asset could be used to estimate the accumulation of the other. But in the world as we know it the discrepancy between the two can be so large that the correct procedure would be to estimate what the definition of net investment in an asset tells us to estimate, which is the (shadow) value of the change in the quantity (or quality) of that asset. This is proved in Appendix 7 of Chapter 2. In the foreseeable future though, using expenditures to reflect the value of the resulting accumulation may be a necessary compromise.

In income-expenditure accounts, GDP as customarily defined is often called final demand. NDP is GDP minus depreciation of capital assets, which is a familiar enough notion; but the Report shows that it is a lot less straightforward than is generally assumed. Complications arise because of the extended sense in which the term "asset" ought to be used. Thus, our analysis has implications for the way national accounts should interpret certain types of expenditures. We illustrate with six examples here, involving the conversion of natural capital into reproducible capital, defensive expenditure, exploration for sub-soil deposits, and expenditures on education and health.

1. If a wetland is drained so as to make way for a shopping mall, the SNA would record the latter as an investment and remain silent on the former. The Report shows that draining the wetland would be a disinvestment and should be so recorded.[9]

2. By "defensive expenditure" we mean resources devoted to reducing the impact of environmental damage on health, machinery and structures, and natural capital. The Report argues that such

[9]In an optimally managed economy the two would cancel each other and wealth would remain unaffected.

expenditure should be deducted from final demand. Not to do so would be to record final demand as rising even while wealth remains constant, possibly even declining.[10]

3. Costs of exploration (for sub-soil resources) are the mirror image of defensive expenditures, in that the costs are incurred so as to augment the resource base. We show that exploration costs should be deducted from final demand, but that the value of new discoveries should be included. The two are typically not the same.

4. Depletion of exhaustible resources amounts to depreciation of natural capital and should be so recorded.

5. It is customary to regard private expenditure on education as consumption and to speak of government expenditure on education as "investment in the young". This is an awkward practice. We show that the appropriate procedure would be to regard education as the formation of human capital and to estimate the shadow value of changes in the quantity of that asset (Appendix 9 of Chapter 2). Education expenditure in turn should be seen as an expense that prevents the accumulation of other forms of capital.

6. It is customary to regard private expenditure on health as consumption and government expenditure on health as the supply of a merit good. We show that the appropriate procedure would be to regard health as a form of human capital and estimate the shadow value of changes in the quantity of that asset (Appendix 10 of Chapter 2). The Report develops methods for estimating the value of health. As with in case of education, expenditure on health in turn should be seen as an expense that prevents the accumulation of other forms of capital.

1.9 Transition to an Improved System of National Accounts

Readers will wish to contrast the data requirements in the national accounts espoused in Chapters 2 and 4 with the codification in Chapter 3 of the data that are sought and collated in India's SNA and SEEA. Chapter 4 provides an outline of the contrasts. The chapters show that it isn't self-evident how the recommendations of our Report are to be framed in ways that are consistent with contemporary national accounts. Even the restricted enlargement of assets in the illustrations in Chapter 5 reveals that several reclassifications will need to be undertaken within the SNA.

But the required enlargements and reclassifications in question cannot be achieved overnight. In Chapter 6 we provide a map of the steps that will be required to be taken if the Report's recommendations are to be adapted to India's national accounts. The chapter provides a brief account of the initiatives that are being undertaken in India toward the development of green accounting. The Report asserts that the adaptation process needs to be informed by three considerations, namely, (a) the reclassifications and extensions should conform to the internal logic of the SNA, (b)

[10] An outline of an SEEA in an optimizing economy where defensive expenditure is undertaken was provided by Mäler (1991).

they reflect a continued improvement in our understanding of socio-ecological processes, and (c) they are based on data that exist or are obtainable with a reasonable degree of accuracy.

1.10 A Word of Caution

Our strategy in this Report has been to begin by providing an outline of an ideal system of accounts (an "ideal SNA", so to speak) and from there to show step by step how very far the current system is from the ideal and how far it can be expected to remain from it. We present a feasible transition path to an ever-improving system, but caution that even if figures for physical stocks were available, the deep problem of estimating shadow prices would remain. The issue isn't merely one of uncertainty about the role environmental resources play in production and consumption possibilities, it is also a matter of differences among people in their ethical values. Wealth estimates should be presented as bands, not exact figures. That people may never agree on the wealth of nations is however no reason for abandoning wealth as the object of interest in policy and sustainability analyses.

Chapter 2

Conceptual Foundations

Conceptual Foundations

2.1 Economic Evaluation

Economic evaluation is an essential activity. We evaluate our own household's economic circumstance, we worry that green is a vanishing colour in our cities, we are puzzled by the growing inequality in living standards in much of the world, we are concerned about the character of economic development in our own country, and we have views on the role mutual trust, personal honesty, economic incentives, and governance play in our lives.

Economic evaluation is also a compulsive activity. We commonly discuss the economic performance of nations and of states within our nation with our friends and neighbours, read reports and commentaries in newspapers and magazines, listen to the views of experts on radio and television, and occasionally take our concerns to our political representatives. We evaluate economies so as to assess and prescribe, and we do so because we are curious to know answers to five questions:

(A) How is the economy doing?

(B) How has it been doing in recent years?

(C) What should our forecast of the economy's performance be under "business as usual"?

(D) How is the economy likely to perform under alternative policies?

(E) Which policies should we support?

Questions A and B direct us to assess the performance of economies. Questions D and E are prompted by the need to prescribe policy. Because any change in policy is a perturbation to "business as usual", obtaining an answer to C is essential if we are to respond to questions D and E.

Assessment should precede prescription. It could be foolish to look for improvements if an economy is doing well, for there would be a risk of making things worse. If on the other hand the economy has been doing badly, we should search for policies and institutional changes that are likely to improve matters. An immediate problem would arise if we don't know what to look for when evaluating the economy's performance. National accounts are crucial for this. They are needed if we are to address any of the five questions.

We refer to the person doing the evaluation as the social evaluator. The social evaluator could be a citizen, thinking about things before casting his vote on political candidates; she could be an ethicist employed to offer guidance to the government; he could be a government official; and so on. Being a social evaluator, the person takes into account the interests and desires of others, not just those of his or her own self.

2.1.1 Human Well-Being

In our Report we take it that the currency in which the evaluation is done is human well-being. Contemporary people count, but so do future people: societies live on even though people don't. The inclusion of future people means that an evaluation of matters that runs from the present into the future requires a forecast of future numbers of people. The kinds of economic evaluation we consider in this Report require demographic forecasts.[11]

Restriction to human well-being would no doubt appear limiting. There are moral conceptions that include the interest of all sentient beings. Most of us adhere to them from time to time. We sometimes protect other life forms because not to do so would be collectively unconscionable. When we citizens reject proposals to convert wetlands into urban thoroughfares that would harm migratory birds, we reject them not only because we care about the birds, but also because we believe the flocks matter independently of all else. When governments deny logging permits because deforestation would hurt endangered species, they do so not necessarily because people feel personally affected by the extinction of species, but because concerned citizens urge them to do the right thing.

Regrettably such ethical sensitivities in the modern world don't usually go beyond visible life forms. We protest against further damage to the habitats of tigers, cranes, spotted owls, and rare orchids, and we like to protect warm and cuddly animals such as pandas. But when it comes to invisible life forms and organisms that annoy modern life-styles, that sense of the worth of species doesn't quite make the cut. We begin to value the myriad forms of bacteria only when natural scientists tell us of the vital role they play in the functioning of the Earth System - decomposing organic waste, driving the nitrogen cycle, and so on. And we have to be reminded of the pollinating services insects provide us before we are willing to accommodate them in our garden without complaint. When we are so reminded, we come to value those life forms in terms of the benefits they offer us. But that's only to look at their instrumental worth, not at their existential worth independent of how we regard them.

Beyond the recognition that species, not just individual sentient beings, have value, we have nothing concrete to say in this Report about those wider ethical considerations. And so, because this Report is aimed at developing the logic underlying a comprehensive system of national accounts, we say nothing further about those wider ethical considerations. It should be evident though that to neglect those aspects of our value system would be to practice economic evaluation in a way that is biased against non-human lives. Citizens who are moved to include the value of other life forms in economic evaluation would wish to add those values to the often opposing demands made on behalf of human interests.

2.1.2 Eliciting Well-Being: Constituents and Determinants[12]

How is the social evaluator to elicit human well-being? Scholars have studied the question by asking variously:

(i) What is the human good?

(ii) What do people care about?

(iii) What do people say when asked how they are, or how they feel?

(iv) What considerations do people take into account when choosing?

[11]Evaluating population policies would require a study of alternative forecasts of future numbers and their consequences.
[12]Sections 1.2-1.4 are based on Dasgupta (2012a).

(v) What do they choose?

It is tempting to assume that one can move seamlessly from (i) to (v) and back. But (i) is a deep question in ethics, while (ii) is prompted by the need to understand human desires and aspirations, whereas (iii) is about the responses people make to questionnaires, and (iv) and (v) involve the psychology and sociology of behaviour under (possibly unobservable) constraints. Moralists warn us responses even to question (ii) may not prove adequate for answering question (i). They point to potential bottlenecks at each link in the chain leading from (i) to (v), not to mention the chain leading from (v) to (i). Values and behaviour could point to different directions, they say. But no matter which ethical conception the social evaluator subscribes to, it is necessary for her to have answers to (iv) and (v). That's because she needs to have a sense of the way people are likely to respond to changes in policy. In any event, without an understanding of behaviour there can be no ethics.

To people of democratic persuasion, data on (v) have always been the first step toward making sense of (ii). The "theory of revealed preference," a bedrock of contemporary welfare economics, tells the social evaluator to postulate the form of an answer to (iv), study data on (v) so as to arrive at empirical estimates of the answer to (iv), and use the estimates to draw conclusions about the answer to (ii).[13] When governments, international and non-governmental organizations use evidence from national accounts such the size of gross domestic product (GDP) to make inferences about the quality of life, they move from (v) to (ii). Applications of revealed preference theory are rather like reverse engineering. But with a difference: the econometric methods that are almost always deployed for drawing conclusions about the structure of the postulated answer to (ii) are such that it isn't possible to judge whether the postulate was correct to begin with. We confirm in subsequent sections that this lacuna matters in the estimation of the social worth of goods and services, especially capital assets.[14]

Questions (i) and (v) suggest there are two ways to measure individual and thereby social well-being. One is to study its constituents (health, happiness, autonomy, security, and the fulfilment of desires), the other is to measure it in terms of its determinants (food, clothing, potable water, shelter, access to knowledge and information). But the determinants can stand in for the constituents in economic evaluation only if they are valued in terms of the constituents themselves. Simply to be told, for example, that calorie intake among the poorest 1 per cent of a population has increased by 10 per cent per person doesn't tell us much. We need to know the value of that increase in terms of the well-being of the poorest 1 per cent. The social worth of a determinant is called its "shadow price", a notion that is developed in Section 2.4. We also show that in ideal circumstances economic evaluation, whether conducted in terms of the constituents of well-being or in terms of its determinants, would point in the same direction.

Even so, why waste time measuring well-being indirectly via its determinants, why not measure well-being itself?

---

[13]See, for example, Vermeulen (2012) in a recent symposium on revealed preference theory in the Economic Journal.

[14]Southerton and Ulph (2013) is a trans-disciplinary collection of essays on consumption behaviour.

2.1.3 Happiness Surveys

The reason is that measuring well-being directly, say, through questionnaires (a route followed for obtaining answers to question (ii)), is limiting. Large scale surveys, such as the World Values Survey, the EuroBarometer, and Gallup, which publish responses people give to questions regarding their sense of well-being - for example, how happy or secure they feel or how trustworthy they regard others to be - provide useful information, but are too coarse-grained for use in economic evaluation. Thousands of Americans, for example, have been asked every year or two since 1972 the question, "Taken all together, how would you say things are these days - would you say that you are very happy, pretty happy or not too happy?" In the Gallup World Poll, which was conducted during 2005-2009, randomly chosen subjects in 155 countries were asked to reflect on their overall satisfaction with life on a score of 1 to 10. Those who responded with a high score were classified as "thriving". Respondents were also asked to recall how they had felt the previous day - whether they had felt well respected, free from pain, intellectually engaged, well rested, and so forth. Answers to those questions enabled researchers to score the subjects' daily experiences. The percentage of people who were found to be thriving on a combined index based on those scores was then used to rank countries in terms of what has been called Gallup's "happiness index". Happiness indices aggregate personal well-beings and equate personal well-being with reported expressions of happiness.

In view of the scope of the questions posed in the surveys, there should be little surprise that the findings are not entirely consistent with one another, nor that they haven't revealed fine-grained features of the human experience. On large-scale matters, though, the surveys have proved illuminating. They have shown that a person's income influences his state of mind (the poor are less happy than the rich), that personal security and political participation matter, that being unemployed or suffering from chronic pain are sources of much unhappiness, and that societies are happier where people are more involved in civic activities. Surprisingly, the surveys have found that affluent societies haven't become much happier even though over the decades their incomes have grown.[15]

The findings do offer guidance to governments. They tell us, for example, that people care about their place in the distribution of income (perhaps we equate income with status), that unconditional growth in GDP should not be a social goal, that protection against physical and mental insults raises happiness, and that civic life is a good thing. But they don't say how governments are to identify good forestry policies or how to decide whether permission should be granted for converting mangroves into shrimp farms. As always, the Devil is in the details; and as economic evaluation is in great measure a study of details, happiness surveys are of little use there.

Whether happiness should be included in discourses on human well-being depends on the purpose of the exercise. There are democratic theories that don't see the State's business as being concerned with citizens' happiness; they see it rather as ensuring that citizens' material needs and freedoms are met. Devising personal

---

[15]Layard (2005), Clark et al. (2008), Bok (2009), and Graham (2009) contain accounts of the various surveys on happiness. See also the wide-ranging discussion in Stiglitz, Sen, and Fitoussi (2009).

projects and advancing one's purposes is the individual's business, not the State's; or so the argument goes.[16]

That said, ethical theories that ignore experiential states are of limited value. It would be distinctly odd if we were to value the formation of the capacity to prepare life plans but were indifferent to its realization and the experiential states that go with its realization. Seeking happiness would seem to be a deep-felt need among humans. But that only means questions (iv) and (v) on our previous list are pertinent in economic evaluation. Observing what people choose and do under different circumstances is one route to addressing question (ii). That is one reason why national accounts focus on the determinants of well-being.

2.1.4 Revealed and Stated Preferences

People's responses to questions regarding their "willingness-to-pay" for specific non-market goods ("stated preferences") reveal information of direct use to the social evaluator. In democratic societies local governments are obliged to determine the extent to which citizens care about local public goods such as libraries, parks, and street lights. Usually "willingness-to-pay" is expressed in monetary units (i.e., in terms of specific bundles of marketed goods and services). Survey methods and statistical techniques such as Contingent Valuation Methods (CVMs) have been developed by environmental economists to elicit citizen's willingness-to-pay for the conservation of natural habitats - wetlands, lakes, woodlands, and so forth. Economists have also used prices of real estate to estimate the additional price residents have revealed as being willing to pay for residing in locations with more agreeable surroundings (this is the "hedonic price" method of eliciting preferences over the quality of residential location). That is an example of the "revealed preference" approach to determining what matters to people. Non-governmental organizations use such information as weapons against moves to transform natural habitats into industrial parks.[17]

But there are caveats. The new behavioural economics has recorded that people are frequently inconsistent in their choices, make simple computational errors, and are bad at probabilistic judgments. There is a plethora of evidence, for example, that people systematically overestimate small risks (air travel) and underestimate large risks (smoking). This may have something to do with an inconsistency between beliefs and behaviour (psychologists call it "cognitive dissonance"), which results in people changing their beliefs to bring them in line with their behaviour, rather than changing their behaviour to bring it in line with their beliefs. The issue isn't so much to do with inadequate information as with the way people process the information they already have. Compulsory safety belts and the requirement for bike riders to wear helmets are "paternalistic" responses to this problem.[18]

Survey methods such as CVMs have also come under criticism for their ambiguity (Hausman, 2012). However, surveys have also revealed

---

[16]Rawls (1972).

[17]The methods are reviewed in the Annexe.

[18]Carlsson and Johansson-Stenman (2012) is an excellent survey of the lessons behavioural economics has for environmental policy.

unexpected features in our values that should inform social ethics, they should not be regarded as ambiguities. People appear to have a more refined notion of what is meant by a commodity than is suggested in economics textbooks. For example, the willingness to pay (for preservation of an object of desire) has been found in surveys to differ substantially from the willingness to receive (in compensation for destruction of that same object). There is evidence too that we value objects especially if we possess them: we demand more in compensation for parting with an object than we are willing to pay for obtaining that same object. Neither response is a denial of rationality. Each points to the fact that commodities should be defined more carefully than they typically are in national accounts. More broadly, these seeming anomalies in our responses should influence our notions of distributive justice.

There are seeming anomalies in responses to surveys that reflect nothing more than that the surveys were badly designed. As social animals we are both competitive and communitarian. The competitive trait is built on the desire for status (Veblen's "conspicuous consumption"). In Appendix 11 we confirm that competitive consumption involves a rat race, where each person tries to "out-do" his peers. As all are so involved, no one wins. There is resource wastage under competitive consumption. The process resembles the famous Prisoners' Dilemma. To be asked in such an environment how much one would be willing to pay to reduce one's air travel is to face an ambiguity: one's answer would depend on whether others would also reduce their air travel.[19]

In contrast, the communitarian trait in us is built on our need to belong, to do as others do (Bourdieu, 1984; Bourdieu and Passeran, 1990). Fads and fashions are a reflection of the trait. But such forms of social preferences aren't confined to cases where people merely desire to conform to the group norm; it can be that people want to engage in communal activities and identify certain commodities that serve as focal points. Commodities whose demand is in part subject to social preferences have been called "relational goods" (Donati, 2011). Religious expenditures, for example, are built around relational goods. Births, marriages and deaths must not only be marked, but marked in significant ways. Club goods are other examples. Food and clothing, reading habits and even reproductive behaviour would appear to be driven at least in part by social preferences.[20] People responding to surveys would understate their preference for the preservation of, say, mangrove forests if they were not assured that others also would be contributing to the preservation.

Using survey responses to question (v) for reaching an understanding of answers to question (ii) requires an explicit recognition of competitive and social preferences. Unfortunately, the economic models of consumer motivation that are used to make consumer demand forecasts mostly don't allow for either competitive or social preferences. The standard economic model of the consuming household sees us instead as pure egotists. But to arrive at a conception of human well-being from that error is to construct a framework for sustainability analysis that misleads (Dasgupta, 2013).

---

[19]Competitive consumption sustains an important form of "consumption externalities". We study externalities in their general form in Section 2.6.1.
[20]See Dasgupta (1993) for the theory underlying conformism in reproductive behaviour, and Bongaarts and Watkins (1996) and Jensen and Oster (2009) for empirical confirmation.

2.1.5 Goods and Services as Determinants of Well-Being

We have drawn a distinction between the constituents and determinants of well-being, but have offered only commodities as examples of the latter. That's because it has proved useful to measure well-being in terms of its commodity determinants. Institutions and society's social mores are also determinants, of course, but they mediate the production and distribution of goods and services. The direct determinants of social well-being are the flows of consumption goods across present and future people.

In contrast, some thinkers have argued that the determinants of personal well-being are human activities and engagements. Friendships, associational activities, meaningful work, and the contemplation of objects and ideas of beauty are the basis of living, or so it has been argued, from Aristotle to the present day.[21]

The two viewpoints are not at odds. Goods and services are necessary inputs in whatever we do; they are also essential inputs in the development of the kind of person we would like to be. Even leisure requires commodities as inputs, including such non-material goods as talents and skills. Personal well-being is therefore dependent on the consumption of goods and services, whether directly or in a "reduced form". Our Report is built on that assumption.

The distinction between consumption goods and the commodities that are inputs in the production of consumption goods is often blurred. There are commodities that serve as consumption goods, capital goods, and producer goods. Water is a prime example. Potable water is a consumption good par excellence. For maintaining hygiene it is a producer good. As a lake or aquifer it is a capital asset. That water has all those flavours doesn't pose a problem so long as we are able to track them and their contributions to well-being. Even multiple-counting is a virtue when a commodity offers joint benefits. Because water serves many purposes, its value should reflect them all.

The distinction between the constituents and determinants of well-being is blurred in the case of some items. Is education a constituent of well-being or is it a determinant? One can argue it is both. The acquisition of education is partly an end in itself and partly a means to increasing future incomes by improving skills. Aristotelian ethics emphasizes the former, while the economics of "human capital" lays stress on the latter. That education has both flavours doesn't pose a problem so long as we are able to track the two and their contributions to well-being. Double-counting is a virtue when a "commodity" offers joint benefits. Education ought to be counted twice. The same can be said of health.

2.1.6 Policy Analysis

Policy analysis, including project evaluation (otherwise known as cost-benefit analysis), addresses questions D and E. The exercise involves evaluating an economy at a point in time, before and after a hypothetical change (the policy change) has been made to it. The idea is to judge whether the change, which would be

[21]Moore (1903) is probably the most recognizable exponent of the view in recent centuries. He came very close to reducing ethics to aesthetics.

expected to have consequences now and in the future, is desirable. Say a government official has been asked to determine whether a wetland should be drained in order to extend a road. The official's task would be to assess the economy with and without the wetland conversion and compare the two situations normatively (question D). In principle, policy analysis can be used iteratively to identify "optimum" development, which is a development path a society would ideally wish to follow (question E).

Policy analysis has a long and distinguished history, with a rich literature on practical methods for evaluating policy change. The perturbation to be evaluated could be a shift in the prevailing structure of taxes and regulations (Atkinson and Stiglitz, 1980) or it could be an injection of investment in a public project (Little and Mirrlees, 1974). Social cost-benefit analysis is the required method for carrying out policy evaluation. It involves estimating the present value of the flow of net social benefits of the policy change. We return to a study of the "present-value" criterion later in this Report.

The idea behind policy analysis is clear enough. But what is sustainability analysis?

2.2 Sustainability Analysis, or, the Idea of Sustainable Development

The requirement that an object should be sustained over a period of time means it shouldn't diminish over the period. Sustainability analysis involves evaluating economic change when the change is brought about by the passage of time itself. The notion of sustainable development is prompted by questions B and C.

A further question arises: what should the social evaluator look for if she is to check whether development has been, or is likely to be, sustainable?

2.2.1 The Flow of Well-Being

Current consumption suggests itself. Debates at home or in class rooms, in the media or in Parliament, frequently turn on whether consumption per capita has maintained itself over time or whether it is likely to be maintained in future years. People no doubt worry about the distribution of consumption too, but the point remains they worry about the rate of consumption. A drop in consumption is viewed with alarm because the factors that directly determine well-being at a point in time are the consumption of goods and services.

To use current consumption as the criterion for sustainable development is to focus on the flow of well-being. So by the flow of societal well-being at a given date we will mean a numerical index of the flow of well-beings of all who are (or are expected to be) present at that date.

A formal account will help. Consider date t. Write the population size at t by L(t). If t is in the future, L(t) is a forecast; otherwise it's a datum. Let individuals be labelled by j, meaning that j runs from 1 to L(t). Now let $U_j(t)$ denote individual j's well-being at t and B(t) the flow of societal well-being at t (B for "beneficence"). To say that B(t) is a numerical index of individual well-beings is to say that it is a numerical function of the $U_j(t)$s.

Classical Utilitarianism and its many variants insist that social well-being is the sum of individual well-beings. If we were to accept that prescription, B(t) would be constructed out of the $U_j(t)$s as

$$B(t) = {}_{j=1}\Sigma^{L(t)}[U_j(t)]. \qquad (1)$$

Although equation (1) is in wide use in economic evaluation, it has been questioned by ethicists.[22] It should therefore be reassuring to readers that our Report is not restricted to the additive form. But because equation (1) is easy to understand, it may prove helpful to readers to think of B(t) as the sum of the individual well-beings $U_j(t)$s.

Recall that we are calling the determinants of well-beings "consumption". If $C_j(t)$ is the flow of consumption goods and services enjoyed by person j at time t, $U_j(t) = U_j(C_j(t))$.[23] Therefore, to insist that B(t) should be sustained would be to claim that an appropriate measure of aggregate consumption must not decline. The idea then would be to construct an index of consumption and study its movement over time. The index that suggests itself is a weighted sum of the flow of consumption goods and services. The weights are called "shadow prices", which may differ greatly from market prices (Appendix 2.1).

Solow (1974) and Hartwick (1977) identified saving rules that ensure aggregate consumption doesn't decline over time. The authors put flesh into an earlier literature on the meaning of real national income, a connection we show below (Section 2.8.2).[24] Empirical work by Nordhaus and Tobin (1972) included leisure and the enjoyment of environmental amenities among consumption goods and services. The authors called their more comprehensive notion of aggregate consumption, MEW (Measure of Economic Welfare). Today Nordhaus and Tobin could be interpreted as saying that a society's economic development would be sustained if and only if MEW was non-declining. Jones and Klenow (2010) is a study in that same spirit.

As a social objective, however, the flow of societal well-being is adequate neither in policy analysis nor in sustainability analysis. The reason is that it doesn't look ahead. The flow of societal well-being could be high today and predicted to increase in the near future even if the long run bodes ill. The point is the flow of societal well-being at a given date, B(t), doesn't include the well-beings of people at dates subsequent to t.

This particular criticism of what we are calling "the flow of societal well-being" should be familiar. It will be recalled that the basis on which policy analysis has traditionally been undertaken isn't the flow of well-being, but rather intergenerational well-being. The theory of social cost-benefit analysis, for example, recommends that an investment project be evaluated on the basis of the PDV of the flow of net social benefits it promises to yield. The PDV-criterion embodies a precise rule for comparing present and future prospects with and without the project. It says that projects should be evaluated in terms of their impact on intergenerational well-being. Consistency of thought requires that we adopt the same underlying ethics in sustainability analysis.

2.2.2 The Brundtland Commission's View

In their classic Report on Humanity's dependence on Nature, the Brundtland Commission (World Commission, 1987) took the future explicitly

[22]The literature is gigantic. Rawls (1972) is the most prominent example.
[23]For brevity we are ignoring social effects, which are discussed in Section 2.6.1 and Appendix 11.2.
[24]The normative significance of national income has been much studied in the literature (Lindahl, 1933; Hicks, 1940; Samuelson, 1961; Mirrlees, 1969; Sen, 1976). Below we show that income misleads.

into account. The Commission re-cast questions B and C by interpreting the object of interest to be current and future human needs. In an oft-quoted passage the Report defined sustainable development as "... development that meets the needs of the present without compromising the ability of future generations to meet their own needs."

Say an economy has enjoyed economic growth by investing in buildings, factories, mines, and transport facilities. If those investments have been accompanied by a depletion of the economy's forests, wetlands, and aquifers, the social evaluator would wish to ask whether economic growth there is sustainable or whether future needs will be compromised. The widespread acknowledgement today that national accounts should include the use and depletion of the natural environment - we shall call the latter natural capital - can be traced to the Brundtland Commission's work.

Notice that the quoted passage from the Brundtland Commission's Report mentions human needs, not human well-being. The requirement is that future generations will have no less of the means to meet their needs than we do ourselves; it doesn't ask for more. As needs are the austere component of well-being, a country's economic development could be sustainable in the Commission's sense without it being judged to be optimal, even efficient.

Notice also that the Commission's definition is directed at sustaining the determinants of human needs (food, clothing, shelter, and so on). Observe though that the determinants would be available only if the society in question were to have access to adequate quantities of assets for producing them. Sustainable development in the Commission's sense would then seem to require that relative to their populations, each generation should bequeath to its successor an access to at least as large a quantity of what may be called a society's productive base as it had itself inherited from its predecessor. The stress is on "access", not "possession", because trade with others enables an economy to depend on assets it does not itself possess. In the world economy, however, access means possession. For simplicity of exposition, we use the term "possession" in this Report.

The term "productive base" suggests a full array of capital assets. The Commission could be interpreted as saying that sustainability analysis involves tracking movements in an economy's portfolio of assets over time. The problem is that it doesn't say how the portfolio should be aggregated to produce a numerical index. The reason our social evaluator needs a numerical index is that she needs to know the rates at which assets can be traded off for one another while preserving the economy's productive base. And she knows those rates have to be derived from somewhere. The viewpoint we are advancing here is that the criterion for sustainable development should be intergenerational well-being (which is an index of the "constituents" of well-being), and that the required index of an economy's productive base (which is an index of the "determinants" of well-being) should be derived by analysis. That derivation would then yield the rates at which the assets can be substituted for one another in economic evaluation. We now study how that's to be achieved.[25]

---

[25]In a literature inspired by the publication of the Brundtland Commission's Report, some scholars distinguished between "weak" and "strong" sustainability. By the latter they meant preserving particular types of capital assets, such as natural capital; whereas the former permits substitution among assets. Lutz (1993) contains a good account of the distinctions.

2.2.3 Intergenerational Well-being

By "intergenerational well-being" we mean a numerical index of the well-beings of present and future people; and by sustainable development we will mean a development path along which intergenerational well-being doesn't decline. We write this formally as

Definition 1: Economic development is sustained over a period of time if during the period intergenerational well-being does not decline.

To make Definition 1 useable in quantitative studies, assume time is divided into discrete dates, say, years. As previously, let B(t) denote the flow of societal well-being at date t. Imagine the social evaluator places herself at that date. t would be a past date if her intention was to conduct sustainability analysis retrospectively (question B); alternatively it would be the current or a future date if she wants to study the shape of things to come (question C).[26]

Intergenerational well-being at t is a numerical measure - we denote it by V(t) - of the flow of societal well-being at all dates starting at t. We may therefore write V(t) as V(B(t),B(t+1),...). The stream of societal well-beings {B(t), B(t+1), B(t+2), ...} is a forecast at t. That means V(t) is based on a forecast. Being a numerical index of present and future well-beings, V(t) is a stock of well-being. In contrast, B(t) is a flow of well-being (well-being per unit of time).

Let u also denote time, representing any date beginning at t. So $u \geq t$. Let T be the length of the period the social evaluator intends to study. We may now re-express Definition 1 as

Definition 1a: Economic development is sustained during the interval of time [t, t+T] if $V(u+1) \geq V(u)$ for all u = t, t+1, ... , t+T-1.

How many generations should be included in V(t)? Even though macroeconomic planning horizons are often not more than 25 years (the horizon in India's "Perspective Plans"), intergenerational well-being V should include the well-beings of a lot more future generations. Computable models of global climate change are today built with a horizon of 100 years or more, and theoretical economists routinely include the whole future! In what follows we don't specify the number of future dates that enter the definition of V, but we assume implicitly that it includes the life-spans of many generations.

Sustainable development is a different notion from optimum development. It is different even from "efficient" development. It can be that intergenerational well-being V grows in an inefficient economy; equally, it can be that it grows in a suboptimal way. Moreover, it can be that an economy develops in a sustainable way for a period but is forecast to fail to do so subsequently unless better policies are accepted. And it can be that the economy is currently following an unsustainable path but is forecast to reverse that trend.

Prominent ethical conceptions (among which are the many versions of utilitarianism) say that V(t) is additive in the B(u)s. Because of the practical convenience it affords for economic

[26] Placing herself at a date other than the date she is at is the sort of sympathetic thought-experiment common in normative discourse.

evaluation, the additive form has proved to be attractive. A general additive form, widely in use in economic evaluation, is

$$V(t) = V(B(t),B(t+1),...) = {}_{u=t}\Sigma B(u)/(1+\delta)^{(u-t)}, \quad \delta \geq 0.^{27} \qquad (2)$$

In words, equations (1) and (2) taken together reflect a moral conception in which intergenerational well-being at any date is an additive function of the well-beings of all who are alive at that date and all who are to follow.

Although equation (2) is in wide use in economic evaluation, it has been questioned by ethicists.[28] So it should be reassuring to readers that our Report is not restricted to the additive form. Nevertheless, because it is so transparent, and to many ethicists a persuasive form, we make use of equation (2) in the Appendices.

Equation (2) expresses intergenerational well-being in terms of its constituents. To see how the objective can be expressed in terms of its determinants, let C(u) be the flow of consumption goods and services at date u. As C(u) is a complete list of who consumes what at date u, it embodies the determinants of B(u). But if experience tells us the future can be relied upon to reveal unexplained needs and wants, B would also depend on the calendar date, u. We may then write B(u) as B(C(u),u). In which case equation (2) becomes

$$V(t) = {}_{u=t}\Sigma B(C(u),u)/(1+\delta)^{(u-t)}, \ \delta \geq 0. \qquad (3)$$

Equation (3) says that the determinants of V are current and future consumptions. But they are only the direct determinants. We will call the source of current and future consumptions the economy's productive base. An economy inherits its productive base from its past. We confirm below however that "productive base" is not another name for "capital assets". An economy's productive base certainly includes the assets it has inherited from the past, but it includes a lot more. There are components of a productive base - the quality of an economy's institutions is an example - that impart value to capital assets but are not assets themselves (at least not in a sense that proves fruitful in economic evaluation). A name is not just a name. We classify capital assets in Section 2.3 and identify those features of a productive base that are not capital assets themselves.

2.2.4 The Idea of Wealth

Imagine we have been successful in constructing a numerical index of an economy's capital assets, with the property that its movement over time faithfully tracks movements in intergenerational well-being. The index could then be used in sustainability analysis. If it is also discovered that the index is a weighted sum of the stocks of capital assets, the social evaluator could be given the weights and be required only to estimate changes in the stocks over the period under review. It transpires that the required index in sustainability analysis is linear, provided the weights are chosen to reflect the assets' social scarcity values. The weights are called shadow prices (Section 2.4) and the weighted sum is called wealth. An asset's shadow price is the contribution an additional unit would make to intergenerational well-being, other things being equal. Shadow prices

[27]See for example, Chakravarty (1969), Arrow and Kurz (1970), and Little and Mirrlees (1974). The non-negative number δ is known as the "pure rate of time preference". As mentioned in the text, we are deliberately not specifying the number of dates following t that are to be included in the notion of intergenerational well-being.
[28]The literature is large. Rawls (1972) is a most prominent example.

connect the determinants of well-being with its constituents. That offers a hint as to why wealth when suitably estimated can replace intergenerational well-being in sustainability analysis (Section 2.5).

It transpires that wealth is the object of interest even in policy analysis (Section 2.5). The way we confirm the latter is by showing that the present value of net social benefits of, say, an investment project is the effect the project is expected to have on the economy's wealth. Taken together these findings tell us that policy analysis and sustainability analysis are at their core the study of asset management.

In order to estimate wealth we need first to list the items in an economy's productive base that are to be included. Let us call those items capital assets. We are then required to weight those assets. The weights are called shadow prices. We then estimate the weighted sum of the capital assets. That weighted sum is the economy's wealth. These matters are discussed sequentially, in Sections 2.3 through to 2.5.

2.3 Unravelling the Productive Base

Classifying the components of an economy's productive base is more complex than could appear to be the case at first blush. Capital assets are patently a part of what one loosely means by a "productive base", but there are intangible objects such as institutions that would not fit the intuitive meaning of "assets" easily and yet are a society's backbone. We provide a classification based on theoretical imperatives. We show in this Report that the classification has proved invaluable in empirical work.

2.3.1 Capital Assets

"Durability" and "tangibility" would appear to be the defining characteristics of capital assets. That assets are durable objects is almost implicit in the term. Tangibility is a less obvious requirement; but it facilitates measurement, and measurement is a prime requirement of national accounts. Certainly, those were basic considerations among quantitative economists of the past. Modern economists have followed a more difficult trail. We follow them and then extend their framework.

Capital assets can be consumer durables (houses, television sets) or producer durables (agricultural land, factories, forests). The notion of assets has, however, become more elastic in recent decades. It has become standard practice to regard "knowledge" as a form of capital (but note that it's intangible), education and health as forms of "human capital" (they too are intangible), and "institutional", "social", and "religious" capital (which are not only intangible, but to many scholars quite beyond the remit of the language of "assets" - Arrow, 2000; Solow, 2000).

What should be included on the list of capital assets is, however, up to a point a matter of convenience. It depends on the purpose to which the notion is put. Here we propose a classification that is useful in sustainability and policy analysis:

(1) Reproducible capital (roads, buildings, ports, machinery and equipment). Reproducible capital is frequently called "manufactured capital" and sometimes as "produced capital". Contemporary national accounts divide an economy's investment in reproducible capital into sectoral investments (manufactures, mining, forestry, agriculture, and so on). Other things being equal, raising the rate of investment in reproducible capital increases

the size of an economy's future productive base. Investment is therefore deferred consumption, a viewpoint we pursue below and then find overly limiting (Section 2.8.1). Market prices are typically used to measure investments in reproducible capital.

(2) Human capital (populations and their endowments of knowledge, skills, health). When economists write about human capital, they usually mean "knowledge and skills". But health is another aspect of human capital. As both education and health are embodied in people, they together make for human capital. Of course, people qua people are themselves assets. So we partition human capital into three categories.

(i) Population (size and demographic profile). Conceptually, this category raises the deepest problems, because people are the reason well-being should occupy the ethical core of sustainability and policy analyses and are as well the means to the realization of well-being. Demographic changes are both the cause and effect of changes in the other components of an economy's productive base.

Each person should be regarded as a separate asset, endowed at any point in time with knowledge, skills, and health. So the population profile matters, including as it does both age and gender distributions. Arrow, Dasgupta, and Maler (2003) showed that estimating the value of population when population movements are acknowledged to be related to movements in, say, GDP per head poses special problems. In the absence of a demographic theory population growth is frequently taken to be exogenously given. Often too, analysts work with population averages. Dasgupta (2001) showed it is a reasonable approximation in that case to incorporate population by expressing the quantities of the other capital assets in per capita terms. That is the route we adopt here (Section 2.5).

(ii) Education. The kind of knowledge included in human capital is in many ways tacit, something a person acquires and is private to him. But as teachers are painfully aware, knowledge isn't costlessly transferable from one person to another; so, education involves costs and should be seen as investment in people.

Knowledge and skills are both ends and means. Reading is a pleasurable activity and thus a form of consumption. The direct benefits of literacy are then reflected in the social value of consumption (consumption's shadow price; Section 2.4). But being able to read is also of indirect value: literacy enhances a person's productivity, implying higher earnings and greater access to consumption goods. Education therefore offers joint benefits. There are now well-known techniques for estimating the value of human capital in a society in terms of earnings. Klenow and Rodriguez-Clare (1997), using methods developed by Mincer (1974), offer simple illustrations of ways to measure human capital in the form of education attainment. Following a review in Section 2.6.3 of the steps needed to estimate shadow prices, we reproduce their methodology in Appendix 9. More comprehensive methods have been developed by Jorgenson and Fraumini (1989).[29]

[29]See also Jorgenson, Landefeld, and Nordhaus (2006) for wide ranging discussions on the framing of national accounts.

Thus far we have stressed the benefits someone enjoys from education. They are private benefits. But when someone learns to read and write and becomes numerate, not only is it he who enjoys a benefit, others do too because they can now communicate with him. The acquisition of education thereby confers "externalities", a notion we develop in detail in Section 2.6.1. Total benefits of education are the sum of private and external benefits.

(iii) Health. Health brings both direct and indirect benefits: (a) an absence of pain and discomfort is one of the defining characteristics of well-being and, other things being equal, healthier people are (b) more productive and (c) live longer.

By "health" we mean both physical and mental health. Disability lowers productivity, which can be measured in principle and often in practice. Physical disability can in various degrees be compensated by the availability of reproducible capital (wheel chairs, reading glasses, hearing aids) and depressions and anxieties by counselling and a less stressful life.

At an extreme, malnourished people lack energy and stamina and are at the bottom of the earnings schedule. Improvements in health over time can thus be measured in terms of increased productivity. It is a significant fact that investments over time in a person's health are complementary, in that damage to one's health at an early stage of life cannot easily be compensated for in later years. Although a person's span of attention and the ability to remain calm even under stressful circumstances are often thought to be "innate" ("in the genes", as the saying goes today), recent work in developmental biology has found that what goes by the name "innate ability" is in part acquired and can be traced to a person's early nutritional and disease history. The epidemiological environment in which an infant grows influences the development of her innate abilities. The social return on investment in the health of women in pregnancy and in the health of infants and children is a lot higher than is often supposed.[30]

We have dwelt on health as means to the enjoyment of a good life ((b) above). But good health also brings direct benefits. By bringing relief from pain, medication improves the quality of consumption (meals taste better in the absence of a head-ache!) and hence an improvement in the quality of life ((a)). Medication would thus appear to be a form of consumption.

Many types of vaccination and inoculation offer only short term protection against pathogens (e.g., a year). It may be thought the expenditures should be classified as consumption; but that would be an error. Defensive measures against pathogens save lives ((c)). To the extent they do, they are a form of investment. Defensive expenditure against environmental pollution (contaminated water, particulates in the air-shed, bed nets) has a similar characteristic.

It is an intriguing and fortunate fact that expenditures that bring relief from pain, or avoid disability, or immunize someone against infectious diseases also help to extend their life. Medication, immunization, and medical treatment thus give rise to joint products: relief from pain and discomfort, greater

[30]For a recent overview of the subject, see Dasgupta (2012b).

productivity, and a longer life. In their work on the measurement of wealth, Arrow et al. (2012a) estimated the value of enhanced life expectancy in a number of countries during the period 1995-2000. Following a review in Section 2.6.3 of the steps needed to estimate shadow prices, we reproduce and extend their methods in Appendix 10.

We have so far classified the benefits an individual enjoys from an improvement in her health. But when someone is immunized against an infectious disease, not only is it she who enjoys benefits, others do too, because they are now less likely to catch the disease. So, immunization confers "externalities", a phenomenon we study in Section 2.6.1 Those "external" benefits should be added to private benefits if we are to estimate the total benefits of health improvements.

(3) Natural capital (local ecosystems, biomes, sub-soil resources). Natural capital is of direct use in consumption (fisheries), of indirect use as inputs in production (oil and natural gas; the wide array of ecosystems), and of use in both (air and water). The value of natural capital may be utilitarian (as a source of food, or as a keystone species) - many people call this its use-value; it may be aesthetic (places of scenic beauty), or it may be intrinsic (primates); or it may be all these things (biodiversity). Their worth to us could be from extraction (timber, gum, honey, leaves and barks) or from their presence as a stock (forest cover), or from both (watershed). The stock could be an index of quality (air quality) or quantity. Quantity is sometimes expressed as a pure number (population size); in various other cases it is, respectively, (bio)mass, area, volume, depth. Even quality indices are often based on quantity indices, as in "parts per cubic centimetres" for measuring atmospheric haze.

The classification offered above is useful in economic evaluation because it is based on the reasons we value Nature. For understanding the changing landscape in contemporary economies, however, the classification in MEA (2005a-d) is more useful. There natural capital is classified in terms of the kinds of services they provide.[31]

There are three further categories of goods that are components of an economy's productive base but which, for reasons to be explained in Sections 2.4 and 2.5, should not be included on the list of capital assets when computing an economy's wealth.

2.3.2 Knowledge

Science and technology and the arts and humanities are commonly regarded as capital assets. They are the seat of discoveries and inventions: Nature's laws, abstract theorems, formulae, algorithms, and historical and cultural narratives. The products are durable, intangible public goods. By calling knowledge a "durable public good" we mean that a piece of knowledge can in principle be used by anyone

[31]Theirs is a four-way classification of ecosystem services: (i) provisioning services (food, fibre, fuel, fresh water); (ii) regulating services (protection against natural hazards such as storms; the climate system); (iii) supporting services (nutrient cycling, soil production); and (iv) cultural services (recreation, cultural landscapes, aesthetic or spiritual experiences). Notice that cultural services and a variety of regulating services (such as disease regulation) contribute directly to human well-being, whereas others (soil production) contribute indirectly (by providing the means of growing food crops). As this Report has been commissioned because of the need to make national accounts "green", we discuss natural capital more fully in a separate section (Section 2.7) and in the Annexe. Bateman et al. (2011) provide a fine discussion of the valuation of ecosystem services.

who wishes to make use of it, and can do so repeatedly. A mathematical theorem knows no cultural or national boundaries.

Many regard scientific and technological knowledge to be the most significant feature of an economy's productive base. Note though that for someone to make use of a piece of knowledge three conditions must be met: (i) a recognition by the person that the knowledge exists; (ii) the person should have the relevant skills (human capital!); and (iii) there should be no legal or social barrier (patents and copyrights) to applying the knowledge. Research and development involves investments in codified knowledge. Frequently though, knowledge can be obtained freely from external sources (for example, once patents have expired). These aspects of knowledge suggest that its instrumental role lies in conferring value to the goods we identified in Section 2.3.1 as being capital assets. Before the advent of the iron-age, for example, iron ore was of little value. But once the art of extracting the ore and converting it into useable iron was discovered, the ore acquired value. Its shadow price rose.

Some types of knowledge are also consumption goods. Contemplating a beautiful idea enhances well-being directly, as does reading literature. They have direct value. The way to estimate the shadow price of public goods that are both durable and serve as consumption goods is discussed in the Annexe.

2.3.3 Institutions

What about institutions? When scholars write on the progress or regress of societies, it is not uncommon today for them to refer to "religious capital", "social capital", "cultural capital", and more broadly "institutional capital". Nevertheless, as in the case of knowledge, it is as well not to regard institutions as capital assets.[32] Let us see why.

Institutions are the myriad of formal and informal arrangements to which people belong. Those arrangements influence the allocation of resources both at a moment in time and through time. Households, firms, communities, and the State are obvious examples of institutions. But institutions also include a broader kind of "enabling assets", such as the rule of law, social norms of behaviour, and habitual social practices. They form the social infrastructure within which goods and services get allocated.

What role do institutions play in economic evaluation? They influence the value of what we are calling capital assets. Suppose the State apparatus in a country is corrupt, in particular the judicial system is unreliable. Because people find it difficult to protect their property rights, the value of the assets they own is small, other things being equal. Corruption reduces the social worth of capital assets.[33]

The above example shows that the key to the efficacy of institutions is the extent to which they elicit trust among people. Consider as an extreme example two islands that are identical in all respects but for the fact that in island 1 households trust one another completely whereas in island 2 households do not trust one another at all. Despite their identical configurations of capital assets, the structure of shadow prices would be wholly different.

[32]Sociologists speak of "symbolic capital" as well. See Bourdieu and Passeran (1990).
[33]No doubt the purpose of corrupt practice is to enhance the market worth of assets owned by the practitioner. In the text we are referring to the social worth of assets.

The reason is that households in island 1 would begin to trade with one another, whereas in island they would remain autarkic. In short, institutions aren't enough. If societies are to progress, people must trust one another and have confidence in their institutions.[34]

Institutions influence the composition of consumption, saving, and the character of future institutions. There are institutions that foster progress by having in place a structure of incentives that encourage people to allocate goods and services in their most productive uses. Well developed competitive markets, tight social norms and codes of conduct, and good governance together can combine to help create and maintain trust and confidence. But mutual trust and the cooperation that can result from it can't be guaranteed even under sound institutions. Opportunistic behaviour can beget opportunistic behaviour. Institutions can founder under a cascade of opportunism unless there are checks and balances in place by virtue of the presence of a mesh of countervailing institutions.

Institutions aren't static. Just as they influence the allocation of resources, the allocation of resources influences the evolution of institutions. Lipset (1959), for example, has argued that economic development fosters democracy. A good theory of political economy would include an account of the mutual influence of institutions, preferences, human motivations, and the productive base of an economy.

A prime example of the mutual influence of institutions and economic development is financial institutions. Expansion of financial institutions helped initiate economic development in late medieval Europe. By the same token, the technological changes that accompanied economic growth over the centuries encouraged the creation of new financial institutions; but not necessarily for the better. Ideal financial markets would not suffer the way countries are currently experiencing.

Financial institutions create and legitimize financial capital. But financial capital does not form a separate category of assets, it consists of claims to capital assets. Someone who owns shares in a firm has a claim to a share of the market value of the firm. His shares reflect the market value of the assets to which he has claim. The same holds for currency and bonds. They are claims to whatever bundle of goods and services the holder wishes to purchase, subject only to the condition that the market value of the bundle does not exceed the value of the currency and bonds he holds. To include financial capital in the wealth of nations would be to make a mess of economic evaluation.

2.3.4 Time

A society's productive base can change for the better or worse simply by the passage of time. Consider a small oil exporting country. Being small, the country has no control over international oil prices. Meanwhile, or so let us imagine, an oil cartel, of which our country is not a member, raises its price on a continual basis. Our country therefore enjoys capital gains on its reserves without having to engage in any form of capital accumulation. Its productive base expands.[35] Similarly, it could be that the

[34]On the role of trust in sustainable development, see Dasgupta (2011).

[35]The same logic says that, other things being equal, an oil importing country would find its productive base shrinking as the international price of oil rose over time.

country enjoys an expansion of its knowledge base by deploying scientific advances elsewhere without paying for that privilege. In both circumstances our country enjoys an expansion of its productive base simply by waiting. It's wealth increases correspondingly. Previously we noted that exogenous population growth is another example. These examples tell us the value of capital assets can depends explicitly on time. The calendar date can matter.

Exogenous changes over time of an economy's productivity appear in macroeconomic data in the form of growth in *Total Factor Productivity* (TFP). TFP growth forms yet another example. It will pay to revisit that familiar notion.

To recall what TFP growth means, suppose over an interval of time a country's (real) GDP has increased. There are now standard methods for decomposing that growth into increases in labour force participation (population growth; increases in women's employment in paid labour), and the accumulation of reproducible capital and improvements in skills and health. Suppose when we have added up all the contributions made by these factors of production, we find that the sum falls short of GDP growth. We are entitled then to interpret that shortfall as an increase in the overall productivity of the economy's capital assets; by which we mean that more output can be produced now than earlier even if the amounts of such factors of production as machines and equipment and skills had remained the same. This is a formal way of acknowledging that there has been a general rise in the efficiency with which goods are produced. Today growth in TFP is called the "Solow residual", in honour of Solow (1957) who, in a study of time series on output, employment, and reproducible capital in the US found that a significant proportion of the growth in output was left unexplained. Solow called that unexplained part a "residual".

The regression equations from which the Solow residual is usually estimated (e.g., Romer, 1996) doesn't include the use of natural capital in production. It's however obvious that if the use of natural capital in production were to have increased over the years but is not recorded in income accounts, the Solow residual would appear to be larger than it actually is. This is doubly ironic. It means ignoring natural capital in national statistics is to make resource depletion appear through the back door as productivity growth! Xepapadeas and Vouvaki (2009) have found contemporary data where the error is substantial.

2.4 Shadow Prices

A commodity's shadow price is its social scarcity value, a notion familiar in social cost-benefit analysis. Here we define shadow prices and study their role in sustainability and policy analyses. Appendix 2.6 contains a formal treatment of the notion; Section 2.6 contains elaborations. The Annexe classifies ways to value environmental resources. It also provides illustrations based on empirical studies.

2.4.1 Definition

Consider first consumption goods. If durable (clothing, shelter), they embody consumption services over time. If non-durable (food), they vanish on consumption. So we may as well use the term "consumption" as it occurs in everyday language, where reference is made to consumption rates. We will take it that consumption is a flow, and that it affects the flow of societal well-being at that date and that date alone.[36] We then have

Definition 2: The shadow price of a consumption good is the contribution an additional unit of it would make to the flow of societal well-being.

Provided the consumption goods are private (i.e., their use isn't associated with significant externalities; Section 2.6.1), their market prices are frequently reasonable approximations of their shadow prices. For capital assets the notion of shadow prices is trickier; for assets are durable and, excepting for consumer durables, they are inputs in the production of other goods. Formally, we have

Definition 3: An assets' shadow price is the contribution an additional unit would make to intergenerational well-being, other things being equal.

The determinants of intergenerational well-being are the consumption goods and services enjoyed by contemporaries and by people across the generations, a point that is explicit in equation (3). Definition 3 can therefore be re-expressed as

Definition 3a: An asset's shadow price is the social worth of the change in the consumption stream an additional unit of it would give rise to, other things being equal.

Capital assets are by their nature durable goods. Some are tangible (roads, wetlands), others are not (skills). Although assets depreciate (machines and equipment undergo wear and tear even when left unused; fisheries are destroyed when over-harvested; and people have been known to lose their skills with age and to take their human capital with them when they die), but they offer a flow of services over time. A desk offers the scholar an object on which she is able to read, write, and type. The value of the desk is the worth of the contribution it is expected to make to scholarly activity. In order to assess that worth, we need to estimate the value of the scholarly activity itself. The latter's value will include the enjoyment the scholar experiences from the activity and the benefits others enjoy from the fruits of that activity. Of course, it could be that she is fully compensated for the benefits others enjoy from her work; the compensation being, say, higher earnings and increased adulation. But it may be that the higher earnings and increased adulation, when taken together, are less than the totality of benefits others enjoy from the fruits of her scholarly activity. In the latter case we should estimate not only the value of the desk to the scholar - that would be the desk's private value to the scholar - but also that part of the value to others that doesn't get reflected in her increased emoluments and social esteem. In short, we should be interested in the desk's social worth. But the desk in question is one among (hopefully!) many desks. That particular desk can therefore be viewed as a marginal unit of the totality of all desks. The social worth of a marginal unit of an asset is its shadow price. That's Definition 3.

2.4.2 The Primacy of Economic Forecasts

As the example of the writing desk makes clear, an asset's shadow price depends not only on its current use, but also on its future use. So the price depends on the forecast of the

[36]Habits, like memories, are stocks, not flows.

use to which the asset will be put. That's an inevitable feature of the worth of anything. A writing desk predicted to rest unused and unrecognised is value-less today. In contrast, if it is predicted that the desk will be used to good effect, its current shadow price would be positive. Social evaluators who agree on everything but the forecasts of the desk's use would impute different shadow prices to it.

In our example the focus has been on the dependence of the desk's shadow price on the way it is predicted to be used. More generally, though, an asset's shadow price depends on the forecast of the economy's future trajectory. To see why and how, imagine that a proposal has been made to cut into a wetland to make way for a highway. Among its many other virtues, the wetland offers residence to pollinators; and agriculture benefits from pollination. If an economy's development path is predicted to be rapacious in the destruction of its wetlands, there will be an especial scarcity of wetlands in the future. The shadow price of the wetland today would be high in consequence, other things being equal. Current shadow prices contain a great deal of information about future prospects.

Ideally, economic forecasts would be detailed enough to contain predictions of what future national accounts will report. And the predictions should be no mere guesses. As a minimum the forecast should be perceived to be technologically feasible; but if they are to carry conviction, forecasts should be based on a defendable theory of the social and natural processes shaping the economy's future. That means shadow prices are based on counter-factuals: they depend not only on the forecast of the shape of things to come, but also on the forecast of future development had the current stocks of capital assets been otherwise.

In practice forecasts are of aggregate quantities such as GDP, consumption, investment, population, and employment. If they are to be plausible, those aggregate variables must be shown to relate to one another in a defendable theory of the economy's evolving political economy. As consumption goods are the immediate determinants of well-being, we focus on forecasts of consumption. Forecasts of the remaining economic variables would be derivable from the forecast of the consumption stream.

Imagine the forecast is to be made at date t. K(t), typed in bold as previously, is a list of quantities of all the economy's capital assets. K(t) is therefore a vector and will have been inherited from the past. Ideally K(t) would be a complete list of who has access to which asset at t; but in practice we would expect national accounts to record K(t) in aggregate terms (so many hectares of agricultural land, so many square miles of forests, so much industrial capacity in the public sector, and so forth). As previously, u is a variable that runs from t onward, and C(u) denotes the consumption vector at u. For notational simplicity, let Z(t) stand for the consumption stream {C(t),C(t+1),...,C(u),...}. As the forecast of Z(t) is based on K(t), counter-factuals enter the picture. The reason they do is that the forecaster should be expected to offer an account of the reasoning that led him to make his forecast. But if he were able to do that, he would be in a position to forecast what the future consumption stream would be if the inherited stock of assets had been otherwise. So, the Z(t) that is forecast is based on K(t) and perhaps also on t to reflect the case where calendar time matters.[37] We may then write Z(t) as Z(K(t),t). In short K(t) and t taken together form a "sufficient statistic" for Z(t).

Because C(u) is a complete list of who consumes what at u, it embodies the immediate determinants of the flow of societal well-being B(u), as in equation (3). That means one can deduce intergenerational well-being from the forecast Z(K(t),t). We may then express V(t) as V(K(t),t), the explicit dependence of V on t reflecting the possibility that calendar time matters. We conclude that V(t) can be inferred from the assets the economy has inherited at t. V(K(t),t) is a reduced form of intergenerational well-being at t.

The conclusion could appear as a sleight of hand, for how can the future be summarized in data pertaining to the present (K(t))? In fact the claim is no more than the ancient wisdom that the future is imprinted in the present. If the analyst has a sufficiently complete model of the features and processes that shape the development of an economy, he should be able to read the future in today's capital stocks. This chain of reasoning explains the primacy of forecasts in economic evaluation. We offer a technical formulation of the idea in Appendix 1.

Shadow prices are the links between assets, K(t), and intergenerational well-being, V(t). If V is sensitive to the distribution of well-being among contemporaries, as it clearly should be, shadow prices would reflect those considerations. (An asset in the hands of someone needy would be valued higher than if in the hands of someone well-off; other things being the same.) Shadow prices also reflect the desirable balance between current and future well-beings (the parameter δ in equation (3)), and thereby the intergenerational distribution of consumption. There is a close connection between "social discount rates" and shadow prices. These connections are drawn formally in Appendix 2.

A pollutant's shadow price would be negative. But the shadow price of even a potentially desirable asset would be negative if the quality of governance in the country is so low that an additional unit of the asset would reduce intergenerational well-being. An oil field whose output finances armaments that enable a war-lord to terrorise opponents has a negative shadow value.

2.4.3 Choice of Numeraire

In what units should shadow prices be expressed? As with market prices, absolute shadow prices have no meaning, only relative shadow prices have meaning. So we need a unit of account in which goods and services are to be valued. Economists refer to the chosen unit of account, numeraire. It has become customary to regard the numeraire as an appropriately selected bundle of consumer goods. The "consumer price index" is based on that thought. Prices of all other goods and services are expressed in terms of that bundle, expressed in domestic currency (for international comparisons prices are expressed in international dollars, PPP). If we agree on the way well-being depends on the chosen numeraire, the "price" of well-being can be expressed in terms of the numeraire.

[37]That calendar date can matter is another way of saying that certain features of an economy may change exogenously (e.g., international prices, knowledge produced by other countries for which payment doesn't have to be made).

In what follows, for simplicity of exposition we adopt intergenerational well-being as numeraire. That way we would be neutral across goods and services. Should readers prefer to work with a particular consumption good as numeraire, the appropriate conversion would be to divide all shadow prices expressed in terms of intergenerational well-being by the shadow price of the new numeraire.[38]

2.4.4 Facing Uncertainty

So far forecasts have been taken to be certain. That's an idealization. Not only is the future shot through with uncertainty, knowledge of even current matters is incomplete and uncertain. Very few countries, for example, maintain a reliable inventory of their assets.

That economic forecasts are frequently made as though they are certain to be realized doesn't mean the forecaster is certain of the eventualities. It could be that his forecast is an average of various possibilities and that he has arrived at the average by turning to the language of probabilities. The probabilities he assigns to various possible futures will mostly be "subjective".[39] Being subjective estimates, even experts disagree. Sharp disagreements among experts are currently illustrated over the probable consequences of carbon emissions, the current rate of biodiversity loss, the ability of the oceans to recycle pollutants, and over many other environmental matters. Not only are there disagreements over, for example, the effect of atmospheric carbon concentration on the spatial pattern of temperature and rainfall and occurrence of extreme climatic events, there are disagreements on the possible consequences of climate change on agriculture, sea level, and so forth. And there are few agreements on the way those consequences should be valued.

That probabilities are all too frequently subjective is no reason for rejecting their use. Just as people's values differ, so do their readings of the processes that shape the world differ. And just as it is possible, even necessary, to discuss values and sift through them, so it is possible, even necessary, to discuss likelihoods and sift through the evidence to narrow them down. In any case, we are rarely faced with problems ab initio. For every new phenomenon there is some related phenomenon about which information is already available. Such evidence, in conjunction with pilot studies, allows one to narrow down probability distributions. As further information becomes available with the passage of time, the family of possible distributions becomes narrower. On the other hand, when genuine surprises occur, the possibilities are enlarged and the distributions thicken. And so on.

So, forecasts are probabilistic. They don't identify consumption streams with certainty but are instead probability distributions over consumption streams, much like weather forecasts. Nevertheless, economic forecasts are often expressed in non-probabilistic terms. When they are, they should be read as the forecaster's expectation of what the future has in store.

---

[38]The procedure here is no different from the way we convert market prices from one currency into another.

[39]Loosely speaking probability distributions over possibilities are said to be "objective" if there have been so many instances in the past that the probability estimates are obtainable from frequency distributions (e.g., rainfall). The term "subjective" is used for all other cases. The terms "risk" and "uncertainty" are often used to distinguish the two cases. There are now a number of excellent texts on the subject. A classic is Raiffa (1968).

Associated with each possible consumption stream would be a corresponding value of intergenerational well-being. Consider now the formulation of intergenerational well-being in equation (3). If the social evaluator were to make use of the classical theory of normative decision-making under uncertainty, she would use the expected value of intergenerational well-being as the object of economic evaluation. The way she would arrive at the expected value of V would be to calculate intergenerational well-being along each possible future consumption trajectory Z(t), weight it by the probability of Z(t)'s occurrence, and sum over them. Let E denote the expectation operator. The expected value of intergenerational well-being at t is then E[V(t)], which means

$$E[V(t)] = E[_{u=t}\Sigma B(C(u),u)/(1+\delta)^{(u-t)}], \quad \delta \geq 0. \qquad (4)$$

Definition 2 can now be suitably re-expressed to incorporate uncertainty:

Definition 4: An assets' shadow price is the contribution an additional unit of it would make to the expected value of intergenerational well-being, other things being equal.

It bears emphasis that so long as the social evaluator has identified the function V she is to use, shadow prices themselves would not be uncertain. What she would be uncertain about is the future; and as Definition 4 says, that uncertainty is reflected in the structure of shadow prices. Appendix 3 demonstrates this formally.

Nevertheless, the social evaluator would be well advised to identify a range of shadow prices for each capital asset. The reason is that she would well-advised to field alternative moral conceptions and not be wedded to a particular functional form of V. Different parametric specifications of V reflect alternative weighting systems for the multitude of social objectives we happen to hold. If the social evaluator were to specify V, she would no doubt obtain a set of shadow prices. But if she were to specify a different V, she would obtain a different set of shadow prices. One way to test the sensitivity of economic evaluation to alternative specifications of V is to test the extent to which economic evaluation is sensitive to the shadow prices of capital assets.[40]

2.4.5 Preservation and Option Values

Natural capital can possess yet another kind of value arising from a combination of two things: uncertainty in its future value and the possibility that its destruction would be irreversible. Preservation has the value of offering society flexibility as regards the future. Future options have an additional worth arising from the fact that with the passage of time more information should be forthcoming about the resource's value. That additional worth is often called an option value.[41]

Nowhere has the desirability of keeping future options open been advanced as persuasively as in discussions on the need for on-site preservation of genetic diversity of plants and crops. Tropical forests are particularly noted for providing a habitat for a rich genetic pool, many as yet untapped while some are even now essential in pharmaceutical products. Ecologists express concern that an increased

---

[40]On sensitivity analysis and its importance in economic evaluation, see Dasgupta, Marglin, and Sen (1972).
[41]The idea of option values is due to Weisbrod (1964), Arrow and Fisher (1974) and Henry (1974).

reliance on high-yield varieties has reduced the genetic variability of crops. As new varieties of crop pests and diseases appear, the chance of locating crop varieties resistant to them will be that much lower if genetic reserves are small. The value of genetic pool will become more and more sharply etched with the passage of time.[42]

2.5 Wealth and Well-Being

Earlier we noted there is a close connection between intergenerational well-being and wealth, and that shadow prices provide the link. But the connection was not made explicit. We now study the relationship between wealth and well-being formally. Appendix 4 contains proofs and elaborations.

2.5.1 Growth in Wealth and Sustainable Development

For expositional ease, we assume for now that population is constant. The assumption allows us to remove population from the list of assets. We re-introduce population in Section 5.4 and show how to include it in economic evaluation. For the moment the list of assets comprises reproducible capital, education, skills and health, and natural capital. As previously, time is discrete and $K_i(t)$ is the stock of asset i. Let $P_i(t)$ denote i's shadow price. We do not specify the number of assets but merely regard the vector K(t) to denote the an indefinite number of stocks $\{K_1(t),...,K_i(t),...\}$. Ideally the assets should be so labelled as to include the individual who has access to it. In practice that labelling isn't feasible, excepting for such broad distinctions as public, state, and private ownership.

Wealth is the social worth of an economy's array of capital assets. We write it as W. In our model economy wealth at date t is

$$W(t) = i\Sigma[P_i(t)K_i(t)].^{43} \qquad (5)$$

We now introduce a familiar notation: If X is a variable, we denote a small change in X by ΔX. Our task is to develop the role wealth plays in sustainability and policy analyses.

Consider a brief interval of time, Δt, starting at t. For concreteness we may think of Δt as a year. Denote the change in V over the year by ΔV(t). Similarly, $\Delta K_i(t)$ denotes the change in the quantity of asset i over the year. If $\Delta K_i(t)$ is positive, there will have been an accumulation of asset i over the year; if it is negative, there will have been a decumulation. We may now use equation (5) to define the change in wealth over the year, ΔW(t), as $_i\Sigma[P_i(t)\Delta K_i(t)]$. The fundamental result in sustainability analysis is

Proposition 1: Wealth and intergenerational well-being track one another: in any brief interval of time wealth increases if and only if intergenerational well-being increases.[44]

Proposition 1 can be re-expressed formally as

Proposition 1a: $\Delta V(t) \geq 0$ if and only if $_i\Sigma[P_i(t)\Delta K_i(t)] \geq 0$.

Recalling Definition 1 we can also express Proposition 1 as

[42]Kumar (2009) contains a recent attempt to estimate the option value of biodiversity.

[43]Some authors refer to W as "inclusive wealth" (World Bank, 2006, 2011; UNEP/UNU-IHDP, 2012), others call it "comprehensive wealth" (Arrow et al., 2012a). However, World Bank (2011) defines inclusive wealth differently. See Appendix 4.5 for a review of their study of the wealth of nations.

[44]The Proposition was proved by Hamilton and Clemens (1999) for an optimizing economy and Dasgupta and Maler (2000) for arbitrary economies.

Proposition 2: An economy's development is sustainable over any brief interval of time if and only if its wealth increases over the interval.

2.5.2 GDP and Wealth

It is as well to illustrate the significance of Propositions 1 and 2. Consider a closed economy with constant population. Suppose in a given year it invests 40 billion dollars in reproducible capital, spends 20 billion dollars on education, and depletes and degrades its natural capital by 70 billion dollars. As Chapter 2 notes, the economy's SNA would record the 40 billion dollars as investment, the 20 billion dollars as a component of aggregate consumption, and remain silent on the 70 billion dollars of loss in stocks of natural capital. In contrast the accounting methods advocated by Propositions 1 and 2 would reclassify the 20 billion dollars as expenditure on the formation of human capital ("investing in the young", in common parlance) and the 70 billion dollars as disinvestment in natural capital. Aggregating over them and assuming that expenditure on education is a reasonable approximation of net human capital formation, the methods advocated here would conclude that owing to the disinvestment, the economy's wealth will have declined over the year by 10 billion dollars (and that's before taking note of the depreciation of reproducible capital). Proposition 1 says development was unsustainable that year. The example also shows that GDP is unsuitable to serve as a criterion by which to judge sustainability. It shows too why HDI is unsuitable. Neither records the depreciation of capital. Appendix 5 goes into details.

It can easily be that GDP per capita grows even while wealth per capita declines. What is impossible would be for wealth per capita to decline indefinitely while GDP per capita increases ceaselessly. That's impossible because in due course the productive base of the economy, which is what wealth measures, would have little left to further degrade and depreciate. The simplest illustration is that of a small economy whose income is based solely on the export of an exhaustible resource. Imagine that the export price is expected to remain constant, say because the rest of the world has access to a technology for manufacturing a perfect substitute for the resource, at a constant unit price. If all export revenues were consumed, GDP in our model country would equal aggregate consumption. NDP, however, would be zero at all times because consumption would always equal depreciation of the economy's sole asset. Wealth, meanwhile would be declining, at a rate equal to the export revenue. Imagine that the national policy is to raise exports annually. In that case GDP (consumption) would increase annually. But the policy could not be followed indefinitely. In due course aggregate GDP would have to decline because of the ever dwindling resource stock.

Propositions 1 and 2 are equivalence relationships. On their own they can't tell whether a country has been on a sustainable development path. What they do is to tell us that wealth can serve as an index with which to judge whether development has been or is likely to be sustainable. The Propositions justify the use of wealth as a normative criterion in economic evaluation.

The equivalence relationship in Propositions 1 and 2 is restricted to evaluations over "brief" intervals of time. Proposition 1a explains why. It says movements in wealth should be measured at constant shadow prices. But if the interval of time is long, changes in relative prices would matter. In Appendix 4 we also show that the Propositions can be adapted to the needs of a social evaluator who tracks an economy's performance over a long interval of time. Note though that the meaning of a "brief interval" depends on the extent to which economic data are presented as time averages. It isn't uncommon to read records of the progress and regress of national economies that involve not-very-brief periods (say, 20 years) but present changes in economic variables in terms of time averages over the entire period. For example, we not infrequently learn of a particular country that population grew at, say, 1.2 per cent a year over the previous 20 years, that GDP increased at 2.4 per cent a year over the same period, that the ratio of investment in reproducible to GDP was 15 per cent, and so on. Propositions 1 and 2 are valid for such data.

In common parlance a person would be said to have invested in an asset if his portfolio now contains more of it. By the same token the person would be said to have disinvested in an asset if his portfolio now contains less of it. Propositions 1 and 2 say that an economy's development path should be described in terms of movements in its portfolio of assets. Proposition 2 for example says that economic development is sustainable if and only if an economy accumulates wealth. That is an intuitive enough notion. The hard part is to know what to include in the concept of wealth and how to measure its accumulation. We discussed a number of those problems in Sections 2.3-2.4 and found answers too. Sections 2.6-2.7 and Appendix 4 resolve certain problems of interpretation in connection with Propositions 1-2.

2.5.3 Income and Wealth

Income is a flow, wealth is a stock. Wealth is the dynamic counterpart of income. It should have come as no surprise that income (alternatively MEW) is an index of the determinants of the flow of societal well-being, a finding that was much discussed in the classical literature (Section 2.2.1). Extending that thought, it should have been expected wealth to be the appropriate index of the determinants of intergenerational well-being. No doubt income and wealth would move in the same way over time if the economy under study is in a steady state. The reason is that in a steady state the composition of the economy remains the same over time, which in turn implies that relative to one another shadow prices remain constant over time. Outside steady states, however, the two formulations differ and a choice has to be made between them. The flow of societal well-being is an ingredient in intergenerational well-being, but isn't a substitute for it.

2.5.4 Growth in Wealth as an Objective of Public Policy

Policy evaluation involves assessing the impact of a perturbation imparted to an economy at a point in time. The perturbation could be an investment project, a change in the tax system, a modification in an institution, and so forth. Although imparted at a point in time, the perturbation has long term consequences. What are the counterparts of Propositions 1 and 2 in policy evaluation?

Consider an investment project. The project involves the reallocation of capital assets from one set of activities to another. Labour and skills, land, machinery, and equipments would be required for the project in each year of its life. Presumably they would be deployed elsewhere if the project was not accepted. The project therefore demands redeployment of those assets. Suppose the project is to commence at date t. The trick is to expand the meaning of a capital asset to include the task to which the asset has been assigned. With that re-interpretation we can re-write Proposition 1a as

$$\Delta V(t) = {}_{i}\Sigma[P_i(t)\Delta K_i(t)]. \qquad (6)$$

Equation (6) has a different interpretation from the equivalence relationship in Proposition 1a. The reason is that although accepting the project would be to perturb the economy, the perturbation would be applied at time t. Let us now recall Definition 3. It says that the right-hand-side of equation (6) is the PDV of social benefits generated by the reallocation of capital assets the project gives rise to. So we may re-phrase the familiar criterion for project evaluation as

Proposition 3. A project contributes to intergenerational well-being if and only if it increases wealth.

2.5.5 Sustainability and Policy Analyses: An Equivalence

Propositions 1 and 3 provide a unified treatment of sustainability and policy analyses. We formally state the unification as

Proposition 4: Wealth is the appropriate criterion in both sustainability and policy analyses.

A corollary of Proposition 4 is that neither GDP per head nor the United Nations' Human Development Index (HDI) can serve effectively in economic evaluation. The reason is that neither GDP nor HDI reflects an economy's wealth. Appendix 5 elaborates on this.

Propositions 1-4 imply that capital accounts should be the basis for economic evaluation. No doubt income and expenditure accounts are necessary inputs in the construction of capital accounts, but it is the latter that provide the social evaluator with information about the economy's portfolio of assets. Economic evaluation involves the study of how an economy's assets are managed and how they ought to be managed.

The changes to national accounts we are advocating here bring with them the need to revise our estimates of familiar economic variables. It is for example customary to regard industrial capital-output ratios to be of the order of 3-5 years. For the economy as a whole the corresponding figures would be wealth-output ratios. And they can be expected to be far larger than the capital-output ratios we usually deal with. We should not be astonished if in the world we are beginning to know, wealth-output ratios are as large as 30-40 years. The reason is clear. Economic output (GDP) involves many more kinds of capital assets than are usually considered in economic models. It is time we acknowledge that an economy's asset base is far deeper and more extensive than is currently recognized.[45]

2.5.6 Population as an Asset

Population is a capital asset. But as people differ by age and gender, we could regard age cohorts as "vintages". Ideally population

[45]In an albeit very crude estimate, Arrow et al (2012a) found the wealth-output ratio in India in the late 1990s to be of the order of 120 years!

would comprise as many types as are given by twice the number of age cohorts, the doubling being a way to distinguish males and females. In practice such disaggregation could prove overly costly. The other extreme would be to aggregate and regard "people" as the asset in question. The size of the population can then serve as the quantity of the asset. If that were to be the practice, one of the assets in equation (4) would be population.

To regard population as another asset is empirically problematic (Arrow, Dasgupta, and Maler, 2003). The matter has to do with estimating its shadow price, which would require us to specify human well-being in a sharper manner than we are accustomed to. It would take us far afield to elaborate on the matter, but it can be shown that if the ethical conception is intergenerational well-being averaged over the generations, then under a not unreasonable set of empirical circumstances the problem can be avoided if we were to measure the quantities of all other capital assets in per capita terms.[46] Proposition 1 in that case can be restated as

Proposition 5: Wealth per capita and intergenerational well-being averaged over the generations track one another: over any brief interval of time per capita wealth increases if and only if intergenerational well-being averaged over the generations increases.

In Proposition 5 population is not seen as a capital asset. Wealth is taken to be the social worth of the economy's array of reproducible capital, human capital (knowledge, skills, and health), and natural capital. We are then required to divide wealth by the population size and track its movement over time. That move makes for great simplification. It means the social evaluator doesn't have to estimate population's shadow price. So long as wealth and intergenerational well-being are measured in per capita terms, the equivalence between the two continues to hold. A proof is sketched in Appendix 4.

2.6 Shadow Prices: Further Considerations

How are shadow prices related to market prices?

2.6.1 Externalities

In idealized circumstances, an asset's shadow price equals its market price. In normal circumstances, however, the two sets of prices differ. By "normal circumstances" we mean circumstances in which the distribution of wealth is ethically indefensible and/or where individual actions give rise to externalities, a class of phenomena that are ubiquitous in economies we have come to know. Here we study the latter.

Externalities are the unaccounted for consequences for others of actions taken by one or more persons. Ideal markets would not countenance externalities. They would mediate to put a price on externalities and thereby eliminate them. Externalities are ubiquitous in the world we know because markets for many commodities either do not exist (e.g., because

---

[46]See Dasgupta (2001). Formally, in place of the expression for V(t) in equation (3), we have
$v(t) = V(t)/[_{u=t}\Sigma L(u)/(1+\delta)^{(u-t)}],\delta \geq 0,(3a)$
where L(u) population size at date u; or in other words,
$v(t) = [_{u=t}\Sigma B(C(u),u)/(1+\delta)^{(u-t)}]/[_{u=t}\Sigma L(u)/(1+\delta)^{(u-t)}],\delta \geq 0.(3b)$

of property rights to them are weak) or are not competitive when they do exist. Externalities are the differences between shadow prices and market prices (below, equation (7)).[47]

Externalities are rampant when we put environmental resources to use, because property rights to prominent classes of those resources are difficult to enforce, often impossible even to define. By "property rights" we mean not only private property rights, but also communitarian rights, even national rights. One reason property rights to various types of environmental resources are weak is their mobility. The wind blows, rivers flow, fish swim, deer flee, birds and insects fly, and even earthworms are known to move. Not unnaturally, they are called "fugitive resources". Property rights to an object are difficult to enforce if you cannot harness it. If markets and communities aren't able to eliminate externalities, the role of an external enforcer becomes apparent. Appendix 6 contains a formal account of the dynamics of several prominent classes of fugitive resources.

To see what problems they raise, consider that the oceans beyond national jurisdiction are open to all. The creation of private property rights to individuals would be otious, but it would also be unworkable: fish don't respect human-made property rights. The absence of property rights means that firms aren't required to pay a fee for the fish they harvest. Consequently there is overfishing in the open seas: the price of fish in the market is less than its shadow price. If an external authority were to impose an appropriate fee for every fish caught, there would be no overfishing. This would not be a market solution though; it would be an administered solution to the problem of overfishing. That humanity has collective responsibility over the state of the world's oceans used to be explicit in the 1970s, when politicians claimed that the oceans are a "common heritage of mankind".

Carbon in the atmosphere raises the reverse problem. Households currently don't have to pay anything for the right to emit the carbon they generate at home. Because emissions defuse through the atmosphere (a fugitive!), it isn't possible to assign private property rights to the open atmosphere. We can therefore be confident that carbon emissions are excessive. Consequently consumption goods with "carbon content" are priced lower than they should be. Today experts judge that world-wide further additions to the stock of carbon in the atmosphere would have a negative value. This means that even though the market price of carbon in the atmosphere is zero, its shadow price is negative. Admittedly we refer these days to the "market for carbon", but such a market is viable only if national governments impose quota restrictions on total emissions, which again is an administered solution.

The general principle to take away from these examples is that when the externalities are harmful, activities giving rise to them are underpriced in the market. The reverse is the case for activities giving rise to beneficial externalities. Ecological services are widely acknowledged to be underpriced in the market. The corresponding assets (e.g., locations of biodiversity) are thereby also underpriced. Note though that ecological services that are contained within a piece of private land wouldn't necessarily be underpriced. If there

[47] Arrow (1971) and Meade (1973) are excellent studies in the pure theory of externalities.

were a reasonably efficient market for land, the value of the services would be included in the land's price. This is especially pertinent in the case of agricultural land.[48] The production of food is the main service provided by such land (MEA, 2005a, calls it a "provisionary service"). But food production also depends on complementary services: soil regulation, water flow, pest and disease regulation, pollination, nutrient cycling, and so on. Their availability would be included in the market value of the piece of land. Of course, it could be that the pollination service is provided by birds and insects inhabiting a neighbouring woodland. In that case the woodland would be undervalued in the market, but not the agricultural land![49]

2.6.2 Scarcity and Time

Earlier we noted that the term "consumption" should be interpreted expansively. We are to think of consumption as the flow of the direct determinants of well-being. Capital assets are our sources of consumption. Because intergenerational well-being depends on the distribution of well-being among contemporaries and among the generations, shadow prices of assets reflect distributional considerations too.

Economic forecasts include future scarcities of goods and services. Definition 1 assures us that those scarcities are reflected in today's shadow prices. Moreover, the greater is the weight placed on future well-being in the conception of intergenerational well-being (i.e., the smaller is δ in equation (3)), the larger would be the influence of future scarcities on today's shadow prices. It follows that the shadow price of, say, an ecological asset depends on the degree to which other capital assets can substitute for it in production - not only today, but in the future as well. Other things being equal, the smaller are those substitution possibilities, the larger is the shadow price of the resource. Appendix 2 illustrates.

2.6.3 Estimating Shadow Prices

Three pieces of information are required for estimating shadow prices:

(i) A descriptive model of the economy moving through time, including not only technological possibilities and ecological processes, but also preferences, tastes, personal and social values, and policies.

(ii) The size and distribution of the economy's capital assets at the date at which the economic evaluation is undertaken.

(iii) A conception of intergenerational well-being.

As noted previously, forecasts are no mere guesses. If they are to carry conviction, forecasts should be based on a defendable theory of the social and natural processes that shape a society's future. A good forecast would be based on requirements (i) and (ii) above. Information on (ii) can be used in (i) to track the economy into and over the future. The forecast would then be fed into (iii). Recall Definition 2. It says shadow prices are based on counter-factuals: they are determined not only by the forecast of the shape of things to come, but also by forecasts of future development were the current portfolio of capital assets to have been otherwise.

---

[48]Perrings (2012) provides an excellent account of this.

[49]Pattanayak and Butry (2005) is an empirical study of the complementarities between forests and adjoining farms.

Shadow prices are no Platonic objects, nor can they be plucked from air on mere whim and prejudice. We will never get shadow prices "right", but we can try to narrow the range within which reasonable people would agree they lie. The social evaluator estimates shadow prices, but recognizes that others may question her estimates. In democratic societies those differences would be resolved through the ballot box.

As externalities create gaps between shadow prices and market prices, market prices prove to be good scaffolding on which to build a system of shadow prices. So we start with market prices and add or subtract corrections to them. Of course, at the end of the process the corrections could well turn out to be large.

If $R_i(t)$ is the market price of asset i at time t, $E_i(t)$ is the social value of the externalities generated by the deployment of an additional unit of i at t, and $P_i(t)$ is the shadow price of i at t, then

$$P_i(t) = R_i(t) + E_i(t). \qquad (7)$$

The term $E_i(t)$ in equation (7) possesses an intriguing feature. In order to estimate it we would need to know the shadow prices of possibly many other assets; which is to say shadow prices are interdependent. Solving a system of simultaneous equations is routine in policy analysis. It is unavoidable also in sustainability analysis.

To cite an example of much complexity and current interest, consider that a further addition to the stock of carbon in the atmosphere today creates externalities (the unaccounted-for- consequences of emissions) lasting many years. Our social evaluator would try to estimate $E_i(t)$ for her country. If an increase in carbon concentration is predicted to be bad for her economy, $E_i(t) < 0$. If the emission is made by someone in her economy and there are no emission charges, $R_i(t) = 0$. In that case $P_i(t) = E_i(t) < 0$. If the additional unit of carbon is emitted by someone in another country, the consequences for her economy is valued at $E_i(t)$. So, again $P_i(t) = E_i(t) < 0$. On the other hand, if the externalities were eliminated by an internationally enforced carbon reduction policy, the resulting market price $R_i(t)$ of carbon would equal its shadow price $P_i(t)$.

As another example, consider a woodland. Among other things the woodland is the habitat for insects and birds. Agriculture benefits from pollination. If an economy's development path is forecast to be rapacious of its woodlands, there will be acute scarcity of woodlands (hence biodiversity) in the future. The woodland's shadow price today would be high, other things being equal. Shadow prices contain a great deal of information about the economy's prospects.

As the above examples confirm, in economic evaluation there should be no presumption that the economy is on an optimum trajectory. Shadow prices ought to be estimated on the basis of the social evaluator's economic forecast (her response to question C in Section 2.1), not on the basis of an ideal that is not about to be attained.[50] We develop the idea of forecasts in Appendix 1 and apply it to determine rules for estimating shadow prices in Appendices 2 and 7-10.

[50]We stress this because the bulk of writings on shadow prices of environmental natural resources limit themselves to optimizing economies (Heal, 1998; Weitzman, 2003).

2.6.4 International Trade, Global Assets and Transnational Externalities

International trade enables a country to expand its capacity, beyond what it is domestically capable of, to transform goods and services into other goods and services. As trade is an adjunct of domestic production, it does not play a special role in "green accounting". By trade we mean recorded trade. The problem is that countries interact with one another not only via recorded trade but also via transnational externalities. Two types of externalities may be distinguished: (i) unidirectional and (ii) reciprocal. We discuss them in turn.[51]

(i) Unidirectional externalities

Unidirectional externalities are just that - unidirectional - where one agent (or a set of agents) inflicts or confers an externality on another agent (or another set of agents). The direction of the externality is in part determined by social norms and legal rules (e.g., whether the rights belong to "polluters" or to "pollutees") and influences the distribution of resources.

Classic examples of transnational unidirectional externalities involve pollutants being transported by wind and water. Acid rains and river pollution have been much studied, but as yet there are few reliable data for use in national wealth estimates.

Exports of primary products often come allied to unidirectional externalities. Ironically, they involve wealth transfers from the exporting to the importing country (Dasgupta, 1990). Let us see how.

Imagine concessions have been awarded in the upland forests of a watershed. As forests stabilize soil and water flow, deforestation gives rise to soil erosion and increased fluctuations in the supply of water downstream. If the law recognizes the rights of those who suffer damage from deforestation (a case of pollutees' rights), it is the timber firm that would be required to compensate downstream farmers. But compensation is unlikely to be claimed, let alone made, when the cause of damage is many miles away and the victims are scattered groups of farmers. Problems are compounded because the damage is not uniform across farms: location matters. It can also be that those who suffer harm (reduced agricultural output) don't know the underlying cause of their deteriorating circumstances. As the timber firm isn't required to compensate farmers, its operating cost is less than the social cost of deforestation; the latter, as a first approximation, being the firm's logging costs plus the damage suffered by all who are adversely affected. We should conclude that the export contains an implicit subsidy, paid for by people downstream. The subsidy is hidden from public scrutiny, but it amounts to a transfer of wealth from the exporting to the importing country.[52]

(ii) Reciprocal externalities

Under reciprocal externalities each party inflicts (or confers) an externality on all others. Unrestricted extraction of groundwater is one example, carbon emissions are another. We alluded to the latter in Section 2.6.3. It will pay

[51]Unidirectional and reciprocal externalities are not limited to the transnational sphere; small scale examples abound.
[52]Pattanayak (2004) provides empirical estimates of the subsidy in a study of waatersheds in Indonesia. They range within 3-10 per cent of downstream farmers' incomes.

to study them further. (Groundwater extraction is discussed in Appendix 7.)

The atmospheric carbon concentration is a global capital asset, but at current levels it is acknowledged to have a negative global shadow price. Without loss of generality let global carbon concentration be indexed as i = 1 on the social evaluator's country's list of assets. So K1(t) is the concentration at date t (the figure currently is 395 ppm). The quantity K1(t) appears in the V function of every country at date t, but its effect differs from country to country. Consider country m. Let P1m(t) be the shadow price of carbon concentration in m. P1m(t) is specific to country m. (If m lies in the tropics, P1m(t) is almost certainly a negative number.) The global shadow price of carbon, however, is the sum of the country-specific shadow prices.

The global shadow price of carbon dioxide in the atmosphere was estimated by Stern (2006) to be minus \$85 per tonne, and by Nordhaus (2008) to be minus \$8 per tonne. Both authors took equation (3) to represent intergenerational well-being (V(t)) - for the world as a whole - and both assumed the same form of the function that represents the flow of societal well-being (B(u)) in the equation - they assumed B(u) = log(C(u)). Where they differed was on their choice of the rate of time discount, δ. Stern assumed δ is 0.1 per cent a year, whereas Nordhaus took it to be 2 per cent a year. The difference in the choice of δ largely explains the huge difference in their estimates of the global shadow price of carbon in the atmosphere. Their numerical computations are a striking illustration of how the social evaluator's attitude toward the future affects her estimate of today's shadow prices.[53]

The above assumes that countries cooperate to implement globally optimum policies. We are nowhere near that now; and it is interesting and important to know why.[54] For the foreseeable future our social evaluator will want to estimate the effect of increase concentrations on her own country. Let us see how she should organize her estimates.

Net global emission of carbon (which is the sum of the country emissions net of what is absorbed by the oceans and the biosphere) adds to global carbon concentration. If X(t) is the net global emission rate at date t, the increase in concentration over a brief period of time Δt is $X(t)\Delta t$, which equals $\Delta K_1(t)$. The shadow value to country m of the increase in concentration is $P_{1m}(t)X(t)\Delta t$ (= $P_{1m}(t)\Delta K_1(t)$), a negative quantity.[55]

We can state matters in a different but familiar way. When country n emits a unit of carbon into the atmosphere, it inflicts an externality on all other countries. The loss it incurs, which is $P_{1m}(t)$, is less than the global loss. The global loss is the sum of the $P_{1m}(t)$s across all countries. Of course, the reason why m continues to emit is that the gain it enjoys from its own carbon emission exceeds the loss. But that's yet another instance of the "tragedy of the commons".

[53]Aldy et al. (2010) presents a concise discussion of carbon mitigation options.

[54]The classic on the question is Barrett (2003).

[55]Arrow et al. (2012a) used this argument to estimate the losses suffered from global emissions by the countries in their sample over the period 2000-2005.

2.6.5 A Common Misconception[56]

Wealth is a weighted sum of an economy's stock of capital assets (equation (1)). Shadow prices are the weights. They are the rates at which assets substitute for one another in the measure of wealth. There are scholars (Daly et al., 2007) who worry that wealth's linear form hides an awkward assumption, that the various forms of capital assets are perfectly substitutable for one another in production and consumption.

The worry is based on a misconception. Propositions 1-4 have no empirical content, they are equivalence relationships. The Propositions only offer a tool for sustainability analysis. Proposition 1, for example, says that if the social evaluator seeks to know whether her economy is on a sustainable development path, she should keep track of the economy's wealth, it says nothing more. Proposition 1 doesn't presume that capital assets can substitute for one another in production or consumption, nor does it insist they are complements. The presence or absence of substitution possibilities in production and consumption among various categories of capital assets enter sustainability analysis via shadow prices.

Imagine that asset i is an ecological resource that is now close to a dangerously low level, crossing which would prove catastrophic to the economy. Suppose too that the exact point at which the threshold would be crossed is unknown. In such a case, if i+1 is a run-of-the-mill asset, Pi(t)/Pi+1(t) would be a gigantic number; so large, perhaps, that it wouldn't be possible to accumulate sufficient quantities of i+1 as compensation for any further decline in the stock of i. Appendix 3 contains an illustration.

2.7 Natural Capital: Further Considerations

We view natural capital here in an inclusive way. At one end are fossil fuels, which are commonly referred to as "exhaustible resources" because each unit used in production is lost forever. Economists sometimes refer to natural capital as "environmental resources", sometimes as "natural resources", and at other times as "environmental natural resources", the double adjective being a way to ensure that readers take their minds off dams, tarmac, bulldozers, chain-saws, and automobiles.

When people refer to environmental resources, they have renewable (self-regenerative) resources in mind. Handled with care, such forms of natural capital can be put to use in a sustained way but get depleted if they are exploited at rates exceeding their ability to regenerate themselves. The central problem in sustainability science is to uncover ways by which a literally indeterminate number of interlocking natural processes that shape renewable resources can be managed so as to enable Humanity to flourish indefinitely. Here we use the term Humanity to cover as small a community as a village to people of the world as a whole. Scale matters of course, but there is a core commonality in the problems faced by groups at all scales.

2.7.1 Valuing Ecosystems

Apart from fisheries and forests as sources of timber, ecosystems have traditionally been

[56]The remarks here have been adapted from Arrow et al. (2007), which was a reply to Daly et al. (2007).

neglected by economists and national income accountants. An ecosystem is a complex of the abiotic environment and plant, animal, fungi, and microorganism communities, interacting as a functional unit.[57] Ecosystems provide innumerable services to us. Among the visible products are food, fibres, fuel, and fresh water, but many remain hidden from view. Among those that remain hidden, ecosystems maintain a genetic library, preserve and regenerate soil, fix nitrogen and carbon, recycle nutrients, control floods, mitigate droughts, filter pollutants, assimilate waste, pollinate crops, operate the hydrological cycle, and maintain the gaseous composition of the atmosphere. As those services are not visible, it is easy to overlook them.

Ecosystems offer joint products: wetlands recycle nutrients and produce purified water; mangrove forests protect coastal land from storms and are spawning grounds for fish; and so on. Unhappily, social tensions arise in those many cases where an ecosystem has competing uses (farms versus forests versus urban development; forests versus agro-ecosystems; coastal fisheries versus aquaculture). As natural capital is a mesh of environmental resources, what one means by an ecosystem is usually influenced by the scope of the problem being studied. A number of ecosystems have a near global reach ("biomes", such as the Savannah), some cover entire regions (river basins), many involve clusters of villages (micro-watersheds), while others are confined to the level of a single village (the village pond).

The tropics harbour some of the most fragile environments. In a pioneering set of publications, MEA (2005a-d) provided an account of the stresses being experienced currently by both global and local ecosystems. The publications record that of the 24 ecosystems investigated for the report, 15 were either degraded or were being used in an unsustainable way. Valuing ecosystems services poses formidable problems. The market price is often zero, which means the entire burden falls on estimating the externalities in equation (7). The Annexe provides an account of the various methods that have been deployed for estimating shadow prices of ecosystem services. The shadow price of an ecosystem itself can be estimated by computing the present discounted value of the benefits derived from the services.

Despite extensive search we have been unable to locate more than a handful of studies where an ecological service in India has been valued using step (i) of the three-step procedure outlined at the beginning of Section 2.6.3.[58] Contingent valuation methods (Section 2.1; see also the Annexe to this chapter) have been deployed in a number of studies, but they are designed to uncover the "willingness-to-pay" for a service, which would mislead if the people surveyed were only dimly aware of ecological dynamics. Empirical studies of the value of ecosystem services in India are sorely needed.

2.7.2 Pollution vs Conservation

Pollutants are the reverse side of natural capital. One way to conceptualise "pollution" is to

---

[57]MEA (2005a-d), Balmford et al. (2011), and Bateman et al. (2011) contain excellent accounts of ecosystems viewed as capital assets.

[58]There are a few in other tropical countries. Ferraro et al. (2012) is an excellent survey of what has to date been unearthed about the value of forest services.

turn one's mind to the depreciation of capital assets. Acid rains damage forests; industrial seepage and discharge reduce water quality in streams and underground reservoirs, killing fisheries and damaging human health; sulfur emissions corrode buildings and structures and harm human health; and so on.[59] The damage inflicted on each type of asset (buildings, forests, fisheries, human health) should be interpreted as a depreciation of that asset. So the task is to estimate the depreciations. Corrosion of buildings and structures is frequently estimated by their replacement cost. This is an imperfect procedure. The correct procedure would be to estimate the loss in output owing to the corrosion which, to use the economist's expression, is the "opportunity cost". Damage to health can be estimated by loss in human productivity and the direct loss in well-being as experienced in pain and discomfort and reduction in life expectancy. This means there is no reason for distinguishing resource management problems from pollution management problems. Roughly speaking, "resources" are "goods", while "pollutants" (the degrader of resources) are "bads". Pollution is the reverse of conservation.

The mirror-symmetry between conservation and pollution is well illustrated by the atmosphere, which serves as both a source of nourishment and a sink for pollutants. The atmosphere is a public good. (If air quality is improved, we all enjoy the benefits, and none can be excluded from enjoying the benefits.) It is also a common pool for pollution. That it is a public good means the private benefit from improving air quality is less than the social benefit. Without collective action there is underinvestment in air quality. On the other hand, as the atmosphere is a common pool into which pollutants can be deposited, the private cost of pollution is less than the social cost. Without collective action, there is an excessive use of the pool as a sink for pollutants. Either way, the atmosphere suffers from the "tragedy of the commons".

2.8 Stocks and Flows

Economic evaluation involves studying changes in the wealth of societies (Propositions 1-5). Sustainability analysis demands in particular that the social evaluator tracks temporal changes in wealth (Propositions 1-2). As the rate of change of a "stock" is a "flow", we would seem to be back with economic flows as the defining variables in economic evaluation. They are. Propositions 1-4 give us a hint about the connection between capital accounts and income and expenditure accounts. Let us study the connection formally.

2.8.1 What is Investment?

The word "investment" could be thought to embody a sense of robust activism, but that's only because national income statisticians have traditionally limited the term's use to the accumulation of reproducible capital. When the government invests in roads, the picture that's drawn is one of bulldozers levelling the ground and tarmac being laid. That's investment! In this Report we have found it necessary to extend the notion of capital beyond reproducible assets to include human capital and natural capital. So we are obliged to stretch the notion of "investment" also. It includes for example the growth of renewable natural resources such as ecosystems. To leave a forest unmolested so as to enable it to grow

[59] Maler and Wyzga (1973) was an early study of ways to estimate the costs of environmental pollution.

would in our extended sense be to invest in the forest. To allow a fishery to restock under natural conditions would be to invest in the fishery. That suggests investment amounts to deferred consumption. But the matter is subtler. To provide food to the undernourished not only increases their current well-being, but enables them to be more productive in the future; and the latter feature makes even consumption among the poor an investment. This suggests that the term investment means any increase in the flow of services that an asset can provide over its lifetime. No doubt that sounds odd, but theory and empirics taken together should determine our usage of technical terms, not preconception nor customary usage. So, by "net investment" in asset i we should mean the value of the rate of change in the stock of asset i (Proposition 1a and equation (6)).

Return to Proposition 4. It comes tantalizingly close to saying that net investment has normative significance not only in sustainability analysis, but in policy analysis too. It does. In Appendix 4 we prove

Proposition 6: Aggregate net investment equals the present discounted value of changes to consumption brought about by it.

Proposition 6 provides the normative significance of the inclusive notion of investment we are advancing in this Report. That inclusiveness should inform the construction of national accounts. We discuss examples in Section 2.9.

2.8.2 Population Change

We now try to make Proposition 4 operational by considering circumstances where wealth per capita can be used as the sustainability and policy criterion. The circumstances are identified in Appendix 4 (Section A4.5). Here we state the finding.

Consider a brief interval of time, say, a year. The change in wealth per capita over the year is per capita net aggregate investment. It could be that net investment in some assets is negative (depletion of sub-soil resources with no compensating discoveries is a ready example). But if net investment in another class of assets more than matches the decline in the stock of sub-soil resources, wealth will have increased. Contrary-wise, if net investment in all other classes of assets falls short of the decline in the stock of sub-soil resources, wealth will have decreased.

We will write variables in per capita terms by lower case letters. Let $\Delta k_i(t)$ be the change in the stock per capita of asset i over the year and $p_i(t)$ the shadow price of asset i per capita. Then $p_i(t)\Delta k_i(t)$ represents per capita net investment in i and ${}_i\Sigma_{pi}(t)\Delta k_i(t)$ represents per capita net aggregate investment. But net aggregate investment is what one would call the change in wealth over the year. So Proposition 1 can be restated as

Proposition 7: Intergenerational well-being averaged over the generations increases over a period of time if and only if per capita net aggregate investment over the period is positive.

Proposition 7 is proved in Appendix 4 (Section A4.5). As with Propositions 1-2, Proposition 7 is an equivalence relationship. On its own it cannot tell the social evaluator whether an economy is following, or has followed, a sustainable development path over the period she is studying. It only offers a criterion for use in sustainability analysis.

Formally, let L(t) denote population size at time t. Using lower case symbols to denote quantities per capita, let $k_i(t)$ be the per capita stock of asset i at t. Thus $k_i(t) = K_i(t)/L(t)$. Now let v(t) denote intergenerational well-being averaged over the generations. Consider a brief interval of time, Δt, starting at t. Δt could be a year, say. Denote by $\Delta k_i(t)$ the change in the stock of i per capita during Δt. Proposition 5 says that if pi(t) is the shadow price of asset i per head,

$$\Delta v(t) \geq 0 \text{ if and only if } {}_i\Sigma[p_i(t)\Delta k_i(t)] \geq 0. \quad (8)$$

Condition (8) tells us that the criterion by which the social evaluator should assess the sustainability of development over the time interval Δt is whether ${}_i\Sigma[p_i(t)\Delta k_i(t)]$ is positive. But the term ${}_i\Sigma[p_i(t)\Delta k_i(t)]$ is what we would call "per capita net investment". Proposition 5 says that sustainability analysis requires the social evaluator to keep her eye firmly on the sign of per capita net investment.

It is however easy to misread per capita net investment. To see why, let us re-write ${}_i\Sigma[p_i(t)\Delta k_i(t)]$ as ${}_i\Sigma[p_i(t)(\Delta k_i(t)/\Delta t)\Delta t]$. If Δt is small, we can approximate per capita net investment at t by ${}_i\Sigma[p_i(t)dk_i(t)/dt]$. Let

$$y_i(t) = p_i(t)dk_i(t)/dt, \quad (9a)$$

$$y(t) = {}_i\Sigma y_i(t) = {}_i\Sigma p_i(t)dk_i(t)/dt. \quad (9b)$$

In equations (9a-b) $y_i(t)$ is per capita net investment in asset i and y(t) is per capita net investment, period. Note though that if population grows at the percentage rate n,

$$p_i(t)dk_i(t)/dt = p_i(t)[dK_i(t)/dt]/L(t) - np_i(t)k_i(t), \quad (10a)$$

$$y(t) = {}_i\Sigma p_i(t)[dK_i(t)/dt]/L(t) - n[{}_i\Sigma p_i(t)k_i(t)]. \quad (10b)$$

Equations (10a-b) draw out a distinction between "net investment per capita" (the first term on the right hand side of equation (10b)) and what we are calling "per capita net investment" (the left hand side of equation (10b)). We have switched the words in the two expressions intentionally. To see why, consider equation (10a). The term $p_i(t)[dK_i(t)/dt]/L(t)$ should be called net investment per capita in asset i, because it is net investment in i, divided by population size. World Bank (2011) would call the quantity "genuine saving per head." But that isn't the sustainability criterion in Proposition 7. An increase in the stock of i merely deepens i, but because population is increasing, there has to be sufficient widening of the stock to cover that increase. The second term on the right hand side of equation (10a) is the negative of the product of the population growth rate and the social value of the per capita stock of asset i. Returning once again to equation (10b), we see that net investment per capita has to exceed the social value of wealth per capita if the economy is to progress at date t. To put it another way, in the face of population growth the World Bank's "genuine saving" has to be sufficiently large to enable an economy to develop sustainably. So, although Proposition 7 says that the criterion for judging whether there is economic progress is the sign of per capita net investment, there is no escape for the social evaluator from having to measure the economy's wealth itself.

2.8.3 Net Domestic Product as a Bound on Consumption

The word "net" in Propositions 6-7 is significant in sustainability analysis. We noted earlier that the reason GDP is unsuitable in economic evaluation is that it doesn't record the depreciation of capital. GDP growth tells us nothing other than GDP growth.

As intergenerational well-being reflects the social good, GDP growth means little. But Proposition 6 hints at the possibility that net domestic product (NDP) is a significant statistic in economic evaluation.

NDP is GDP minus capital depreciation, which means that in a closed economy NDP is consumption plus net aggregate investment. Let C(t) denote aggregate consumption. By net aggregate investment we mean the value of net changes the economy's capital assets. As previously, let well-being be numeraire.

For notational simplicity assume time is continuous. If the period being studied is brief, ΔKi(t) could be expressed as [dKi(t)/dt] Δt. If Q(t) is the shadow price of aggregate consumption, we define net domestic product at date t as

$$(NDP)t = Q(t)C(t) + {}_{i}\Sigma P_i(K(t),t)dK_i/dt. \quad (9)$$

In equation (9) C(t) includes government consumption and $P_i(K(t),t)dK_i/dt$ includes government investment in asset i.

C(t) and dK_i/dt are flows. Equation (9) forms the basis of income-expenditure accounts and is of fundamental importance. The equation tells us which expenditure items should be included and which should be excluded (examples are studied below; Section 2.9).

Using equation (9) and Proposition 5, Proposition 2 can be recast as

Proposition 8: Intergenerational well-being averaged over the generations increases over a brief interval of time if and only if aggregate consumption per capita is less than net domestic product per capita.

Propositions 7 and 8 embody the ethical significance of net domestic product. They say that consumption per head must not exceed NDP per head if development is to be sustainable.[60] Propositions 2 and 8 reveal the connection between an economy's income and capital accounts.

2.9 Income-Expenditure and Capital Accounts: Simple Rules

In this Report the conclusions reached in Chapter 2 are used in Chapters 3-6 to help extend the system of national accounts (SNA) and the system of environmental and economic accounts (SEEA). We now use our findings to arrive at rules for arriving at estimates of NDP from estimates of final demand, or domestic income, which equals the sum of aggregate consumption and gross investment in reproducible capital.

2.9.1 Defensive Expenditure

By defensive expenditure we mean resources devoted to reducing the impact of environmental damage on health, machinery and structures, and natural capital. Put another way, defensive expenditure aims to soften capital depreciation. It is customary to include such expenditure in final demand, but equation (8) tells us that it is bad practice. If the expenditure targeted at a depreciating asset protects the asset fully, the asset would not depreciate, but the expenditure wouldn't add to the stock of capital either. If on the other hand the expenditure isn't

[60] A formal proof is provided in Appendix 7. An early version of the Proposition was proved by Solow (1974), Hartwick (1977), and Dixit, Hammond, and Hoel (1980).

undertaken, output will be correspondingly lower than previously and the asset will have depreciated. The rule that follows is that in estimating NDP, both defensive expenditure and depreciation should be deducted from final demand.[61]

2.9.2 Exploration for Sub-Soil Resources

By the stock of a sub-soil resource we mean (and should mean) known reserves. The right analogy is with knowledge, the stock of which at any moment in time is knowledge that's been discovered, not knowledge that's waiting to be discovered. Changes in known reserves of sub-soil resources equal the difference between new discoveries and the quantities extracted. Known reserves are reduced when discoveries fall short of extraction. In that case depletion should be deducted from net investment. That much is clear, but by the same token if discoveries exceed depletion, known reserves increase and that adds to wealth. The rule that follows is that in estimating NDP, the value of the net increase in reserves should be added to final demand.[62]

Exploration costs are the mirror image of defensive expenditures. In social cost-benefit analysis they appear as investment outlays and are compared to the value of the discoveries that are expected to be made in consequence. But because new discoveries would be recorded in capital accounts as additions to wealth, exploration costs should be deducted from final demand (equation (8)). Not to do so would be to regard both exploration costs and new discoveries as additions to wealth. That would involve double counting. Appendix 8 contains a formal analysis.

The above discussion assumes that discoveries are small relative to known reserves. If a newly discovered reserve is large, the value of the total stock of the sub-soil resource increases discretely. Shadow prices have to be re-estimated.

2.9.3 Pricing Groundwater

Groundwater basins are frequently subject to unrestricted extraction, usually by farmers. If no charges are levied on extraction it may be reasonable to assume that farmers draw water to the point where the marginal value of extracted water to farmers equals the unit extraction cost. This means groundwater rents are dissipated entirely, yet another example of the "tragedy of the commons". Ideally an extraction charge would be levied, equal to the shadow price of water in the aquifer; but suppose, for whatever reasons, it isn't.[63] The forecast is that rents will continue to be dissipated until the basin is exhausted. It could seem that the shadow price of groundwater would be zero. In fact it is positive. To see why, assume that the unit cost of extraction is constant and that farmers' demands are also constant. In that case the aggregate rate of extraction would be constant until the basin is exhausted. But now imagine that an additional unit of water is added to the basin. In that case the date of depletion would be postponed slightly. That's a gain to farmers. That gain is the shadow price of groundwater. Appendix 7 develops a formula for estimating that shadow price.

---

[61]Maler (1991) is the fundamental paper on the subject.

[62]We are assuming implicitly that the shadow price of the resource in the newly discovered deposit is not too different from the resource's shadow price in the known reserve. If the newly discovered deposit were of low quality, wealth could decline under the circumstances just mentioned in the text.

[63]Governments are known to go further and subsidize extraction costs.

2.9.4 TFP Growth: Technological Change and Institutional Reforms

Research and development (R&D) are inputs in the production of knowledge. Expenditure on R&D is therefore part of net investment (in scientists, laboratories, and so on), the returns on which would be enjoyed as greater future output. But suppose the growth in knowledge is "exogenous", as would be the case if domestic firms simply make use of knowledge created abroad without payment. In that case the economy's productive base expands costlessly. Similarly, institutional reforms (lowering of corruption and rigidities in the ability of citizens to go about their businesses) increase an economy's productive base.

Macroeconomists not infrequently measure technological and institutional changes in terms of changes in total factor productivity (TFP). In Appendix 4 we confirm that exogenous increases in TFP would translate into time dependent shadow prices of assets.

An alternative procedure would be to regard TFP as yet another capital asset and to then estimate its shadow price from an aggregate model of the economy. Arrow et al. (2012a) have followed that route. They identified conditions under which it is a reasonable approximation to simply add the rate of growth in TFP to the percentage rate of growth of the aggregate capital stock. The procedure is described in Appendix 4.

Contemporary estimates of TFP should, however, be treated with the utmost caution. TFPs are typically estimated on the basis of models that don't have natural capital in them (e.g., Collins and Bosworth, 1996). If natural capital in fact declines over a period, the TFPs obtained from regressions based on those models would be overestimates. The implication is more than just ironic: the regressions would misinterpret degradation of the environment as an increase in knowledge and an improvement in institutions![64]

2.9.5 Education

In earlier days capital assets in formal growth models were confined to what we have been referring to as "reproducible capital". The pioneering work of Schultz (1974) showed ways to measure education as a form of human capital. Klenow and Rodriguez-Clare (1997) and others have shown that in rich countries human capital in the form of education vastly dominates the value of reproducible capital, by a factor of 3 or more. Appendix 9 sketches the method they used to estimate the value of education.

2.9.6 Health

The indirect benefits of improved health are increases in productivity. Those benefits would be reflected in higher outputs and incomes. But there are two ways in which health contributes directly to human well-being: enhancing the value of consumption and extending life. And broadly speaking there are two ways to estimate those benefits. One is to seek people's "willingness-to-pay" for improvements in health (the "stated preference" approach; Annexe); the other is to infer the value of health from "revealed preference". Here we discuss how improvements in life expectancy can be valued by a study of revealed preference (a formal treatment is provided in Appendix 10).

---

[64]On this, see Dasgupta (2001) and Vouvaki and Xepapadeas (2009).

At its basis is the "value of a statistical life" (VSL), the most common method for estimating which is to uncover differences in wages for jobs involving differential risks. To illustrate, imagine that someone is willing to pay up to US $85 annually to reduce a mortal risk to him from 1/10,000 to 1/30,000. Denote the reduction as Δp. In our example, Δp = 1/10,000 - 1/30,000 = 1/15,000. The value of a statistical life, V_L, is defined by $V_L \Delta p = \$85$, or $V_L = 420/\Delta p = \$1.3$ million.

Contrary to what is widely thought, V_L is not the value of life, it is the value of a statistical life. In the present example it means 15,000 identical people would be willing to spend up to $6.3 million collectively to reduce the expected number of deaths due to this particular risk by 1. Across countries VL has been found to vary positively with GDP per capita. As choices in so many other spheres of life reveal, the tradeoffs that the poor are obliged to make differ cruelly from those that can be accommodated by the rich. In a study of cross-country estimates of V_L, Viscusi and Aldy (2003) found that $V_L = bY^{0.6}$, where Y is GDP per head and b is a positive constant. For India VL is approximately $1.3 million.

From the value of a statistical life to the value of a statistical life-year is but a short step. In Appendix 10 we elaborate on the method that uses VSL to estimate the value of an increase in longevity. The surprising finding of a recent empirical study (Arrow et al., 2012a) is that as a share of per capita wealth of nations, health capital per capita (the value of the expected number of years remaining for a person) surpasses the combined shares of all other forms of capital assets by an order of magnitude. The sample included developing economies. That suggests that at least in poor countries there has been an under-investment in health, especially the health of infants and pregnant and lactating women.

Set against the finding is the fact that many forms of natural capital, most especially ecosystems, were seriously undervalued in the estimates in Arrow et al. (2012a). It is a reasonable conjecture that when natural capital is valued with the detail the other forms of capital assets currently enjoy, health and the environment will outweigh reproducible capital by a large margin.

2.10 The Significance of Green Issues in Developing Countries

Despite the findings we have so far reported here, a nagging question remains: how significant is the need for green accounts in a developing country? Shouldn't the need for economic growth (for which, read growth in GDP) trump the desire to protect our environment? We address these questions now.

2.10.1 Economic Growth and the Environment

It is today a truism that much natural capital is not only intrinsically valuable, it also has functional worth. But scratch an economist and you are likely to find someone who regards natural capital as a luxury. It is commonly thought that, to quote an editorial in the UK's The Independent (4 December 1999), "... (economic) growth is good for the environment because countries need to put poverty behind them in order to care," or, to quote The Economist (4 December, 1999: 17), "... trade improves the environment, because it raises incomes, and the richer people are, the more willing they are to devote resources to cleaning up their living space."

The underlying idea was popularized in World Bank (1992). Emissions of nitrous oxides (NOx), sulfur oxides (SOx), particulates, and lead were found to have declined since 1970 in OECD countries even while GDP had increased. World Bank (1992) also found that among countries where per capita GDP was under US $1,200 per year, the less poor among the countries suffered from greater concentration of sulfur dioxide, but that among countries enjoying per capita GDP in excess of US $1,200, those that were richer had lower concentrations. The relationship between GDP per capita and concentration was found to be an inverted-U (Figs. 1-2) Among environmental economists the relationship was promptly christened the "environmental Kuznets curve," because a similar relationship between GDP per head and income inequality had been found decades ago by the economist Simon Kuznets. The environmental Kuznets curve was interpreted in such terms as the following:

"People in poor countries can't afford placing a weight on the natural environment over material well-being. So, in the early stages of economic development pollution is taken to be an acceptable, if unfortunate, side-effect of growth in GDP. However, when a country has attained a sufficiently high standard of living, people care more about the natural environment. This leads them to pass environmental legislation and create new institutions to protect the environment."

The literature on the environmental Kuznets curve is now huge.[65] However, studies confirming the inverted-U shape have continued to focus on ambient air pollution in cities (e.g., Harbaugh et al., 2002). Notice that such pollutants literally blow away. The air-shed over a city would be expected to improve in quality if emissions there were to decline. But sewage is another form of pollution that would be "subject" to the environmental Kuznets curve. Health in the cities declined at the beginning of the Industrial Revolution, largely owing to an increase in urban pollution. With rising incomes, the local environment eventually improved. Because it is consistent with the notion that as their incomes rise people spend proportionately more on environmental quality, it has proved tempting to believe that the environmental Kuznets curve holds for environmental quality generally.

The temptation should be resisted.[66] If the degradation of natural capital were irreversible, economic growth could be at risk and we wouldn't observe an inverted-U. And there are other reasons we should reject the environmental Kuznets curve as a metaphor for the relationship between GDP per capita and the state of the natural environment. Here are four reasons:

First, the inverted-U has been found for pollutants involving local, short-term damages (sulphur, particulates, fecal coliforms), not for the accumulation of household and industrial waste, nor for pollutants involving long-term and more dispersed costs, such as carbon dioxide, which typically have been found to increase continuously with GDP (World Bank, 1992). Secondly, the relationship between GDP

[65]For reviews, see S. Dasgupta et al. (2002), Dinda (2004), D.I. Stern (2004).
[66]The observations below are taken from Arrow et al. (1995), which was republished, with comments by a number of experts, in Environment and Development Economics (1996), Vol. 1, No. 1.

per head and environmental pollution wouldn't be the inverted-U if the feedback from pollution to the state of ecosystems is positive (D.I. Stern et al., 1996). Third, the inverted-U hides system-wide consequences of emissions. Reductions in one pollutant in one country, for example, could involve increases in other pollutants in the same country or transfers of those same pollutants to other countries. Acid rains are an example of the externalities that emitting countries impose on countries down wind.

And fourth, in most cases where pollution concentrations have declined with rising GDP, the reductions have been due to local institutional reforms, such as environmental legislation and market-based incentives to reduce environmental impacts. Such reforms may ignore their possible adverse side effects on the poor and on future generations. Where the environmental costs of economic activity are borne by those under-represented in the political process, the incentives to correct environmental problems are likely to be weak. The upper panel of Figure 1 can mislead one into thinking that it reflects a universal relationship between the environment and economic development.

The solution to environmental degradation usually lies in such institutional reforms as would offer incentives to private users of resources to take account of the social costs of their actions (the externalities!). The inverted-U curve suggests this can happen in some cases, that is all. Moreover, as we have shown, growth in GDP per capita is a wrong objective; we should instead be studying movements in wealth, not movements in GDP. Movements in wealth over time pick up the right tradeoffs between the factors that determine intergenerational well-being. If there are tradeoffs that can be exploited between different types of capital assets, shadow prices would reflect them and wealth would summarize them in the right way. Appendix 2 demonstrates that shadow prices reflect those tradeoffs.

2.10.2 Necessities vs. Luxuries

A large part of what Nature offers us is a necessity, not a luxury. Many of the services we obtain from natural capital are "basic needs". Among the visible products are food, fibres, fuel, and fresh water (MEA, 2005a-c, calls them "provisioning services"). Many are hidden from view. A number of services filter into a global context, but many are geographically confined. Human well-being and the state of our natural environment are closely linked.

Natural capital offers joint products. Circulation of material (ocean currents and the wind system) transfers energy across the globe (e.g., it influences precipitation) and dilutes pollutants. Wetlands recycle nutrients and produce purified water. Mangrove forests protect coastal land from storms and are spawning grounds for fish. And so on. Unhappily, social tensions arise in those many cases where an ecosystem has competing uses (farms versus forests versus urban development; forests versus agro-ecosystems; coastal fisheries versus aquaculture[67]). Sachs et al. (1998) traced the location of world poverty in part to the fact that the tropics harbour some of the most fragile ecosystems, including those that regulate disease.

[67]See Tomich et al. (2004), Tomich et al. (2004), MEA (2005a-d), and Palm et al. (2005) on those tensions.

A resource can be a luxury for others even while it is a necessity for some. Consider watersheds, which nurture commercial timber, protect agricultural land, create recreational opportunities, and supply both market and non-market products (gums, resin, honey, fibres, fodder, fresh water, timber, and fuel-wood). Watershed forests purify water and protect downstream farmers and fishermen from floods, droughts, and sediments. In tropical watersheds, forests house vast quantities of carbon and are the major home of biodiversity. A number of products from watersheds are necessities for local inhabitants (forest dwellers, downstream farmers, and fishermen), some are sources of revenue for commercial firms (timber companies), while others are luxuries for outsiders (eco-tourists). Some of the benefits accrue to nationals (agricultural products and fibres), while others spill over geographical boundaries (carbon sequestration). So, while watersheds offer joint products (protection of biodiversity, flood control, carbon sequestration, household necessities), they also provide potential services that compete against one another (commercial timber, agricultural land, biodiversity). Competition for Nature's services has been a prime force behind the transformation of our landscape. Politics often intervenes to ensure that commercial demand trumps local needs, especially under non-democratic regimes. Governments have been known to issue timber concessions in upstream forests to private logging firms, even while evicting forest dwellers and encouraging siltation and the risk of floods downstream. Nor can the international community be depended upon to apply pressure on governments. When biodiversity is lost at a particular site, eco-tourists go elsewhere that has rich biodiversity on offer. That is why international opinion is often at best tepid. In both examples, local needs are outflanked by outsiders' demands.

2.10.3 Irreversible Uses

Ecosystems are driven by interlocking non-linear processes that run at various speeds and operate at different spatial scales (Steffen et al., 2004); which is why ecosystems harbour multiple stability regimes (Appendix 7). The global climate system is now a well known example, but small-scale ecosystems also contain multiple stability regimes; and for similar reasons. So long as phosphorus run-off into a fresh water lake is less than the rate at which the nutrient settles at the bottom, the water column remains clear. But if over a period of time the run-off exceeds that rate, the lake collapses into a eutrophic state (Carpenter, 2001; Scheffer, 2009). Usually the point at which the lake will collapse is unknown (Appendix 3). That means the system is driven by non-linear stochastic processes.

When wetlands, forests, and woodlands are destroyed (for agriculture, mining, timber extraction, urban expansion, or whatever), traditional dwellers suffer. For them, and they are among the poorest in society, there are no substitutes. For others, there is something else, often somewhere else, which means there are substitutes. Degradation of ecosystems is like the depreciation of roads, buildings, and machinery - but with three big differences: (i) depreciation of natural capital is frequently irreversible (or at best the systems take a long time to recover); (ii) except in a very limited sense, it isn't possible to replace a depleted or degraded ecosystem by a new one; and (iii) ecosystems can collapse abruptly, without much prior warning. Imagine what would happen to a city's inhabitants if the infrastructure connecting it to the outside world was to break down without notice. Vanishing water holes, deteriorating grazing fields, barren slopes, and wasting mangroves are spatially confined instances of corresponding breakdowns among the rural poor in poor countries. In recent years we have also seen how an ecological collapse accompanying high population growth, such as the one that has been experienced in recent years in the Horn of Africa and the Darfur region of Sudan, can trigger rapid socio-economic decline (Homer-Dixon, 1999; Diamond, 2005; Collier, 2007). The range between a need and a luxury is thus enormous and context-ridden. Macroeconomic reasoning glosses over the heterogeneity of Earth's resources and the diverse uses to which they are put, by people residing at the site and those elsewhere.

2.10.4 Substitution Possibilities

Environmental debates are often over the extent to which people are able to substitute one asset for another. Many believe that problems arising from the depletion of natural capital can always be overcome by the accumulation of reproducible capital, knowledge, and skills. Lomborg (2001) is an example from the popular literature. But the viewpoint also pervades academic economics. Macroeconomic growth theories, for example, are mostly built on economic models in which Nature makes no appearance (Romer, 1996; Barro and Sal-i-Martin, 2003; Helpmann, 2004). The implicit assumption there is that reproducible capital and human skill and ingenuity can be relied upon to make the sustainability of Nature's services unimportant. In contrast there are scientists who argue that, globally, Humanity has reached the stage where there are severe limits to further substitution possibilities among large numbers of natural resources and among environmental resources and other forms of capital assets (Ehrlich and Goulder, 2007).

Four kinds of substitution help to ease resource constraints, be they local or global. First, there can be substitution of one thing for another in consumption (nylon and rayon substituting for cotton and wool; pulses substituting for meat). Secondly, manufactured capital can substitute for labour and natural capital in production (the wheel and double-glazing are two extreme examples). Thirdly, novel production techniques can substitute for old ones.[68] Fourthly, and for us here most importantly, natural resources themselves can substitute for one another (e.g., renewable energy sources could substitute for non-renewable ones). The examples point to a general idea: as each resource is depleted, there are close substitutes lying in wait, either at the site or elsewhere. The thought that follows is that even as constraints increasingly bite on any one resource base, Humanity should be able move to other resource bases, either at the same site or elsewhere. The enormous additions to the sources of industrial energy that have been realized (successively, human and animal power, wind, timber, water, coal, oil and natural gas and, most recently, nuclear power) are a prime historical illustration of this possibility.[69]

Humanity has been substituting one thing for another since time immemorial. Even the final conversion of forests into agricultural land in England in the Middle Ages was a form of substitution: large ecosystems were transformed

[68]For example, the discovery of effective ways to replace the piston by the steam turbine (i.e., converting from reciprocating to rotary motion) was introduced into power plants and ships a little over 100 years ago. The innovation was an enormous energy saver in engines.

[69]But these shifts have not been without unintended consequences. Global climate change didn't feature in economic calculations until very recently.

to produce more food.[70] But both the pace and scale of substitution in recent centuries have been unprecedented. Landes (1969) has shown that the discovery of vast numbers of ways of substituting resources among one another characterized the Industrial Revolution in late eighteenth century. The extraordinary economic growth in Western Europe and North America since, and in East Asia more recently, has been another example of finding new ways to substitute goods and services among one another and to bring about those substitutions. That ecosystems are spatially dispersed has enabled this to happen. The ecological transformation of rural England in the Middle Ages probably reduced the nation's biodiversity, but it increased income without any direct effect on global productivity.

But that was then and there, and we are in the here and now. The question is whether it is possible for the scale of human activity to increase substantially beyond what it is today without placing undue stress on the major ecosystems that remain. The cost of substituting reproducible capital for natural capital can be high. Low-cost substitutes could turn out to be not so "low-cost" if the true costs are used in the accounting, rather than the costs recorded in the marketplace (Section 2.6.1). Depleting one type of natural capital and substituting it with another form of natural capital or with a type of reproducible capital is frequently uneconomical. The example of global climate is a constant reminder of that.

2.10.5 Ecosystem Resilience

Degradation of an ecosystem not only affects the volume and quality of the services it provides, but also challenges the system's resilience, which is its capacity to absorb disturbances without undergoing fundamental changes in its functional characteristics. To interpret an ecosystem's loss of resilience, one needs to view it as having moved to a different stability regime. Sudden changes in the character of shallow lakes (from clear to eutrophied water) resulting from increases in nutrients, and the transformation of grasslands into shrub-lands consequent upon bad cattle-management practices are examples of regime shifts. Human societies have on occasions been unable to avoid suffering from unexpected flips in their local ecosystems. Fishermen on Lake Victoria and nomads in the new shrub-lands of southern Africa are examples from recent years; the inhabitants of the Mayan states in early ninth Century and those of Easter Island in the eighteenth Century are examples from earlier eras.[71]

Estimating damage to ecosystems from pollution is especially difficult in cases where the ecosystem is destroyed, or more accurately, gets transformed. Phosphorus seepage from agricultural fertilizers into fresh water lakes causes eutrophication. Reversing the damage

---

[70]Forests in England had begun to be denuded earlier, by Neolithic Britons and the Romans

[71]The decay of Mayan civilization has been traced by some scholars to an overuse of agricultural land. Soil degradation made Mayan populations more vulnerable to crop failure in times of low rainfall. Martin and Grube (2000) have offered evidence that the collapse of a number of Mayan cities occurred in the remarkably-short interval AD 800-830 (see also Yaeger and Hodell, 2008). The death of Easter Island has been the subject of much recent debate. Brander and Taylor (1998) give a short historical account and construct a formal mechanism by which a seemingly sophisticated island economy could collapse over a short period of time. In a Special Issue on "Critical Perspectives on Historical Collapse", The Proceedings of the National Academy of Sciences (2012, Vol. 109, No. 10, March 6) has published articles uncovering reasons for the collapse of certain past societies.

can be costly, in some cases impossible. Regime shifts are a potential feature because the processes governing ecosystems are non-linear. In Appendix 7 we present a model of Human-Nature interactions involving reproducible, human, and natural capital. As the natural system in the model is subject to a threshold, the economy has two stability regimes.[72]

2.10.6 Biodiversity

Determining the functional value of biodiversity is a delicate matter. When ecologists speak favourably of biodiversity, which they do in unison and with regularity, they make an implicit assumption that the diverse species have co-evolved under selection pressure. They don't mean a simple head-count of "objects" constituting the diversity. The diversity of species increased when the Nile perch was introduced into Lake Victoria. But not for long; the lake, as a fishery, was devastated.

Biodiversity, appropriately defined, would seem to be a key to ecosystem productivity (Tilman, 2012). By "productivity" we mean the production of biomass, termed "primary productivity". It has been found in experiments in field stations that species-rich plots yield greater biomass than species-poor ones, which would indicate that the total productivity of a population of species is greater than the sum of the productivities of the individual species grown in isolation. This reflects a form of synergy, making ecosystems resilient to changes in the circumstances they experience. The minor species in a lightly grazed grassland could be regarded as "waiting in the wings" to take over, if required to do so because of intense grazing. The thought here is that species abundance in ecosystems is like spare capacity, it offers an insurance device for ecosystems (Tilman, Reich, Knops, 2006).

It remains a popular belief though that the utilitarian value of biodiversity is located primarily in the potential uses of the genetic material it harbours (e.g., for pharmaceutical purposes). Preserving biodiversity is seen as a way of holding a diverse portfolio of assets with uncertain payoff. The idea of option value (Section 2.4.3) finds its most striking illustration in "biodiversity" viewed as a potential source of new genetic material. But biodiversity is valuable more broadly (Balmford et al., 2011). It is essential for the maintenance of a variety of services on which humans depend for survival (species complementarities are involved). This has the corollary that to invoke the idea of substitutability among natural resources in order to play down the usefulness of biodiversity is a wrong intellectual move. The point is that if biodiversity is necessary for an ecosystem to provide essential service, the importance of that same biodiversity cannot be downplayed by the mere hope that for every species there are substitutes lying in wait within the same ecosystem. Recall the famous analogy in Ehrlich and Ehrlich (1981) relating species in an ecosystem to rivets in an airplane. One by one, perhaps, species may disappear and not be missed. There is spare capacity, meaning "species substitutability". Eventually, though, the cumulative effect of biodiversity loss will lead to the crash of ecosystem functioning ("species complementarity" will kick in), just as the cumulative loss of redundant rivets will lead to the crash of an airplane.

---

[72]In 2003 the journal, Environmental and Resource Economics (Vol.26, No.4) published a Symposium on the economics of (non-linear) ecosystems and regime shifts.

2.11 Economic Growth as Growth in Wealth

The central finding in this Report has been that by "economic growth" we should mean growth in an economy's wealth (per capita), not growth in GDP. As an adjunct, the finding says that when we worry about the distribution of well-being in a society, we should worry about the distribution of wealth, not income. Of course, the point of economic policy wouldn't be to maximize the rate of wealth accumulation, it would be to determine optimum accumulation rates, which could well be to aim at a gradual increase in wealth.

Wealth is an intuitively congenial economic object. We commonly use the term "wealthy" to describe rich people and nations and on occasion recall that Adam Smith's great treatise was on the wealth of nations. Our discussion has however revealed that behind what is a commonplace term lie unexpected complexities. We have shown that many of the complexities are conceptual while others concern the nuts and bolts of practical national accounting. A large part of this Report has been directed at unravelling those complexities and building a unified conceptual structure for economic evaluation. In Chapter 2 and 5 we show how to put our findings to use in the preparation of national accounts.

Despite wealth's appeal, economic decision-makers and commentators can be expected to be drawn to GDP for a variety of reasons, long familiarity with it being only one. Appendix 11 offers reasons why it may prove difficult for governments to wean themselves away from GDP as their chosen benchmark for judging economic performance over the long run. There are also well founded reasons why macroeconomists have found time series of GDP useful. They have proved important for analyzing behaviour and assessing under-used capacity. But if the social evaluator is to conduct economic evaluation, there is no getting away from her need for wealth accounts.

Without demand supply rarely comes forth. Because there has been no official demand for resource accounts, particularly ecological accounts, there are few estimates of the value of natural capital anywhere in the world. And without that there isn't much point in talking about wealth and its movement over time. Early estimates (Dasgupta, 2001; Arrow et al., 2004) of movements in the inclusive form of wealth that appears in Proposition 5 indicated that during 1970-2000 wealth per capita in a number of countries in sub-Saharan Africa and South Asia declined, even though GDP per capita rose and HDI improved. Their findings, taken at face value, say that development during 1970-2000 had been unsustainable in those economies.

Unfortunately, the estimates were woefully crude. Among natural capital assets the authors were able to include only forests (that too, valued in terms of their timber content), sub-soil resources, and carbon concentration in the atmosphere. Water resources (both aquifers and rivers) were missing, as were fisheries and the myriad of ecosystem services that fall outside the recorded system of use and transactions. On the other hand, improvements in health and education were measured in terms of public expenditure on health, which is in all probability wildly below their shadow values. Despite the shortcomings, those early empirical estimates of wealth and its movements over time were useful if only because they alerted us to the possibility that in recent years growth in GDP per capita in poor countries has been achieved by running down wealth per head. The flip side of the message is that a move to sustainable development may well require cutting down growth in GDP per capita.

Arrow et al. (2012a) and UNU-IHDP/UNEP (2012) have made improvements to wealth estimates by measuring human capital and its improvements in line with the methods suggested in Section 2.4 and developed in Appendices 8-9. With but one exception (Venezuela) in their sample of five countries, Arrow et al. (2012a) found that both GDP per capita and wealth per head increased during the period 1995-2000. The authors found that in Venezuela GDP per capita increased even while the country's wealth per head declined (owing to depletion of oil). But the list of natural assets in Arrow et al. (2012a) was the same as it was as in the earlier publications. UNU-IHDP/UNEP (2012) made a valiant attempt to obtain estimates of fisheries' stock, but they were able to locate them for only four of the twenty countries in their sample. That suggests the estimates in those two publications of wealth changes are biased upward.

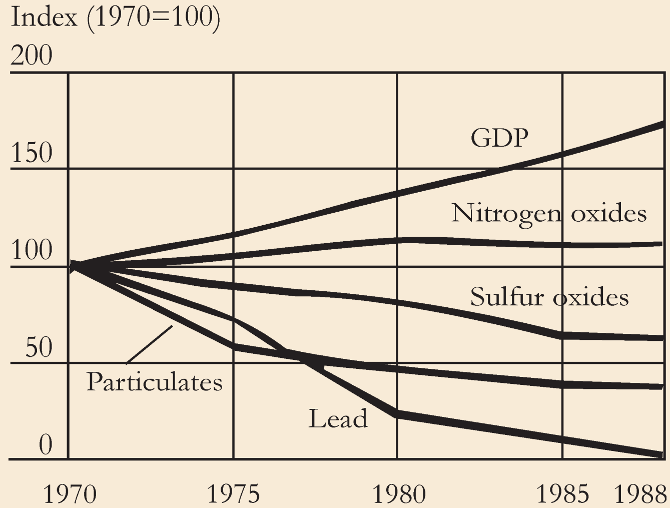
Of course, in a hugely distorted economy a government may be able to have its proverbial cake and eat it too. It could be that by a judicious choice of policy it is possible for a developing country today to aspire to the accumulation of wealth per capita and enjoy modest increases in GDP per head as well for a while. Only further work in wealth accounting will enable decision makers to know whether that is indeed possible.

These are early days in the preparation of wealth accounts (Chapter 5). But it is sobering to realize that 60 years ago estimates of national incomes were subject to uncertainties of a magnitude people are minded to think no longer exists in current estimates. That said, we take contemporary estimates of national income too much at face value. Official estimates are silent on the proportion of incomes that go unrecorded. Estimates of transactions falling outside the market system or operating within a black market system suggest that the errors in official estimates of national income are substantial.

Official ignorance of the state of an economy's stock of natural capital assets should now be a matter of extreme embarrassment to governments. In a review of the empirical literature on forest services (carbon storage, ecotourism, hydrological flows, pollination, health, and non-timber forest products), Ferraro et al. (2011) have found little that can be reliably used in wealth estimates. However, even if figures for natural resource stocks were available, the deep problem of imputing values to them would remain. Market prices may be hard facts, but shadow prices are soft. The issue isn't merely one of uncertainty about the role natural capital plays in production and consumption possibilities, it is also a matter arising from the fact that people differ in their ethical values. The sensitivity of wealth to shadow prices should become routine exercise in national accounts. We should expect wealth estimates to be presented as bands, not exact figures. That people may never agree on the wealth of nations is, however, no reason for abandoning wealth as the object of interest in sustainability analysis. Our ignorance of the economic worth of natural capital remains the greatest barrier to an understanding of the history of economic development. Until that ignorance is lifted policy analysis will remain crippled and sustainability will continue to be a notion we admire but cannot put into operation.

Figure 1

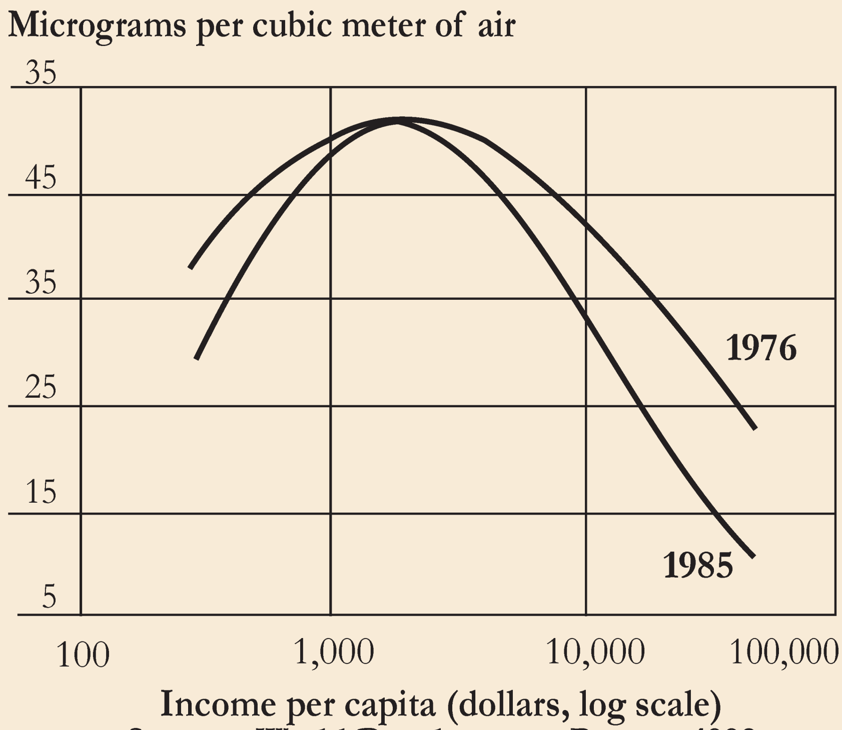
The practice: GDP and emissions in OECD countries



Note: GDP, emissions of nitrogen oxides, and emissions of sulfur oxides are OECD averages. Emissions of particulates are estimated from the average for Germany, Italy, Netherlands, United Kingdom, and United States. Lead emissions are for United States.
Sources: OECD 1991; U.S. Environmental Protection Agency 1991.

Figure 2

Concentrations of sulfur dioxide



Source : World Development Report, 1992

Appendix 1

The Primacy of Forecasts

In the text it was argued that forecasts are meaningful only when the forecaster is able to respond to counter-factuals (the "what if the assets the economy had inherited been otherwise?" sort of reasoning). So as to formalize those arguments, we first study a model that is undoubtedly an extreme caricature, but it enables us to determine the evolution of an economy in explicit terms. We then generalize.

For notational ease we assume time is continuous. The forecast is made at an arbitrary date t. The future consists of dates following t. As in the text let u also denote time, with the understanding that $u \geq t$. The dynamics of the economy will therefore be characterized in terms of u. This is an unusual move, but as we will confirm presently, it is useful in sustainability analysis.

A1.1 Forecasting in a One-Good Economy

The economy is assumed to possess an all-purpose non-deteriorating commodity, the stock of which at t is K(t). K(t) is given, it is a datum. Population is constant; which means we can save on notation by ignoring it. Output (GDP) at date u, which we write as Y(u), is proportional to K(u), the constant of proportionality being A (> 0). Thus

$Y(u) = AK(u)$.[73] (A1.1)

A is the rate of return on holding capital.

Output can be either consumed or saved. What is saved is invested. The behavioural assumption we make about people is that they save a constant proportion of output. Let s be the rate of saving ($0 < s < 1$). Assuming that intended investment and realised investment are equal, the rate of investment is given by the equation

$$dK(u)/du = sY(u) = sAK(u). \quad (A1.2)$$

Integrating equation (A1.2), we have

$$K(u) = K(t)e^{sA(u-t)}. \quad (A1.3)$$

K(t) is the "initial condition" for the social evaluator. If C(u) denotes consumption at u, equation (A1.1) says

$$C(u) = (1-s)Y(u) = (1-s)AK(u). \quad (A1.4)$$

Using equation (A1.3) in equation (A1.4), we have

$$C(u) = (1-s)AK(t)e^{sA(u-t)} \quad (A1.5)$$

The model isn't believable because it forecasts indefinite exponential growth in capital, output, and consumption (the rate of growth is sA). But it has the virtue of expressing forecasts in explicit terms, which is why we are illustrating "forecasts" with its help. Suppose the forecaster knows A (technological data) and s (behavioural data). Equations (A1.3) and (A1.4) say that he can then forecast both K(u) and C(u) on the basis of the current capital

[73] This is the famous Harrod-Domar model of economic growth.

stock, K(t), and the distance between u and t. The latter facts means calendar date doesn't matter: the economic system is "autonomous" in time. This is the sense in which the entire future of the economy is written in the present state, K(t). Specifically, equation (A1.5) tells us that

$$C(u) = C(K(t)), \qquad u \geq t. \qquad (A1.6)$$

Imagine now that the conception of intergenerational well-being the forecaster deploys is the "utilitarian" form of equation (3) in the text:

$$V(t) = {}_{u=t}\Sigma B(C(u))/(1+\delta)^{(u-t)}, \ \delta \geq 0. \ (A1.7)$$

Using equation (A1.6) in equation (A1.7) we confirm that V(t) is a function of K(t); that is

$$V(t) = V(K(t)). \qquad (A1.8)$$

Equations (A1.5)-(A1.7) enable the forecaster to track the evolution of the economy no matter what the initial stock of capital, K(t), happens to be. This is the sense in which counter-factuals are an essential ingredient in forecasts.

A1.2 Generalized Forecasts: Resource Allocation Mechanisms

We now consider a world with many capital assets (including population) and many consumption goods. As in the text, let K(u) denote the vector of capital stocks and C(u) the vector of consumption goods at date u. The forecaster is interested in the consumption sequence {C(t),C(t+1),...,C(u),...}, which for brevity we write again, as in the text, as Z(t).

The economy faces not only technological and ecological constraints, but also institutional constraints. By "institutions" we mean market structures, the structure of property rights, tax rates, non-market institutions (for credit, insurance, and common property resources), the character of various levels of government, and so forth. We do not assume that the government is bent on maximizing intergenerational well-being (V). It could be that the government is ill-advised or neglectful and has objectives of its own that are not congruent with intergenerational well-being. Nor do we assume institutions to be unchanging over time. What we do assume is that institutions co-evolve with the state of the economy and that the forecaster recognizes this. It is no doubt a truism that social and political institutions influence the evolution of the state of an economy, but it has also been argued that the state of an economy influences the evolution of social and political institutions (Lipset, 1959; Acemoglu and Robinson, 2006). The idea of a "resource allocation mechanism" (RAM) developed below acknowledges this mutual influence.

K(t) is the state variable of the economy at t. It represents data for the forecaster. We now define RAM in its most general form. Let D[{K(t),t}] be the set of all possible {K(t),t) pairs (the symbol D stands for "domain"), and let R[{Z(t)]] be the set of all imaginable Z(t)s, whether feasible or not (the symbol R stands for "range"). Dasgupta and Maler (2000) generalized the idea of forecasts to the concept of a resource allocation mechanism (RAM) via

Definition A1.1: A resource allocation mechanism (RAM), is a many-one mapping M, such that

$$M: D[\{K(t),t\}] \rightarrow R[\{Z(t)\}].$$

Notice that each {K(t),t} in the set D[{K(t),t}] is mapped by M to a unique consumption path Z(t). RAM is a many-one mapping. As an illustration, we note that equation (A1.6) defines the RAM in the one-good economy studied in Section A1.1.

M is a mapping defined on the set of possible {K(t),t}s. However, for t to be in the domain of RAM would mean that the calendar date at which the forecast is made matters. That would be the case if, say, technology is expected to improve at an exogenous rate (e.g., because technology is borrowed from abroad at no cost and foreign countries are known to invest in R&D). Knowledge only of the stock of capital wouldn't suffice for the forecaster in such a situation; the date at which he is to make the forecast would matter too. On the other hand, if the economic system were time-autonomous, M would map a given vector of capital stocks K(t) to the same Z(t) no matter what t happens to be. The toy model of Section A1.1 was autonomous in time, meaning that calendar date didn't matter there.

Although RAM's range R[{Z(t)}] consists of the set of all imaginable consumption streams, RAM maps every member of the set D[{K(t),t}] to a feasible consumption stream (or more precisely what the forecaster regards to be a feasible consumption stream). If they are to be believable, economic forecasts should be based on a RAM. Definition A1.1 says that on using the RAM he has arrived at, the forecaster can express his forecast as

$$Z(t) = Z(K(t),t), \qquad (A1.9)$$

thereby,

$$V(t) = V(K(t),t). \qquad (A1.10)$$

If the economy is autonomous in time, as in the one-good economy of Section A1.1, equations (A1.9)-(A1.10) reduce to

$$Z(t) = Z(K(t)), \qquad (A1.11)$$

$$V(t) = V(K(t)). \qquad (A1.12)$$

The RAM most frequently studied by economists is that of an optimizing economy.[74] For every {K(t),t} in D[{K(t),t}], M in the optimizing economy identifies the optimum consumption stream Z(t) and maps the pair {K(t),t} to the corresponding optimum Z(t).

This Report is not based on any such assumption as that the economy for which national accounts are being prepared is optimizing the allocation of resources. So we emphasize here that assumptions about institutions are embedded in the way RAM appears in Definition A1.1. Aspects of the concept of "social capital" (Putnam, 1993) appear in RAM as part of the defining characteristics of M, as do ideas relating to "social capability" (Adelman and Morris, 1965, 1967; Abramovitz, 1986), and "social infrastructure" (Hall and Jones, 1999). The prevalence (or absence) of trust and honesty are embodied in M, whereas other aspects of the concept of social capital such as personal networks enter as components of human capital.

[74]Book length treatments of the subject are Chakravarty (1969), Arrow and Kurz (1970), Heal (1998), and Weitzman (2003).

Appendix 2

Shadow Prices: Formalization

We make us of the notation introduced in the text and Appendix 1.

A2.1 Consumption Goods

Once the forecaster has identified the RAM that corresponds to his economy, he is in a position to forecast future development. As in Section 2.3 of the text, let C(u) be the flow of consumption goods and services at date u. As C(u) is a complete list of who consumes what at u, it embodies the determinants of the flow of societal well-being at u, which we continue to write as B(u). But if experience tells the forecaster that the future can be relied upon to reveal unexplained needs and wants, B would also depend on the calendar date, u. In that case we write B(u) as B(C(u),u). For concreteness, imagine that the ethical conception adopted by the social evaluator yields the utilitarian form (equation (3) in the text) to reflect intergenerational well-being. Let $Q_k(u)$ denote the shadow price of consumption good k at date u. $Q_k(u)$ should be thought of as a spot price. From Definition 2 we have

$$Q_k(u) = \partial B(C(u),u)/\partial C_k(u), \quad u \geq t. \quad \text{(A2.1)}$$

Of particular interest to us here are environmental services that are consumption amenities. The Annexe discusses methods that have been deployed to estimate their shadow prices. The basis for those methods is equation (A2.1).

A2.2 Capital Assets

Once the forecaster has identified the RAM that corresponds to his economy, he can, as equation (A1.10) shows, express intergenerational well-being as

$$V(t) = V(K(t),t). \quad \text{(A2.2)}$$

Shadow prices of capital assets can then be defined from equation (A1.10), or in the time-autonomous case from equation (A1.12). To see how, let $P_i(t)$ be the shadow price of asset i at the date the social evaluator is doing her study. Recall Definition 3a in the text. Using it we have

$$P_i(t) = \partial V(K(t),t)/\partial K_i(t). \quad \text{(A2.3)}$$

The way to estimate shadow prices of capital assets is to make use of equation (A2.3). The equation implies that the shadow price of a capital asset at date t is a function of the entire stock of assets, K(t), and possibly (if calendar time matters) of t itself. Thus

$$P_i(t) = P_i(K(t),t). \quad \text{(A2.4)}$$

Should RAM be time-autonomous, equation (A2.4) reduces to

$$P_i(t) = P_i(K(t)). \quad \text{(A2.5)}$$

In Section 2.6 of the text we present an outline of the steps required to estimate Pi(K(t)). The Annexe discusses estimation problems that are unique to particular assets.

A2.3 Special Features of Shadow Prices

Shadow prices contain an enormous amount of information, both about values and facts. To illustrate, let us re-write the additive form of intergenerational well-being (equation (3) in the text):

$$V(K(t),t) = {}_{u=t}\Sigma B(C(u),u)/(1+\delta)^{(u-t)}, \quad \delta \geq 0. \qquad (A2.6)$$

Assume the economy is time-autonomous. In that case C(u) is a function of K(t). So we write equation (A2.6) as

$$V(K(t)) = {}_{u=t}\Sigma B(C(K(t))/(1+\delta)^{(u-t)}, \quad \delta \geq 0. \qquad (A2.7)$$

Using equation (A2.7) in equation (A2.3) we may conclude

(1) If δ is large (small), the influence on today's shadow prices of future scarcities would be small (large). δ determines the relative weights between future and present flows of societal well-being.[75] An asset's current shadow price reflects not only current scarcities, but future scarcities too.

Imagine next that the economy has been profligate in the use of natural capital in the past and that the RAM predicts continuing profligacy. Natural capital (or at least some forms of natural capital) will in that case be particularly scarce in the future. That means an additional unit today of a natural capital, say asset i, would be valued highly. That's a way of saying that, other things being equal, $\partial V(K(t),t)/\partial K_i(t)$ is large. We therefore have

(2) Future scarcities are reflected in shadow prices via the economic forecast. To the extent assets are not easily substitutable in production or consumption, those that are seriously depleted and not easily renewable would be valuable even today. Equation (A2.3) reflects that. Economists call an asset essential if substitution possibilities between it and other assets in either consumption or production are very limited.

[75] We commented on this in Section 2.6.4 of the text when noting the large difference in the estimates in Stern (2006) and Nordhaus (2008) of the global shadow price of carbon concentration in the atmosphere.

Appendix 3

Shadow Prices under Uncertainty

To illustrate the influence of uncertainty on shadow prices, consider a fishery. We denote its stock by K. Imagine the social evaluator has studied fisheries well enough to know that there is a threshold population size, call it K_c, such that the fishery would be doomed if the population were to drop below it, but could survive indefinitely if the population were to be above it and were not over-exploited. To formalize the loss that would be suffered if the fishery were to cross the threshold, imagine that $V(K_c)$ is the value of the fishery if K is marginally in excess of K_c, but would be a small fraction, α, of $V(K_c)$ if K were marginally less than Kc. Crossing the threshold would mean a discrete loss, amounting to $(1-\alpha)V(K_c)$. That means V(K) is discontinuous at K_c. But equation (A2.3) in Appendix 2 was based on the assumption that V is differentiable. What could the fishery's shadow price mean in such a situation?

Let us suppose that even though the social evaluator doesn't know the true value of K_c, she knows that it is not above K** nor below K*. So she knows that Kc lies somewhere in the range [K*, K**]. To have an interesting problem, imagine next that the stock is currently above K** but there are signs of over-fishing, which is why the social evaluator has been called upon to give advice.

In order to study the problem, she constructs a discrete analogue of the fishery by dividing the interval [K*, K**] into N equal sub-intervals of length Δ. So, $\Delta = (K^{**}-K^{*})/N$. For simplicity of exposition we imagine that the social evaluator believes K_c to lie in one of those N sub-intervals with equal probability. Currently the fishery's size is just above K**. Suppose under business as usual the stock at time t would drop to $(K^{**}-\Delta)$. The expected loss in well-being would be $(1-\alpha)V(K_c)/N$. If N is large, the expected loss is small, meaning that the expected value of V (equation (4) in the text) is a smooth function of K at K_c. But that means the shadow price of a marginal unit of fish, $P(K_c)$, is well-defined.

Imagine next that a policy analysis persuades the social evaluator that the risk to the fishery under business as usual is worth it. She recommends business to remain as usual and the fishery enters the interval $[K^{**}-\Delta, K^{**}]$. There are now two possibilities:

(a) It is discovered that the threshold did in fact lie in the interval $[K^{**}-\Delta, K^{**}]$. As the fishery is now known to be doomed, society will have entered a new accounting regime. All shadow prices will have to be recomputed. But Proposition 1 in the text would hold subsequently.

(b) The fishery is discovered to be safe. The social evaluator realises that the threshold lies in the interval $[K^{*}, K^{**}-\Delta]$, but now there are (N-1) sub-intervals left. Being a good Bayesian probabilist, the social evaluator concludes that the probability Kc lies in any of them is 1/(N-1). That's still a small number, so the previous argument continues to hold. And it will continue to hold so long as the probability that Kc lies in the next sub-interval remains small. But once that probability becomes appreciable, the fishery's "shadow price" becomes a meaningless term. Both policy analysis and sustainability analysis would require the social evaluator to estimate the discrete loss in human well-being that would result from the fishery crossing its threshold. The method to be adopted in this case is similar to the rule in social cost-benefit analysis that for large projects the benefits should include "consumers' surplus". Shadow prices don't suffice when the changes to be evaluated are appreciable in size.

Appendix 4

The Measurement of Wealth

We begin by proving Propositions 1 and 2. As noted in the text, the Propositions are valid for sustainability analysis covering short intervals of time. The Propositions are then extended to cover discrete time intervals. Finally we show that the list of capital assets is to an extent a matter of choice.

A4.1 Equivalence of Wealth and Well-Being

For analytical convenience we assume time is a continuous variable. As previously Pi(t) is the shadow price of asset i at t (the date the social evaluator is conducting her study). K(t) is the vector of capital assets. The population profile is included in the list of assets. On the basis of the forecaster's RAM intergenerational well-being is represented by the function V(K(t),t). Definition 3, which was formalized in Appendix 2 (equation (A2.3)), says

$$P_i(t) = \partial V(K(t),t)/\partial K_i(t). \qquad \text{(A4.1)}$$

The economy's wealth (equation (5) of the text) is

$$W(t) = {}_i\Sigma[P_i(t)K_i(t)]. \qquad \text{(A4.2)}$$

Consider a small interval of time [t, t+Δt]. Denote the change in V(t) over the period by ΔV(t). Because V(t) can be written more explicitly as V(K(t),t),

$$\Delta V(t) = \Delta V(K(t),t). \qquad \text{(A4.3)}$$

During Δt the composition of capital assets changes slightly. Let $\Delta K_i(t)$ be the (small) change in the stock of i. Because "Δ" represents a small perturbation, the right hand side of equation (A4.3) can be expressed as

$$\Delta V(K(t),t) = {}_i\Sigma[\partial V(K(t),t)/\partial K_i(t)]\Delta K_i(t) + [\partial V(K(t),t)/\partial t]\Delta t. \qquad \text{(A4.4)}$$

Define r(t) as

$$r(t) = \partial V(K(t),t)/\partial t. \qquad \text{(A4.5)}$$

r(t) is the "shadow price of time", a term that could appear ludicrous, for it suggests that time is a capital asset. It isn't ludicrous though. If exogenous forces were a feature of the economy's RAM, intergenerational well-being would be an explicit function of time. In that case we would regard time as an additional capital asset, subsumed in the list of assets in Section 2.4. But for vividness let us keep time separate from the other assets. Below (Section A4.4) we confirm that an alternative would be to not regard time as an asset but subsume it in the structure of shadow prices of quality-adjusted measures of the more grounded assets, which are reproducible capital, human capital, and natural capital.

Using equation (A4.1) in equation (A4.5) we obtain

$$\Delta V(K(t),t) = {}_i\Sigma P_i(t)\Delta K_i(t) + r(t)\Delta t. \qquad \text{(A4.6)}$$

Dividing both sides of equation (A4.6) by Δt and taking the limit as Δt goes to zero, we have

$$dV(K(t),t)/dt = {}_i\Sigma P_i(t)dK_i(t)/dt + r(t). \qquad \text{(A4.7)}$$

Equation (A4.7) is Proposition 1.

A4.2 Sustainability Analysis On Intervals of Time

Equation (A4.7) gives us an equivalence relationship between wealth and well-being; but its validity requires that the interval of time is short. How should sustainability analysis be conducted if the interval is not short?

For expositional ease, assume that the economy's RAM is time-autonomous. In that case $r(t) = 0$ and so $V(K(t),t) = V(K(t))$. Equation (A4.7) then reduces to

$$dV(K(t))/dt = \sum_i P_i(t)dK_i(t)/dt. \qquad (A4.8)$$

Suppose the interval to be studied is [t,t+T]. Integrating both sides of equation (A4.8) by parts and using equation (A4.2), we have

$$V(t+T) - V(t) = W(t+T) - W(t) - \int_t^{(t+T)}[\sum_i(dP_i(u)/du)K_i(u)]du. \qquad (A4.9)$$

Equation (A4.9) says that the difference between intergenerational well-being at dates t+T and t is the difference between the economy's wealth at those two dates, corrected by a quantity representing changes in the shadow prices over the period.

A4.3 What Does Investment Measure?

Proposition 7 gave us the normative significance of net investment. It says the value of net investment equals the gain in intergenerational well-being brought about by the investment. To prove the Proposition, let K(t) be the stock of capital assets at t. Now imagine that the economy is awarded a further stock amounting to ΔK(t) over the brief period [t,t+Δt], where as before, Δ signifies a small change. If intergenerational well-being has the additive form of equation (3), the resulting change is

$$V(K(t)+\Delta K(t)) - V(K(t)) \approx \int_t [dU(C(u)/dC(u)] \Delta C(u)e^{-\delta(u-t)}du. \qquad (A4.10)$$

We now interpret ΔK(t) to be the increase in the stock of capital assets owing to an increase in investment at t. So the stock of capital assets at t+Δt is K(t+Δt) = K(t)+ΔK(t). Now let Δt tend to zero. Equation (A4.10) then yields Proposition 7.

A4.4 Is Time a Separate Asset or Should Shadow Prices Subsume Time?

In this Report we have repeatedly had to accommodate variables that are exogenous functions of time. Some appear to be exogenous even though they are not only because we don't have an adequate understand of the world. Total factor productivity (TFP) is an example. Macroeconomic models frequently regard TFP as an exogenous function of time because we don't yet have an adequate understanding of the mutual influence of knowledge and institutions and economic performance. Population growth is another, which is why it is customary to forecast future numbers on the basis of past trends, not on a detailed demographic theory. However, there are variables whose movements are truly exogenous, as when a small oil-exporting country enjoys capital gains on its reserves owing to the efforts of oil cartels. How should exogenous changes enter national accounting?

There are two ways. One is to regard time as an asset and estimate its shadow price (r(t)). The dynamical system that characterizes the economy is non-autonomous. This is the route we followed in Section A4.1. The other is to trace the influence of the exogenous forces on capital assets and measure the assets in "efficiency units". When we do that, the assets are quality-adjusted. The resulting dynamical system is autonomous. We now show that the two methods are equivalent.[76] We do that by studying how we should decide which objects to include in the list of capital assets.

Assume population is constant over time. Output Y(t) at time t is taken to be a power function of a single all-purpose asset, which we write as K(t). Thus

$$Y(t) = A(t)K^{\alpha}(t), \qquad 0 < \alpha < 1.^{77} \qquad (A4.11)$$

A(t) is TFP at t. It reflects the economy's institutions and knowledge base. Imagine that A(t) grows at a constant, exogenous rate γ. As noted in the text (Section 2.4), γ is usually referred to as the "Solow residual".

Suppose consumption C(t) is a constant proportion, (1-s), of output Y(t). As s is the saving rate, the dynamics of the economy are described by the equations

$$dK(t)/dt = sA(t)K^{\alpha}(t), 0 < s < 1, \qquad (A4.12)$$

$$dA(t)/dt = \gamma A(t). \qquad (A4.13)$$

Equations (A4.11)-(A4.13) define the economy's RAM.

One way to interpret the equations is to regard both A and K as state variables. In that view of things the model has two assets: A and K. Notice that equations (A4.11)-(A4.13) represent an autonomous system. Intergenerational well-being V is therefore a function of A and K:

$$V(t) = V(A(t),K(t)). \qquad (A4.14)$$

Shadow prices of the pair of assets are then, respectively,

$$P_A(A(t),K(t)) = \partial V(A(t),K(t))/\partial A(t), \quad (A4.15a)$$

$$P_K(A(t),K(t)) = \partial V(A(t),K(t))/\partial K(t). \quad (A4.15b)$$

Wealth is

$$W(t) = P_A(A(t),K(t))A(t) + P_K(A(t),K(t))K(t). \qquad (A4.16)$$

However, to regard A(t) as another asset, and so to regard the system as autonomous is something of a cheat. The reason is that A(t) is a mere transform of t itself. It would make equal sense to express (A4.14) as

$$V(t) = V(t,K(t)), \qquad (A4.17)$$

which exposes the fact that the economic system is in reality non-autonomous!

The alternative route is to amalgamate A and K into a single asset. That can be done by measuring the quantity of K in efficiency units. To see what it involves, define the variable A* as

$$A^{*\alpha} = A. \qquad (A4.18)$$

Using equation (A4.14) we may then re-write equation (A4.11) as

$$Y(t) = [A^*(t)K(t)]\alpha. \qquad (A4.19)$$

Now define the variable X as

$$X = A^*K. \qquad (A4.20)$$

In interpreting X we may think of K as improving in quality at an exogenous rate. X is then quality-adjusted K.

Using equation (A4.20) we re-write equation (A4.11) as

$$Y(t) = X^{\alpha}(t). \qquad (A4.21)$$

---

[76]The analysis is taken from Arrow et al. (2012b)

[77]In practice K(t) would be a combined aggregate numerical index of reproducible capital, human capital, and natural capital.

Equation (A4.21) says that the economy has a single, composite asset X. Intergenerational well-being is now a function solely of X. Thus

$V(t) = V(X(t))$.(A4.22)

The dynamical system is autonomous.

Comparison of equations (A4.14) and (A4.22) tells us that by changing the way we measure economic objects we can alter the list of an economy's capital assets.

In sustainability analysis we are interested in the sign of the change in W over time at constant prices. In their empirical work the measurement of wealth, Arrow et al. (2012a) went further. The authors estimated the percentage rate of change in W at constant prices. Equation (A4.22) says that the corresponding exercise here would involve estimating the percentage rate of change in X(t). Let g(.) the percentage rate of change in any variable. Equations (A4.17) and (A4.20) imply

$$g(X(t)) = g(K(t)) + \gamma/\alpha. \qquad \text{(A4.23)}$$

As K is an aggregate of all three categories of capital assets in a world of constant population, α should plausibly be taken to equal 1. But in that case consumption grows super-exponentially, an awkward feature unless s is so small that the data are not at variance with super-exponential growth. Arrow et al. (2012a: 327) noted that if s is small and $\alpha = 1$, the second term in equation (A4.23) is γ. The equation says that in that case the Solow residual should be added to the growth rate of wealth to obtain the index of sustainable development, which is g(X(t)).

A4.5 Wealth per capita as an Approximate Index of Well-Being

In this and the previous Appendices we have regarded population as an aspect of human capital. However, Arrow, Dasgupta, and Maler (2003) showed that estimating the shadow price (more precisely, prices) of population involves especial difficulties. The question arises whether wealth per capita could serve as an index of well-being across the generations. What we require is an equivalence relation, as in equation (A4.7), but between movements in an index of well-being across the generations and wealth per capita. If such a relationship were to exist, we could remove population from the list of capital assets and measure wealth in terms of capital stocks per capita.

Dasgupta (2001) showed that such an equivalence relation exists, provided human-nature interactions over time can be represented in terms of the movements in per capita capital stocks and population size and provided that in place of intergenerational well-being the ethical objective were average well-being across the generations.

For notation simplicity suppose there is a single consumption good, C. If L(u) be population size at date u, C(u)/L(u) is per capita consumption at u. Write C(u)/L(u) = Z(u) and let U(Z(u)) denote per capita well-being at date u. Aggregate well-being among all who are alive at u is then L(u)U(Z(u)). As previously, K(t) is the vector of capital stocks (excluding population) at date t. Let

$$k_i(t) = K_i(t)/L(t). \qquad \text{(A4.24)}$$

$k_i(t)$ in equation (A4.24) is the per capita stock of asset i.

In the obvious notation, define

$$V^*(k(t),t) = [{}_{u=t}\Sigma L(u)U(Z(k(t),u)/(1+\delta)^{(u-t)}]/{}_{u=t}\Sigma L(u)/(1+\delta)^{(u-t)}, \quad \delta \geq 0. \quad \text{(A4.25)}$$

Notice that the denominator on the right hand side of equation (A4.25) is the present discounted value at t of population sizes from t onward. So $V^*(k(t))$ is average well-being across the generations. Let

$$p_i(t) = \partial V(k(t),t)/\partial k_i(t), \qquad (A4.26)$$

$$r(t) = \partial V(k(t),t)/\partial t. \qquad (A4.27)$$

In equations (A4.26) and (A4.27) $p_i(t)$ and $r(t)$ are the shadow prices of asset i per capita and of time, respectively.

Dasgupta (2001) showed that if the conditions just mentioned are satisfied, then

$$dV^*(k(t),t)/dt = {}_i\Sigma p_i(t)dk_i(t)/dt + r(t). (A4.28)$$

Equation (A4.28) gives us the equivalence relationship stated in Proposition 7.

A4.6 The World Bank's Alternative Measure of Wealth[78]

World Bank (2011) has studied the relationship between wealth and well-being empirically. The authors were not so much concerned with sustainability analysis as with estimating the composition of wealth in terms of its various categories. On this, however, their method differs substantially from the one we have arrived at in this Report.

The authors estimated the social worth of natural capital, reproducible capital, and education. They did not, however, attempt to value what they call "intangible capital", including institutions, knowledge, and human lifespan. They avoided the problem of estimating intangible capital by first creating an estimate of a measure of wealth (we show below that they did not so much estimate it but postulate it) and then attributing to the social value of intangible wealth the difference between their postulated estimate of wealth and the value of the components of wealth they did estimate. More importantly, the authors defined wealth not as the value of an economy's stock of capital assets (equation (6) in the text of our Report), but as the present value of aggregate consumption. Their procedure for estimating the present value was to assume that consumption in each country in their sample will grow at a specified constant rate. If the authors had postulated a different rate, their estimate of wealth would have been different; consequently the value they derived for intangible capital would have been different.

The procedure has at least three problems. First, as the authors assume they know the rate at which per capita consumption is and will be growing for the indefinite future, the sustainability of economic development in the countries in their sample is assumed, not studied. Secondly, there isn't, not can there be, an empirical basis for estimating future consumption that does not include the present basis for it, namely, the current productive base. There is then circularity in their approach to measurement. Third, the identification of wealth with the present value of consumption is valid only under the assumptions that (i) the economy under study is on an optimal path and (ii) the production structure exhibits constant returns to scale. Assumption (i) is otiose for reasons to do with the contemporary political economy of development, and (ii) is unacceptable because as a rule, not as an exception, the processes governing natural systems exhibit non-linearities.

[78]This Appendix is taken from Arrow et al (2012b)

Appendix 5

Inadequacies of GDP and HDI in Economic Evaluation

Currently the two most popular indices of societal well-being are GDP per capita (alternatively, gross domestic income) and the United Nations' HDI. Here we study whether they are suitable in exercises in economic evaluation.

A5.1 GDP

GDP is the total market value of the final goods and services an economy produces. The rogue word in gross domestic product is "gross". GDP doesn't deduct the depreciation of capital. Strikingly, it doesn't deduct the depreciation of natural capital.

In the macroeconomic models that appear in leading economics journals and textbooks, nature is taken to be a fixed, indestructible factor of production.[79] The assumption is wrong. Agricultural land, forests, watersheds, fisheries, fresh water sources, river estuaries, and the atmosphere are capital assets that are self-regenerative but suffer from depletion or deterioration when they are over-used (Appendix 6-7).[80] To assume away the physical depreciation of capital assets is to draw a wrong picture of future production and consumption possibilities that are open to a society.

Here is an illustration of what goes wrong when depreciation is ignored. Repetto et al. (1989) and Vincent et al. (1997) estimated the decline in forest cover in Indonesia and Malaysia, respectively. They found that when depreciation is included, national accounts look quite different: net domestic saving rates are some 20-30 per cent lower than recorded saving rates. In their work on the depreciation of natural resources in Costa Rica, Solorzano et al. (1991) found that the depreciation of three resources — forests, soil, and fisheries — amounted to about 10 per cent of GDP and over a third of domestic saving.

A5.2 HDI

The United Nations' Human Development Index, HDI, is a linear combination of GDP per capita, life expectancy at birth, and literacy. The former measures the market value of economic activity, while the latter two measures reflect aspects of "human capital" (health and education, respectively). HDI is a pure number, lying between 0 and 1. Since 1990, UNDP in its annual Human Development Report has used HDI each year to rank countries; but users of the index (including UNDP) have gone further and tracked the HDI of countries over time, to judge whether a country has improved its performance or fallen behind. And there lies one of its problems. We show below how and why.

To describe HDI formally, let k (k = 1, 2, 3) denote a desirable attribute: 1 for GDP

[79]See for example Romer (1996), Barro and Sal-i-Martin (2003), and Helpman (2004).
[80]For the moment we are excluding oil and natural gas, which are at the limiting end of self-regenerative resources.

per head; 2 for life expectancy at birth; 3 for literacy. Suppose the number of countries being compared is L (l = 1,2,...,L). Let $X_{kl}(t)$ be the numerical index of attribute k in country l. Write max$\{X_k\}$ as the highest figure attribute j can possibly attain (100 per cent for literacy; 100 years (say) for life expectancy; 80,000 international dollars (say) for GNP per head); and write min$\{X_k\}$ as the minimum figure k can possibly attain (e.g., 0 per cent for literacy). UNDP defines country l's "performance gap" in attribute k in year t to be,

$$I_{kl} = [\max\{X_k\}-X_{kl}(t)]/[\max\{X_k\}-\min\{X_k\}]. \quad (A5.1)$$

In words, the numerator in equation (A5.1) is the gap between the maximum value k can attain and the value attained by country l; while the denominator is the difference between the highest and lowest possible values of k. Clearly, Ikl is a number lying between 0 and 1, depending on the performance of the country.

Now use equation (A5.1) to construct the average performance gap for country j as,

$$I_l(t) = {}_k\Sigma[I_{kl}(t)]/3. \quad (A5.2)$$

Il(t) is a number lying between 0 and 1.

HDI for country l in year t is then defined as,

$$[HDI(t)]_l = (1-I_l(t)). \quad (A5.3)$$

Equation (A5.3) says that $[HDI(t)]_l$ is a number lying between 0 and 1; the higher is $[HDI(t)]_l$, the better is country l's achievements in terms of the three attributes.

HDI has been much advertised by the United Nations Development Programme for over two decades. And because it is a simple index, HDI now has many adherents. But as a quality-of-life measure at a moment in time, it has serious deficiencies. First, formula (A5.3) is entirely ad hoc. There are an infinite number of numerical indices that could be created to reflect the idea that GDP per capita, life expectancy at birth, and literacy matter. Take some other index based on those same attributes, and we would obtain a different ranking of contemporary countries. More importantly, UNDP has never attempted to justify the tradeoffs among the three attributes that are implied in equations (A5.1)-(A5.3); the tradeoffs are postulated and taken as desirable. When the Classical Utilitarians proposed the sum of individual utilities as the desired social objective, they offered a moral conception to justify the move. UNDP haven't attempted to provide a justification.

UNDP (2010) has introduced greater substitution possibilities among its three constituent indices than the linear form of equation (A3.3). But again, the authors have provided no justification for their chosen functional form. The new measure reveals odd tradeoffs. Ravallion (2012) has shown that under the new HDI the value of longevity in Zimbabwe is 51 US cents per year. That means if Zimbabwe's authorities were to make a policy change that increases national income by a mere 52 US cents per person per year at the cost of reducing average life expectancy by one year, the country will have promoted human development. That doesn't feel right.

The second thing to note about HDI is the absence of natural capital. That alone should tell us that HDI is incapable of serving effectively in sustainability analysis. In view of Proposition 3, HDI is incapable of serving effectively in policy evaluation as well. Both theory and empirics show that a society's HDI could increase over a period of time even as wealth per capita declines (Dasgupta, 2001). As an index of intergenerational well-being HDI has to be rejected.

Appendix 6

Fugitive Resources

Many resources are mobile in their natural habitat. They are often called fugitive. The term appears to have been coined for aquifers, and oil and natural-gas reserves, which reconstitute under pressure gradients.

Understandably, property rights to fugitive resources are often weakly specified. Even when specified, they are all too frequently unenforceable (e.g., aquifers). So, using those resources creates externalities. The question arises as to how fugitive resources should be modelled. Sometimes it is suggested that in view of their mobility, it may prove to be a mistake to consider them as capital assets in the conventional sense. River water flows everywhere, so where is the stock that's supposed to represent the asset we call a "river"?

The correct move is to define stocks of mobile resources in a location-specific manner. The "service" that can be obtained from those stocks would then be identified also in a location-specific way (Sections 2.6.3 and 2.6.4). In some cases, though, scientists have ignored the spatial character of mobile resources by modelling their mobility in a "reduced-form" (Section 2.6.2). The classic equations governing the spread of infectious diseases (reviewed in Anderson and May, 1991, Ch. 6), for example, don't mention location; but instead postulate the dynamics of a three-way division of host populations: susceptible, immune, and infected members. The parameters of the model stand for host-population density, its geographical spread, social habits of the members of the host population, and so forth. Empirical work on the spread of infections, of course, requires explicit spatial modelling and is so conducted (Anderson and May, 1991).

In what follows we construct four canonical examples to illustrate the various ways mobile resources have been modelled. The dynamics would be the basis on which shadow prices would be estimated. Denote time by t. In what follows t is taken to be continuous.

A6.1 Percolation of Oil, Natural-Gas, and Ground Water

Under the rule-of-capture, wild-caters in the late 19th century were able to expropriate more oil than had lain under the land they had claimed as their private property. They were able to do so because oil diffuses underground in response to pressure gradients caused by drilling. Slant drilling accentuates the diffusion. Percolation theory offers the most effective way to model sub-soil movements of liquids and gases, but the simple model that follows captures the essence of pressure gradients.

Imagine two identical tanks filled with water but connected at the bottom by a narrow tube. As water is extracted from the tanks by a pair of "wild-caters", it flows from one to the other in response to any resulting pressure difference. Because the tanks are identical, the volume of water in a tank can serve as an index of water pressure at the tank's bottom.

At time t water is extracted at rates $C_1(t)$ and $C_2(t)$ from tanks 1 and 2, respectively. Let $K_1(t)$ and $K_2(t)$ be the stocks of water in the tanks. If ε (> 0) is the diffusion rate through the tube, we have the mass conservation condition:

$$dK_1(t)/dt = -C_1(t) + \varepsilon[K_2(t) - K_1(t)], \quad (A6.1a)$$

$$dK_2(t)/dt = -C_2(t) + \varepsilon[K_1(t) - K_2(t)]. \quad (A6.1b)$$

Equations (A6.1a-b) say that each wild-cater inflicts a "stock externality" on the other. It can be shown (but it turns out not to be trivial to show it!), that in the absence of cooperation, both parties would drill at rates that are faster than they would agree to if they were able to reach collective agreement on the rate of extraction.

Under collective agreement the extractors would regard the tanks as a single reserve. The aggregate stock of ground water, K(t), would obey the dynamical condition obtained by summing equations (A6.1a-b):

$$dK(t)/dt = - C_1(t) - C_2(t), K(t) = K_1(t)+K_2(t). \quad (A6.2)$$

If the extractors were to choose $C_1(t)$ and $C_2(t)$ in an agreed-upon manner, there would be no externalities. Enforcement of the agreement would eliminate the stock externality. In Appendix 7 (Section A7.2) we show how to estimate the shadow price of ground water when there is free access to the reserve.

A6.2 Fishery

Let K denote the fish stock, measured in, say, units of biomass. The natural regenerative rate, G(K), of a single fishery is most commonly taken to be quadratic. If C(t) is the catch at t,

$$dK(t)/dt = G(K(t)) - C(t), \quad (A6.3)$$

$$G(K(t)) = rK(t)(1 - K(t)/K^*), r, K^* > 0. \quad (A6.4)$$

In equation (A6.4), r and K* are parameters.

The idea underlying equations (A6.3)-(A6.4) is that the fishery enjoys a constant rate of food supply. If fish are not harvested (C = 0) and K were small to begin with (i.e., K^2 is negligible relative to K), growth would be exponential at rate r because the supply of food would to all intents and purposes be unlimited. But as fish biomass grows, the constancy of the food supply begins to bite and constrains growth (the negative quadratic term, K^2 in equation (A6.4) becomes large). Left un-harvested, K = K* is the unique stable equilibrium (Fig. 3). K* is therefore the fishery's carrying capacity. It is simple to confirm that at K = K*/2 the fishery offers its maximum sustainable yield (MSY) and that the MSY is rK*/4.

The r-K* model is the single-most important ingredient in ecological theory. It appears everywhere, under different interpretations, of course. We return to it in a different guise in Appendix 7.

Because fish populations are mobile, sighting them is costly. Moreover, the smaller is the population, the larger is the unit cost of harvesting the prey. We may then write the unit harvest cost as e(K), where e (standing for "effort") is a declining function of K. Total harvest cost at t is then e(K(t))C(t). In short, the mobility of fish is reflected in e(K).[81]

[81]Dominant fishing companies have elaborate spatial models in the oceans, in which migratory routes are identified from feeding and breeding grounds, oceanic currents, and so forth.

A6.3 Diffusion of Atmospheric Pollution

Atmospheric particulates (e.g., SO_x, NO_x) diffuse across space. The simplest formulation is in terms of the equations governing Brownian motion. (Winds are an added factor in such diffusion processes.) The most common models assume point sources of emission. The resulting models are a special version of what are known as "reaction-diffusion equations."

To illustrate, let x denote location, where for simplicity of exposition, space is taken to be the real line. Let K(x,t) be the stock of the particulate at point x at time t. If Y(x,t), I(x,t), and O(x,t) are, respectively, the rates of emission, inflow, and outflow of the particulate at (x,t), then mass conservation says

$$\partial K(x,t)/\partial t = Y(x,t) + I(x,t) - O(x,t). \quad (A6.5)$$

Specification of the point emission sources (Y(x,t)) and the dynamical equations characterizing the way the particulate diffuses across space give us I(x,t) and O(x,t). Together with equation (A6.5), they enable the analyst to chart K(x,t) as a function both of x and t.

A6.4 Rivers

We imagine that the river has as its source a glacier (Gomukh). We should then regard the glacier as a capital asset. The flow of river water is a location and time specific service generated by the glacier. In other words, the source of the river is the capital asset (glacier, lake, underground spring). The water flow is the service that the source offers along its basin.

For simplicity of exposition, we take the unit of time to be a year. That way we can average over the annual cycle and ignore the accumulation and melting of the glacier across the seasons. The move enables us to ignore the time dimension.[82] As in the previous example, let the river be linear ($x \geq 0$). x = 0 is taken to be the glacier's location. To avoid additional notation, imagine that the river has no tributaries (i.e., further sources of water that are added at certain points along the river). Let Y(x) be the water flow at x, net of seepage and evaporation. If C(x) is the water withdrawn at x, then

$$C(x) \leq Y(x), \qquad \text{for all } x, \qquad (A6.6)$$

$$Y(x) = Y(0) - \int_0^x [C(s)]ds, \quad \text{for all } x. \qquad (A6.7)$$

Humanity is able to draw on river water (C(x)), subject to constraint (A6.6). Equation (A6.7) is the mass conservation condition.

For concreteness we should think of Y(x) as the flow of available water at x, and C(x) as water withdrawn for agriculture, industry, and urban residents. The difference between Y(x) and C(x) in condition (A6.6) is the water taken up by plants and drunk by animals who reside in the river basin. When additional water is withdrawn at a location, biodiversity there suffers. That's one potential source of social conflict. The construction of dams at, say, x raises Y(x) at the expense of water downstream as well as life at x. Equation (A6.7) points to potential conflicts between upstream and downstream residents. The river's worth is the present discounted value of the flow of water (with a multitude of shadow prices) all along the river and its drainage basin. The flow of water is the asset's spatially distributed service.

[82]Building in the seasons is a routine, but tiresome exercise.

Appendix 7

Human-Nature Interactions

Three pieces of information are required for estimating shadow prices:

(i) A descriptive model of the economy moving through time, including not only technological possibilities and ecological processes, but also preferences, tastes, values, and policies.

(ii) The size and distribution of the economy's capital assets at the date at which the economic evaluation is undertaken.

(iii) A conception of intergenerational well-being.

The concept of RAM, developed in Appendix 1, is integral to organizing (i) and (ii). The idea of well-being ((iii)) was the subject of Section 2.2 of the text. Here we construct a pair of models to illustrate (i).

Formal models of the economy are of the utmost relevance for preparing national accounts. They inform the accountant of the correct way to classify activities in income-expenditure accounts. They also give the social evaluator the framework for estimating shadow prices. The first model is of a non-linear economic-ecological system containing two stability regimes. The analysis shows how societal catastrophes can occur. We then analyse a common-pool resource.

A7.1 Ecological Thresholds and Catastrophes

There is a single reproducible commodity that can be consumed or saved. For vividness we move away from the practice of labelling capital assets by i and denote them mnemonically instead. Output (GDP), which we write in the familiar manner as Y, is produced by means of three capital assets: reproducible capital (K), human capital (H), and services extracted from ecological capital, whose "quantity" we denote by S (for "stock"). For concreteness we will measure the stock in units of biomass. Labour is supplied in-elastically. Extraction amounts to depleting the ecosystem's biomass (e.g., by habitat destruction). Population is constant and the economy is deterministic. Aggregate consumption is denoted by C.

The economy is imperfect. Human behaviour is described by three parameters: a constant proportion c of GDP is consumed; a constant proportion h of GDP is invested in the accumulation of human capital; and a constant proportion d of the ecosystem is extracted for use in production. Our specification is very much in line with the way such statistics are presented in time series data. The unit cost e of extracting ecosystem services, measured in terms of output, is assumed to be independent of the rate of extraction. Time is continuous. As previously, it is denoted by u and t ($u \geq t$). The evaluation is conducted at t.

We may now express consumption as

$$C(u) = cY(u). \qquad (A7.1)$$

This leads to the fundamental income-expenditure identity at u:

$$dK(u)/du = (1-c-h)Y(u) - edS(u). \qquad (A7.2)$$

Human capital accumulates at the rate at which investment is made in it, but because of death, depreciates at a constant rate β, the net accumulation rate is

$$dH(u)/du = hY(u) - \beta H(u). \qquad (A7.3)$$

If the flow of ecosystem services into production is R,

$$R(u) = dS(u). \qquad (A7.4)$$

Output possibilities are given by the aggregate production function

$$Y(u) = A(u)F(K(u),H(u),R(u)). \qquad (A7.5)$$

In equation (A7.5) A denotes TFP. Marginal products of the three factors of production are assumed to be positive but subject to diminishing returns. The degree to which the assets are substitutable in production is reflected in the production function F, a feature of importance to which we will return presently. If TFP grows exogenously (Manna from heaven!), as assumed in Appendix 4, $A'(u) > 0$.

Before formulating the regeneration function for natural capital, it will prove useful to recall the general characteristics of ecosystems.

Ecological processes display positive feedback, by which is meant the whole is greater than the sum of an ecosystem's parts. The system's integrity is compromised when it is in a state of continued deterioration. The danger points are called thresholds. When an ecosystem crosses a threshold its character changes significantly, as when grassland turns into shrub-land, or worse, a wasteland. The transformed system also has biomass of course, but its composition is wildly different. As we have a non-spatial index of the natural capital in question, we take thresholds to be particular values of S.

Let G(S) be the ecosystem's regeneration rate. So in the absence of human predation,

$$G(S(u)) = dS(u)/du. \qquad (A7.6)$$

Let us consider the form

$$G(S) = r[S - S^*][1 - (S-S^*)/(S^{**}-S^*)], \text{ if } S > 0$$

$$= 0, \text{ if } S = 0;$$

$$r, S^*, (S^{**}-S^*) > 0. \qquad (A7.7)$$

Equation (A7.7) is simply a horizontal translation of the quadratic growth function in equation (A6.4). The way to connect equation (A7.7) to those features of ecosystems we have just recounted is to observe that the ecosystem under study has three equilibria: 0, S^* and S^{**}. We may ignore $S = 0$ because at that biomass the ecosystem is dead. So we study S^* and S^{**} (Fig. 4).

S^* is unstable. It is the ecosystem's threshold and is the source of the system's non-linearity. In contrast, S^{**} is a stable equilibrium and is the ecosystem's carrying capacity. Simple calculation shows that the ecosystem's maximum sustainable yield (MSY) is at $S = (S^{**}-S^*)/2$, and that $MSY = r(S^{**}-S^*)/4$. So long as S is some distance above S^*, the ecosystem is resilient, which is to say moderate disturbances would keep the system away from its threshold.

As the ecosystem is however a part of the economy, its net regeneration rate is the natural regeneration rate minus the rate of extraction:

$$dS(u)/du = G(S) - R(u) = G(u) - dS(u). \quad (A7.8)$$

Equations (A7.1)-(A7.8) describe a complete dynamical system with state variables, K, H, and S. They enable the forecaster to identify the economy's RAM. K(t), H(t), and S(t) define the "initial condition" for the forecaster (item (ii) above). Shadow prices can be defined on the basis of the economy's RAM (Appendices 1-2).

We may now compute NNP. Let well-being be numeraire and let Q(t) be the shadow price of consumption. Denote the shadow prices of K, H, and S, respectively, by P_K, P_H, and P_S. We define NNP as aggregate consumption plus aggregate net investment. On using equation (8) in the text, we know that in the economy under review

$$NNP(t) = Q(t)C(t) + P_K(t)dK(t)/dt + P_H(t)dH(t)/dt + P_S(t)dS(t)/dt. \quad (A7.9)$$

Equation (A7.9) yields Proposition 8 in the text.

Now use equations (A7.1)-A7.8) in equation (A7.9) to conclude that NNP can also be written as

$$NNP(t) = Q(t)Y(t) - \beta P_H(t)H(t) - P_S(t)[edS(t) - G(t) + dS(t)]. \quad (A7.10)$$

Equation (A7.10) is probably the more familiar form of NNP. For notice that Q(t)Y(t) is what is often called final demand. Equation (A7.10) confirms that extractions costs ($edP_S(t)S(t)$) should be deducted from final demand, as should the net depreciation of capital assets, which aggregates to ($\beta P_H(t)H(t)+dP_S(t)S(t)-P_S(t)G(t)$).

Suppose the rate of extraction d is large. Using the economy's RAM, forecasters would conclude that unless d is reduced, the ecosystem will in time cross the threshold and collapse. This is valuable information for the social evaluator. She will now wish to search for policies that would help to reduce extraction rates.

Can the economy survive ecological collapse? If substitution possibilities in production (equation (7.5)) between R and a combined index of K and H are limited when R is low and there are bounds on the extent to which technology can be expected to overcome future resource constraints, the economy would face catastrophe. In such a world preserving the ecosystem would be vital. The way to save the ecosystem from collapsing would be to introduce policy measures that target extraction. If the rate of extraction is reduced sufficiently, the ecosystem wouldn't ever cross S*. In Appendix 3 we saw how the shadow price of S can be estimated if S* is not known with certainty. When environmental scientists warn growth economists not to ignore the potency of Nature's non-linearities, it is the class of issues raised by equations (A7.1)-(A7.8) they allude to.

A7.2 Common Pool Resources

Shadow prices of exhaustible resources when depletion rates are optimal have been much studied.[83] What is the structure of shadow prices when an exhaustible resource is a "common pool"? We consider the case of a ground water basin.

[83] Hotelling (1931) is the pioneering work.

Time is continuous. The date at which the evaluation is undertaken is t. We assume water is extracted by a large number of farmers. Let R(t) be the aggregate extraction rate at t. We take income to be the numeraire. Let U(R) be the area under the farmers' collective demand curve below R. U(R) is "consumers' surplus", a familiar notion in social cost-benefit analysis. It follows dU(R)/dR is the aggregate demand function.[84] Assume that the demand function is downward sloping. The rate at which revenues and costs are discounted by the farmers is r (> 0).

Let S(u) be the stock of water in the basin at u. Then,

$$dS(u)/du = -R(u), \qquad \text{(A7.11)}$$

Assume that the unit extraction cost is a constant, m (> 0). Because the aquifer is a common pool, ground water rents are dissipated completely. The equilibrium extraction rate therefore satisfies the equation,

$$dU(R(u))/dR(u) = m, \quad \text{for all u for which } R(u) > 0. \qquad \text{(A7.12)}$$

Even though groundwater rents are dissipated to zero, the shadow price of groundwater is positive. To see why, let R* be the solution of equation (A7.12). We then have,

$$dS(t)/dt = -R^*. \qquad \text{(A7.13)}$$

Equation (A7.13) says that farmers will extract water until t+T, where T = S(t)/R*. Let us now normalize U(R) setting U(0) = 0. It follows that the inter-temporal benefits to the farmers, taken collectively is

$$V(t) = \int_t^{(t+S(t)/R^*)}[U(R^*) - mR^*]e^{-r(u-t)}du = [U(R^*) - mR^*]\int_t^{(t+S(t)/R^*)}[e^{-r(u-t)}]du. \qquad \text{(A7.14)}$$

From equation (A7.13) we know that the dynamics of the common pool is time-autonomous. So let P(S) be the shadow price of ground water when the stock is S. From equation (A7.14) it follows that

$$P(S(t)) = \partial V(t)/\partial S(t) = [(U(R^*) - mR^*)/R^*] e^{-rS(t)/R^*} > 0. \qquad \text{(A7.15)}$$

The shadow value of the underground basin is P(S(t))S(t).

Write dU(R)/dR = U'(R) and P*(t) = P(t)/U'(R), the latter being the ratio of the reserve's shadow price to its unit extraction cost (equation (A7.12)). Equations (A7.14) and (A7.15) imply

$$P^*(t) = [(U(R^*) - mR^*)/kR^*]e^{-rS(t)/R^*}) > 0. \qquad \text{(A7.16)}$$

Notice that P*(t) increases as the aquifer is depleted and attains its upper bound at the date at which the pool is exhausted. If reserves are large (S(t) is large), P*(t) is small, and free access involves no great loss - a familiar result.

What are plausible orders of magnitude? Consider the linear demand function. Assume therefore that

$$U(R) = aR - bR^2, \; a > m \text{ and } b > 0. \qquad \text{(A7.17)}$$

From equations (A7.12) and (A7.17),

$$R^* = (a - m)/2b. \qquad \text{(A7.18)}$$

Substituting (A7.16) and (A7.17) in (A7.15),

$$P^*(t) = [(a-m)/2m]e^{-2brS(t)/(a-m)}. \qquad \text{(A7.19)}$$

[84] It is a derived demand function, in as much as the water extracted is used for irrigation.

Equation (A7.19) says that

$P^* \geq 1$ if and only if $rS \leq [(a-m)/2b]\ln[(a-m)/2m]$. (A7.20)

Condition (A7.20) expresses the magnitude of P* in terms of the parameters of the model. Suppose, for example, that r = 0.02 per year, S/R* = 100 years (i.e. at the open access rate of extraction, the aquifer will be exhausted in 100 years), (a-m)/2m = 20 (e.g., m = $0.50 and (a-m) = $20). Then

$P^* = 20\exp(-2) = 7$.

The value that ought to be attributed to ground water is high (about 7 times extraction cost). As the date of exhaustion gets nearer, the shadow price of ground water rises to its upper bound, 20.

Appendix 8

Exploration and Discoveries

How should expenditure on explorations for sub-soil resources enter national accounts? It's best to liken explorations to R&D activity. The analogy becomes obvious when known reserves are made to serve as the counterpart of the state of knowledge.

Let time be continuous, denoted by u and t ($u \geq t$). t is the date at which the evaluation is conducted. Let S denote known reserves and R(u) the rate of extraction. For simplicity of notation we assume extraction costs are nil and that accumulated extraction has no influence on exploration costs.

Turning to the technology of discovery, assume that the rate, N, at which new reserves are discovered is an increasing function of current expenditure on explorations, E. So, the discovery function is N(E(u)) and

$$dS(u)/du = N(E(u)) - R(u).^{85} \qquad \text{(A8.1)}$$

We suppose as in previous Appendices that there is an all-purpose non-deteriorating good, K, which in conjunction with R can reproduce itself. The production function for output Y is F(K,R). If C is aggregate consumption, the economy's income-expenditure equation is,

$$dK(u)/du = F(K(u),R(u)) - C(u) - E(u). \qquad \text{(A8.2)}$$

For concreteness, we revert to the simple behavioural specification we have been making in the Appendices, that constant proportions of output are devoted to investment activities. If c is the proportion of output consumed and e is the proportion spent on exploration,

$$C(u) = cF(K(u),R(u)) \qquad \text{(A8.3)}$$

$$E(u) = eF(K(u),R(u)) \qquad \text{(A8.4)}$$

Similarly, assume that a constant proportion, b, of proven reserves is extracted at each moment. That means

$$R(u) = bS(u). \qquad \text{(A8.5)}$$

The model has two capital assets K and S. K(t) and S(t) are data representing "initial conditions". Together with equations (A8.1)-(A8.5) they enable the forecaster to derive the economy's RAM and make a forecast for the economy. Shadow prices are then estimated on the basis of the forecast.

Let $P_K(u)$ and $P_S(u)$ denote the assets' shadow prices at u. If V(t) denotes intergenerational well-being at t, Proposition 2 in the text implies that

$$dV(t)/dt = P_K(t)dK(t)/dt + P_S(t)dS(t)/dt. \qquad \text{(A8.6)}$$

Equation (A8.6) says that aggregate investment is the sum of investment in reproducible capital and changes in known reserves, $P_S(t)$ [N(t)-R(t)]. Recall equation (8) in the text. Let Q(t) denote the shadow price of consumption

[85] The model is deterministic. Introducing uncertainty would yield nothing other than terms representing the social evaluator's attitude to risk.

in terms of well-being. It follows that NNP in this economy is

$$NNP(t) = Q(t)C(t) + P_K(t)dK(t)/dt + P_S(t)\,dS(t)/dt. \qquad (A8.7)$$

Using equations (A8.1)-(A8.6) in equation (A8.7) we have

$$NNP(t) = P_K(t)F(K(t),S(t)) - P_K E(t) + P_S(t)[N(E(u)) - R(u)]. \qquad (A8.8)$$

Final demand in the economy is F(K(t),S(t)). Equation (A8.8) says that as exploration costs don't amount to investment, they should be deducted from final demand.

Equation (A8.1) assumes continuous discoveries. An alternative is to imagine that discoveries occur in spurts, but that when they do occur they are major finds. This requires a different form of modelling: at each discovery the entire structure of shadow prices changes discretely. It's as though the economy starts afresh at each new discovery, with new stocks (Dasgupta and Heal, 1974).

Appendix 9

Education

In the text we separated human capital into two categories: education and health. When estimating their value they give rise to different kinds of problem. In this Appendix we sketch a method for estimating human capital in the form of education (health is the subject of Appendix 10). We follow the methods introduced by Klenow and Rodriguez-Clare (1997), which in turn were built on Mincer (1974). A more comprehensive methodology has been put to work by Jorgenson and Fraumini (1989).

Assume investment in education earns a social rate of return, r. Being a social rate, r includes the benefits others enjoy when someone acquires education. Let T be the average number of years of educational attainment in the country. Assuming a steady state as a first approximation, the amount of education per worker is then proportional to e^{rT}. The constant of proportionality is obtained from the wages of unskilled workers, for whom T = 0. The stock of education capital is then obtained by multiplying education capital per worker by the number of workers, the quantity being adjusted for mortality during the working life.

If we now assume that the labour market is sufficiently competitive to imply that the marginal productivity of education capital equals the real wage, the shadow price of education capital would equal the total real wage bill divided by the stock of education capital. Arrow et al. (2012a) have adopted this method in their empirical work on the measurement of wealth.

Appendix 10

Health

Health brings both direct and indirect benefits: (a) an absence of pain and discomfort is one of the defining characteristics of well-being and, other things being equal, healthier people (b) live longer and (c) are more productive. So, health is both an end and a means. That (a)-(c) are conjoined is a deep and fortunate fact for Humanity. They are joint products of improvements in nourishment and avoidance of infectious diseases. The idea then is to decompose improvements in health into their direct and indirect components. The former would be reflected in increases in output and consumption, data for which should be available, albeit in very approximate forms, in national accounts.

The complete capital model of Appendix 7 contained an account of (c). Here we illustrate (a) by means of a single-period model and (b) by means of a two-period model (generalizing which to many periods is routine but tedious). We then study the way the benefits of increases in life expectancy can be estimated.[86] We assume explicitly that the value of improvements in health in terms of (a) and (b) is the value that people attach to those benefits. Throughout we consider a single individual. In order to estimate the social benefits of health programme, spill-over of the benefits of health programmes across individuals (the externalities!) have to be added to the private benefits we study here.

A10.1 Health as Consumption

Consumption is denoted by a numerical index C and the flow of well-being by U. C is a determinant of U, but the effectiveness of C as a source of a person's well-being depends on his state of health. Health, a capital asset, is denoted by the numerical index H. For example, H could be Body Mass Index. Assume U is an increasing function of H and C.

H and C are in part complements, in part substitutes. It is simplest then to multiply H and C an so construct a composite commodity, HC. In that case the person's well-being function is U(HC). The product, HC, transforms consumption, measured in its own units, into consumption measured in "efficiency" units. Put another way, measured in its own units, consumption contributes more to personal well-being if health improves. A marginal improvement in the person's health yields the benefit CU'(HC).[87]

The analysis can be readily extended if we assume that H is maintained over the person's lifetime of, say, T years. If r is the social discount rate, the shadow price of health capital, P_H, is

$$P_H = CU'(HC)[1-e^{-rT}]/r.$$

Suppose it requires a continuous expenditure (health care) E to maintain H. Then the present value of health costs would be $E(1-e^{-rT})/r$.

---

[86]We follow Arrow et al. (2012a), who extended the approach taken by Becker et al. (2005). The latter publication studied the contribution that improvements in life expectancy make to income. Here we follow Arrow et al. (2012a) in tracking the contribution that improvements in life expectancy make to wealth.

[87]U'(HC) is the derivative of U with respect to the composite good HC.

The social evaluator would advocate further expenditure on health if CU'(HC) > E.

A10.2 Health as Extension of Life[88]

The above model assumes life expectancy is fixed. In order to study the value of increasing it, let us assume time is discrete. Imagine someone who is alive in period 1 and will survive to period 2 with probability π. We are interested in the case where expenditure in health can raise π. Suppose the price that must be incurred to obtain π is $H(\pi)$. We assume H is an increasing (and, plausibly, a convex) function of π, and that $H(0) = 0$. For simplicity we now imagine that health expenditures yield no benefits to the person other than an increase in the probability of survival. A complete analysis of health as a form of capital would require an amalgamation of the analysis in Section (A10.1) and the one we now undertake.

Well-being in any period is a function of consumption in that period. We write that as U(C). Imagine the person faces competitive markets for consumption in period 1 (labelled as C(1)) and for contingent consumption in period 2 (labelled as C(2)). The market price of C(2) relative to C(1) is P. By "contingent consumption" we mean consumption that would be available to the person should he survive. He pays P in period 1 for the right to a unit of period-2 contingent consumption.

The person begins life with total wealth W, expressed in period-1 consumption. His expected lifetime well-being, which we write as V, is assumed to be

$$V = U(C(1)) + \pi U(C(2)).^{89} \qquad \text{(A10.1)}$$

To have a meaningful problem we have to assume in addition that there exists a consumption level C*, such that $C^* > 0$ and $U(C^*) = 0$. C* has been called the "welfare subsistence rate" (Meade, 1955). That means $U(C) < 0$ for low values of C and $U(C) > 0$ for high values of C. From the perspective of preparing national accounts, this requirement, which is forced upon us if we consider variations in life expectancy, makes health an unusual capital asset.

For simplicity of calculations we assume that the population consists of a large number of identical people and that the survival probabilities are independent of one another. In period 1 the individual chooses C(1), C(2), and π so as to maximize (A10.1) subject to his budget constraint

$$C(1) + PC(2) + H(\pi) = W.^{90} \qquad \text{(A10.2)}$$

Before proceeding to the optimization exercise, we note that (trivially) the rate of increase in $\pi U(C(2))$ when π is increased marginally is U(C(2)). Equation (A10.1) then says that the benefit to the individual of a marginal increase in survival probability π is U(C(2)). In the text we noted that health economists express U(C(2)) in terms of consumption goods and then estimate it by uncovering a person's

[88]The material in this Section is taken from Arrow et al. (2012b).

[89]Notice that equation (A10.1) has the same additive form as the form for intergenerational well-being in equation (3) in the text, with $\delta = 0$.

[90]Notice that the person faces a single budget constraint. If he survives to period 2, he consumes the C(2) he purchased in period 1. Obviously he does not receive consumption in period 2 should he not make it to period 2.

revealed willingness to pay for a small increase in the probability of survival. That's called the value of a statistical life (VSL).

$H'(\pi)$ in contrast is the VSL when the latter is measured in terms of rate at which the person is able to transform wealth into an increase in the probability of survival (the budget constraint, (A10.2)). At a personal optimum the two are of course the same (see equation (A10.3c) below).

Assuming that the individual's optimum π is positive, the first order conditions of his optimization exercise are

$$U'(C(1)) = \mu, \tag{A10.3a}$$

$$\pi U'(C(2)) = \mu P, \tag{A10.3b}$$

$$U(C(2)) = \mu H'(\pi), \tag{A10.3c}$$

where μ (> 0) is the multiplier associated with the budget constraint (A10.2). Equation (A10.3a) says that μ is the value of period-1 consumption in terms of period-1 well-being.

Recall that the person is one among a large population of identical individuals; moreover, mortality risks are independent of one another. It follows that in market equilibrium P equals the individual's optimum choice of π. So P is the actuarially fair price.

Equations (A10.3a)-(A10.3b) and the fact that $P = \pi$ imply

$$C(1) = C(2) = C \text{ (say)}. \tag{A10.4}$$

Equations (A10.3a) and (A10.4) allow us to re-express equation (A10.3c) in consumption units as

$$U(C)/U'(C) = H'(\pi). \tag{A10.5}$$

In competitive equilibrium either side of equation (A10.5) can serve as the VSL. The equation also confirms that $U(C) > 0$ in equilibrium.

A10.3 From VSL to Health Capital[91]

A rise in life expectancy translates into an increase in capital in the form of human health. In order to measure that increase we need a formula for estimating the value of a life-year. We now derive the value to individuals of an additional life year in terms of VSL. Suppose for simplicity that the value to someone of an additional year of life, which we denote as h, is independent of age, a.[92] If δ (> 0) is the time discount rate, we can express the value, V for an individual of age a to survive to age T as

$$V(a,T) = h\{\int_a^T[e^{-\delta(u-a)}]du = h(1 - e^{-\delta(T-a)})/\delta. \tag{A10.6}$$

Let f(T) be the probability density that someone at birth will die at age T, and let F(T) be the corresponding cumulative distribution. If $f(T:T \geq a)$ is the conditional probability density of death at age T, given survival to age a, then it follows trivially that

$$f(T:T\geq a) = 0, \quad \text{if } T < a$$
$$= f(T)/[1-F(T)], \quad \text{if } T \geq a. \tag{A10.7}$$

Let m(T) be the mortality hazard rate (the probability density that someone aged T will die at age T), and define

$$M(T) = \int_0^T[m(u)du]. \tag{A10.8}$$

[91]The material in this Section is taken from Arrow et al. (2012a).
[92]The analysis can easily be extended to the case where h is a function of a (probably a declining function of a (at least for large a!), but at the cost of additional notation. See Murphy and Topel (2006).

Then we can prove the identity

$$f(T:T\geq a) = m(T)e^{[M(a)-M(T)]}. \qquad (A10.9)$$

From equations (A10.6)-(A10.9) we arrive at the value of human-health capital H(a) of an individual of age a: It is the expected value, at age a, of survival to a random age. Thus

$$H(a) = \int_a^\infty [V(a,T)f(T:T\geq a)dT], \text{ or}$$

$$H(a) = \{1 - \int_a^\infty e^{-[\delta(T-a)+M(T)-M(a)]}m(T)dT]\}h/\delta. \qquad (A10.10)$$

Let $\varrho(a)$ be the proportion of people of age a and let the per capita human-health capital in the economy, measured in life years, be denoted simply as as H. Then

$$H = \int_0^\infty [\varrho(a)H(a)]da. \qquad (A10.11)$$

Recall that h is the (age-independent) value of a statistical life-year (VSLY). It follows that the right hand side of equation (A10.11) is the same as the VSL. In short, H is the VSL.

Appendix 11

The Attraction of GDP and Conspicuous Consumption

In the text it was shown that GDP is not an index of intergenerational well-being. That should come as no surprise. The construction of GDP wasn't meant to serve the purposes of economic evaluation over the long run. GDP is a measure of market activity and was designed for use in a world where a significant proportion of people were unemployed and resources lay idle. The index allows economists to estimate the gap between potential output and actual output. Moreover time series of GDP enable macroeconomists to study household and corporate behaviour. In addition, as national income is the source of government taxation, Finance Ministers are naturally drawn to GDP forecasts. And finally, estimating depreciation and obsolescence introduces errors, which is why GDP is more appealing to the national income statistician than NDP. As a criterion for evaluating short run economic policy, GDP has served admirably. Our Report argues though that the practice of ignoring depreciation of reproducible and human capital and degradation of natural capital is indefensible practice in economic evaluation concerning the long run.

Nevertheless, GDP is so attractive that without international cooperation it would be hard for any government to abandon it as an index of progress. Why?[93]

A11.1 GDP as a Strategic Weapon

GDP is the market value of final goods and services. Those goods and services can be deployed so as to gain advantage in the international sphere. Never mind if a country enjoys a large GDP by depleting its natural capital; GDP can be (and is routinely) used by governments as a strategic weapon in a world where nations compete against one another for economic and political influence. Not only does a nation's status in the world rise if it enjoys GDP growth, high GDP enables a nation to tilt the terms of trade with the rest of the world to its advantage. History is replete with examples that demonstrate the strategic advantages of GDP growth.

The competitive advantages associated with GDP growth lead to a to-date unexplored form of the "tragedy of the commons": nations vie with one another for competitive advantage by bolstering GDP, thereby jeopardizing future well-being within each of their borders. As in classic instances of the tragedy, international recognition of the wasteful nature of such a form of competition is a needed first step in shifting national economic policies toward the accumulation of wealth. This Report is on national accounts and assumes that the international race in question will continue in the foreseeable future. So we don't recommend that national accounts should abandon GDP.

[93]We gloss over differences between GDP and GNP because nothing is lost in our account by doing so.

But to call for GDP growth and demand sustainable development at the same time is to seek two incompatible desires.

A11.2 Conspicuous Consumption

What holds true for governments has as its base humanity's sociability. As social animals, we are both competitive and conformist. We want to attain status in our community in certain ways and yet want simultaneously to be like others in other ways. In his classic work on the Gilded Age, Veblen (1899) spoke of "conspicuous consumption" so as to draw attention to consumption as a status symbol (fancy automobiles, expensive clothing, mansions). Notice that if a consumption good is to be a status symbol, it must be conspicuous; hence the title of Veblen's classic.

Veblen's notion of status has been extended greatly to cover the more general tendency of people to try to out-do the "Jones's". Social scientists have modelled such forms of consumption competition more generally as "rat races", in which each household tries to surpass all others in their consumption patterns, in an ever-losing proposition: no one is much happier, even though all are consuming larger and larger amounts of conspicuous goods (Easterlin, 1974, 1995, 2001; Oswald, 1997).

To get a sense of the pathway, consider a world with two consumption goods (labelled 1 and 2), of which commodity 1 is "conspicuous". We may think of commodity 1 as a "positional good" (Hirsch, 1977). Commodity 2 is assumed to be "inconspicuous". Q_1 and Q_2 are their market prices (in units of well-being). Let C_1^* denote the average consumption of good 1 in the economy. To draw out the implications of competitive consumption in a simple way, assume that the economy consists of a large number, N, of identical people. Write $Y_1 = C_1/C_1^*$. An individual's preferences for consumption goods are represented by $U(C_1,Y_1,C_2)$, where U is a concave, increasing function of C_1, Y_1, C_2.

The dependence of U on Y1 (= C1/C1*) reflects the person's competitive motivation. The externality is reciprocal: each person's consumption of commodity 1 affects all other people directly. To be sure, because N is large no one can on their own influence C1*; but the sum of the infinitesimal influences sums a finite amount, which is why market equilibrium would be inefficient.

It is an easy exercise to confirm that competitive consumption involves excessive consumption of commodity 1 (Arrow and Dasgupta, 2009). To put it figuratively, consumers in the market economy are engaged in a "rat race". Each person tries to consume more of commodity 1 than the others. Of course, in equilibrium no one is successful in beating the others. As people are identical, all consume the same quantity. The process creates a "problem of the commons", albeit in a different sphere from common-property resources. Structurally however they are the same. They both reflect aspects of the well-known Prisoners' Dilemma in game theory.

How could people be made to take the externalities they impose on others into account when deciding how much to consume? It is a familiar notion in public economics that the way to do that is for the government to impose a consumption tax on commodity 1. The trick is to choose the tax rate so that market equilibrium is socially optimal. Public policies are to be chosen in such a way that individual incentives are in line with the realization of the social optimum.

People don't compete with others in every sphere of life. But if goods relying hugely on natural capital (e.g. automobiles, airplanes) were underpriced in the past and remain underpriced, and if those goods are conspicuous (again, automobiles and airplanes), then they would be natural focal points for competition. Habits reinforce the motivation for status. They influence our current taste for goods and services. To the extent habits have a persistent influence, the past is ever present. This leads to history dependence, or path dependence, of the course of events. Extreme forms of history dependence are often called "lock-in effects".

Complementing habits are economic and social infrastructures, whose growth accompanies conspicuous consumption (gas stations, expanding motorways, airports). Together they give rise to a spiralling process involving the exploitation of natural capital, one that continually increases but adds far less to human well-being than anticipated. Crucially, the spiral jeopardizes the well-being of future generations. Here again, the process resembles the "tragedy of the commons": Everyone consumes more and depletes natural capital at faster rates than they would if they all agreed to consume less, but are unable to find a mechanism for enforcing the agreement (Schor, 1998). Eliciting well-being from stated preferences (that is, preferences inferred from answers to questionnaires) or revealed preference (e.g., from behaviour in the market place) can therefore be misleading. That makes the estimation of shadow prices of goods and services especially hard.

Figure 3

Quadratic Growth Function

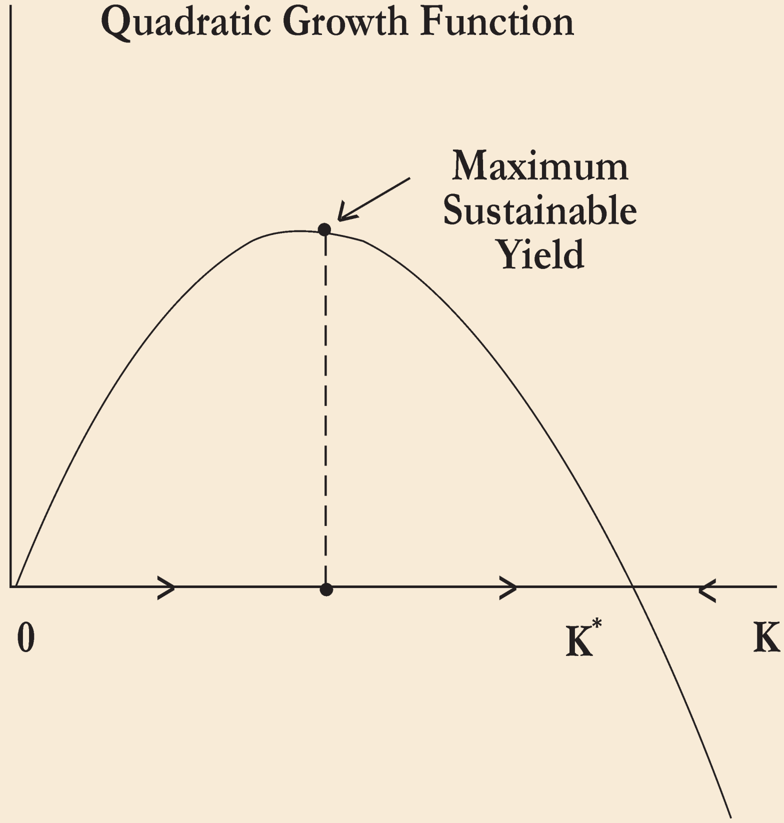
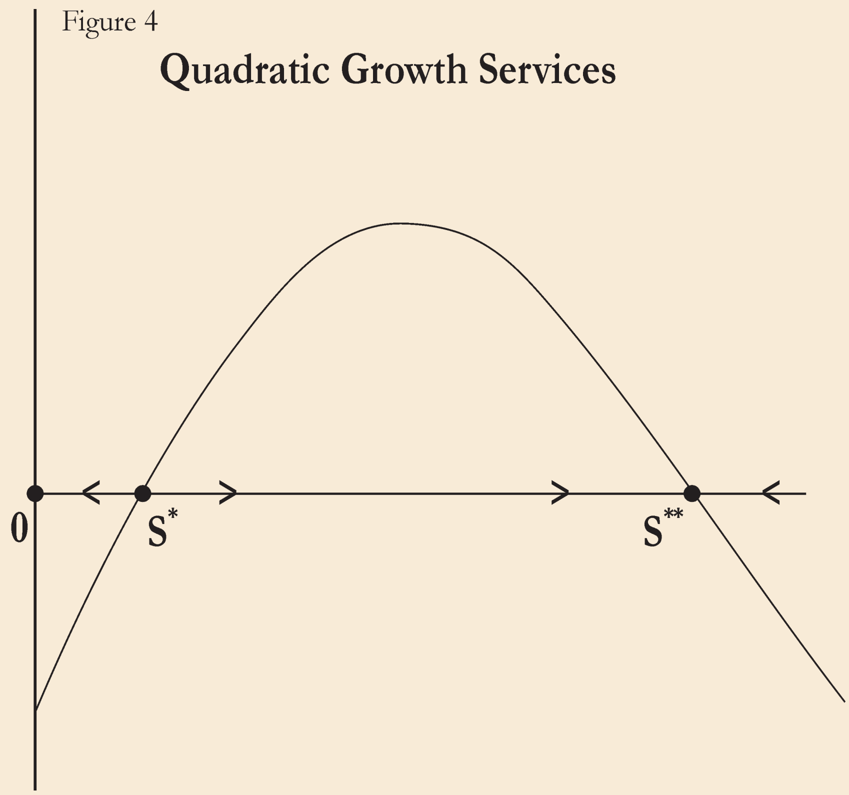


Figure 4

Quadratic Growth Services



Chapter 2 Annexe

Valuation – Empirical Considerations

Introduction

Environmental change is often a result of external costs imposed by productive economic activities. Many environmental resources also tend to have public good characteristics. People cannot be excluded from experiencing the effects of a change in the good or one person's consumption of the good may not reduce another person's use of the same. The public good (non-rival and non-excludable) nature of environmental goods – clean air, for instance -- allow consumption of the good to occur without a reduction in its availability until some thresholds are reached. Private agents will necessarily under-provide public goods and over-supply public bads since they will not bear the full social benefits or costs. Furthermore, the causal connection between specific economic activities and their contributions to environmental changes may be unclear, with visible and measurable environmental changes often transpiring in distant places and times. Finally, many environmental goods and services are not traded in markets and there is no price signal that acts as an indicator of increasing depletion, scarcity or pollution. For these reasons, economic activities can result in environmental changes that are un-accounted for and easily ignored.

In order to account for resource and environmental losses, these changes need to be measured and valued. While it can be argued that some aspects of life are invaluable, most people recognize the presence of trade-offs and act based on some understanding of relative gains from different activities. These decisions allow economists to either identify the values of or ascribe values to goods and services. In the case of natural resources that are traded, market prices may offer reasonable measures of value. However, for environmental goods where market prices either do not exist or where markets are lean, economists have devised various methods to identify the value of such goods.

In this note, we first examine different methods for valuing non-market goods. We then discuss specific tools for valuing the costs associated with four types of on-going environmental changes in India: a) deforestation and degradation; b) decline in land quality; c) changes in water resources and d) mineral extractions.

Valuing non-market goods

Environmental goods offer different services that result in a variety of benefits. These benefits can be categorized into use values and non-use values (Freeman 1993, Haque et al. 2011). Use values refer to current direct and indirect ways in which people make physical use of an environmental good. For example, the value a farmer gets from using river water to irrigate his crops is considered a use value.

Environmental goods also provide indirect benefits in the form of hydrological services, biodiversity and so on. These are the non-use values conferred by environmental resources. In addition, people also obtain utility from environmental resources even if they do not personally use them (Krutilla 1967). Thus, some resources have existence values -- e.g., the benefits obtained from simply knowing about the existence of the Bengal tiger. Finally, there is yet another category of environmental value that is referred to as option value (Wiesbrod, 1964). Option values accrue to economic agents when there is uncertainty about supply and or demand for an environmental good. For example, people may want to preserve the option of saving forests because of potential medicinal benefits that may emerge in the future.

Since many environmental goods and services are not traded in markets, economists use

Box 1: Revealed preference valuation methods

Revealed preference methods for valuing environmental changes are based on an examination of people's behavior and actions. They typically include the travel cost approach, hedonic methods and production or damage cost approaches.

- The travel cost method is frequently used to assess the demand for recreation when the source of recreation is a publicly provided good such as a national park or beach. Based on the costs that people are willing to incur to travel to a public amenity, the aggregate value of the amenity can be identified.

- Hedonic methods estimate the value of an environmental good by looking at the market prices of linked goods and services that are influenced by the environmental good. For example, dirty ditches and sewerage water smell are a disamenity that often reduces the property value of nearby homes. Since markets for homes exist, it is possible to identify how much the market value of homes is affected by the presence of the disamenity. From this information, a not too difficult next step is to estimate the costs (negative value) associated with the environmental disamenity.

- The damage cost or production function approach is another method that is particularly useful in developing countries. Here, the damage cost from an environmental change to a final output is estimated by examining how the final good is affected. For example, the external costs of shrimp farming can be valued by estimating the change in paddy production in nearby fields as a result of increased soil salinity. Thus, the cost of the externality is the salinity induced loss of profits from paddy crops.

- In some cases, a replacement cost approach is also used to value environmental changes. In this approach, for example, the benefits of providing clean water are identified by estimating the costs of filtering and cleaning the water to make it drinkable.

Box 2: Stating preferences and valuing the environment

Stated preference methods are a popular valuation method. Their attractiveness can be attributed to the fact that many environmental goods don't have markets and because people are willing to pay for preservation based on 'non-use' values. The contributions to rain forest related charities from distant countries, for instance, are a reflection of these values. Existence and option values can, in some cases, only be captured by asking economic agents about their willingness to pay for conservation.

Stated Preference methods can be broadly classified into contingent valuation and choice modeling.

- Contingent valuation refers to a survey based strategy where economic agents are provided a hypothetical market-like scenario and asked to estimate their willingness to pay for a change in a particular environmental good. Care is taken to make sure that the scenario and the change proposed are well understood and to minimize 'cheap talk' or biased responses to the proposed hypothetical situation.

- Choice modeling is a tool used to identify the value of changing specific attributes of an environmental good. It seeks to examine preferences for individual attributes of a good or service. For example, choice modeling may be used to identify how much people are willing to pay if the lodging infrastructure in a national park is improved versus if wildlife sightings increase versus if the vistas or views of landscapes improve. This sort of analyses would allow park managers to make investment decisions based on visitor preferences.

Over the last two decades, our understanding of the usefulness and limitations of stated preference methods of valuing environmental goods has grown tremendously. Choice modeling, in particular, has become a widely used tool for private sector market research.

various methods to measure the value these 'non-market' goods. Broadly, non-market valuation techniques can be categorized into revealed and stated preference methods. Revealed preference methods provide methodologies for estimating environmental values in the context of consumers and producers making consumption and production choices in markets. For example, the value of soil erosion to a farmer can be estimated by identifying the contribution of soil erosion to reduced farm outputs. Here the benefits of the environmental change, soil conservation, are empirically assessed by observing farmers' actions and the results of these actions. Stated preference methods are more direct. They rely on values that are expressed by consumers and producers in the context of hypothetical markets scenarios.

Environmental valuation requires careful examination of both physical changes and human behavior. Good valuation depends on how well we understand the change in the environment and how readily measurable these changes are. For instance, in order to estimate the losses from deforestation related hydrological changes, we need to have a clear understanding of how and to what extent forest cover changes result in changes in stream flow. Second, we need to account for how people change their behavior in response to the changed environment. The changes in stream flow may result in farmers altering the quantity of some inputs and therefore farm output will change further. It is only after this that the welfare impacts of the changes on economic agents or the value of the change can be estimated. While increasingly sophisticated surveys and econometric analyses are used to obtain unbiased estimates of value, both stated and revealed preference methods require careful research. Before venturing into valuation, it is useful to keep in mind the need for a sound understanding of environmental science and that estimates can vary based on methods used and are subject to error.

Valuing forest losses

Forests provide a variety of goods and services. These include provisioning services such as fuelwood, timber and minor forest products; regulating services such as flood control, storm protection and water purification; cultural services where there are sacred forests, for instance; and supporting services such as biodiversity, primary production and nutrient re-cycling. For economic analyses, it may be easier to classify services into final (provisioning and cultural) and intermediate services (supporting and intermediary). When we examine changes in forests, we are trying to answer the questions how have final and intermediate forest services changed and what the resulting impact on human well-being is.

It is useful to think of forests ecosystems as a capital asset that results in different flows. As the asset degrades, the flows from this asset change. The value of the change in the asset is therefore equal to the net present value of the resulting changes in the flows that occur. This formulation builds on an understanding that forest degradation today changes services today as well as in the future. Given the different services provided by forests, to value the losses from degradation and deforestation, we need to estimate losses from a reduction in any of these services. The first empirical challenge is to identify the degree of deforestation/ degradation and its consequent impact on a particular service. Once this is done, the next task is to ask how and whose welfare is affected.

While forests provide multiple services, three different goods and services are more readily amenable for valuation: a) provisioning services (or goods) such as timber and non-timber forest products; b) carbon sequestration services; c) recreational services. In limited cases and geographic areas, it may also be possible to estimate the value of losses in biodiversity, storm protection, flood regulation and water purification. While these services are very important, valuation may require significantly more effort. Das and Vincent (2009), for instance, examined the effect of the 1999 super-cyclone in Orissa and asked to what extent mangroves provided storm protection services. They found that villages with larger breadth of mangroves between them and the coast experienced significantly fewer deaths as a result of the cyclone. Such studies provide key evidence of the importance of ecosystem services. However, a great deal of data and analyses and larger investments are required to undertake such valuation at a national scale.

With provisioning services or goods, market prices are often used to value current losses. The value of lost timber and NTFPs at any point in time is the sum of lost resource rents or $\sum(p_i q_i - C_i)$, where pi is the market price of the ith good, qi is the quantity lost as a result of degradation and C_i is the cost of extraction. For timber, for instance, Gundimeda (2005, 2006) estimates resource rents based on price and cost data obtained from CSO. For NTFPs, national data is limited and quantity and price data are only available for a few commercially traded NTFPs. Where markets are lean, NTFP values can be ascertained by asking a sample of local households how they trade or transact different forest products amongst themselves (Adhikari 2005). However, such exercises will require detailed sampling and data collection. Further, in the absence of national data, costs of extraction, particularly for subsistence related NTFPs, will need to be assumed to be close to zero.

Some 12 to 20% of annual greenhouse gas emissions into the atmosphere are attributable to land cover changes, including forest losses (Sunderlin et al. 2010; van der Werf et al. 2009). Thus, conserving forests also results in carbon sequestration. The carbon services lost as a result of deforestation and degradation can be identified if there is a good data on the type of forests and tree species. The Forest Survey of India provides estimates of degradation, based on which biomass and consequent carbon losses have been estimated (Gundimeda, 2005, 2006). While establishing above and below ground carbon releases is challenging, once this is done, the value of the carbon released can be estimated. Releasing a unit if carbon into the atmosphere through forest loss in India, has an impact on India and all other countries in the world over a period of time (because of climate change). Estimating the marginal social damage of unit of carbon is enormously challenging. Tol (2005), based on a review of 28 different studies with 94 different estimates, argues that marginal damages from climate change are not likely to exceed $50 per ton of carbon.[94] Gundimeda (2005, 2006) has used the value of USD 20/ton of carbon to evaluate carbon sequestration in India. Any estimate of the benefits of carbon sequestration will require choosing from a limited number of international estimates of marginal damages.

Recreational services can be valued by using the travel cost method and choice modeling. This method requires data on costs of travel to different forested tourism and recreational areas. Using a set of sample surveys, it will be possible to estimate tourists' willingness to pay to visit different types of forested areas. By incorporating choice modeling, we can estimate both the overall value of the forest resources for tourism and any costs from changes in the quality of the forests. Obtaining the consumer surplus or the benefits from recreation in a sub-set of areas will allow us to obtain the change in the aggregate value of recreational services as result of forest loss. We need to ensure that we value recreational changes only in those areas where recreation is allowed and where there is some on-going or threat of degradation.

Valuation of land and land degradation

Land is a generic resource that is put to a number of uses and provides a range of

[94]Tol finds that the mean marginal social damage from climate change to be $16/ton of carbon if he assumes a 3% pure rate of time preference (4-5% social discount rate). The combined mean he obtains from the reviewed papers is $51/ton of carbon if he assumes a 1% pure rate of time preference.

services. Based on the major outputs or services provided, land is generally categorized into agricultural land, forest land and urban land.[95] Agricultural land amounted to 46.28% of India's geographical area in 2005-06. Urban land (land under non-agricultural use) covered 8.19% of geographical area, and forests, in the main government owned, covered 22.86% of land area.

In a vein similar to SEEA (2003), we distinguish between five major types of land resources:

- land underlying buildings and structures (or urban)
- Agricultural land and associated surface water
- Wooded land and associated surface water (forest land)
- major water bodies
- other land

Our main interest is in land under agriculture and wooded or forested lands.

Land degradation occurs when land use change takes place and is accompanied by a decrease in fertility or the ecological value of the land. Some degradation may be the consequence of natural processes such as desertification. Valuation of land degradation requires assessing the difference between the value of land under different uses. Three different kinds of degradation are of significance in India. Degradation occurring from:

1) Land-use change within agriculture, such as from paddy to shrimp farming. Such change is driven by prices and results in externalities such as soil salinity. Degradation related losses can be captured by examining the impact on the original land-use (in this case paddy). See, for example, Umamaheshwari et al. (2011), who examine the effect of shrimp-induced productivity changes on paddy land. As they establish, methodologies for estimating value of the degradation exist. However, assessing the externality-driven costs of degradation will require carefully done local valuation studies. Such studies will need to be undertaken in multiple sites before any attempt is made to account for national level degradation.

2) Farmer driven soil degradation because of over-use of fertilizers or irrigation: this constitutes an important depletion of natural capital. Some studies exist in India on this. Parikh and Ghosh (1991) and Parikh (2012), using the productivity approach for state level data, find that the depreciation of cultivated lands amounts to 0.38 percent to 0.89 percent of GDP. Data from the National Bureau of Soil Studies and Land Use Statistics can be used to update these estimates.

3) Land-use change from areas of high ecological value lying within forest or wooded land to built areas or towards extractive use such as mining. From 1980 to mid-2011, nearly 12 lakh hectares of forest land are estimated to have been diverted to non-forest use. More than two-thirds is diversion for industry, mines, dams, roads etc. Some of these forests are high biodiversity areas contributing

[95]Indian official data refer of course to a well-understood classification of land: forests, land not available for cultivation (including urban), net area sown, other uncultivated land excluding fallows and fallow land.

Box 3: An anomaly in using valuation for assessing degradation: the need for physical accounting of 'no-go' areas

Driven by India's high rates of urbanization, demand for land for urban construction and infrastructure continue to push the price of land to very high levels. Undoubtedly these are higher than values yielded by 'traditional' valuation of ecosystem services. Tensions from differing land values associated with different uses and different stakeholders are rapidly increasing. For instance, supply side ecosystem services based approach to valuation yielded estimates of forest and deemed forest land between Rs. 7 to 9 lakhs per hectare for dense natural forests (Supreme Court Expert Committee 2007, Chopra and Dasgupta 2008). This was much higher than the compensatory afforestation payment of Rs. 50,000 per hectare paid for conversion. But demand driven urban land use could garner a price of up to Rs. 90 lakhs per hectare or more. A similar situation exists for land diverted to mining. The drivers in this case may be high export prices.

In the face of the huge demand from urban use, retaining land for agricultural or ecological use is not going to be easy if valuation alone is used as the decision criteria. Underlying asymmetries in the distribution of income, information and power of different stakeholders, and capacity to pay, lead to high demand driven prices. While valuation of land for ecosystem services may provide additional inputs, an understanding that there exist ' inviolate areas', whether for ecological or distributional justice reasons will have to be a critical component of policy. Although ecologists and economists in the past have frequently employed a notion of "scientific or economic rationality," current environmental problem solving requires them also to use "ethical rationality."

Thus, we need laws to prevent conversion of 'no-go' or inviolate areas, thus conserving supporting ecosystem services such as biodiversity and top soils. The loss of natural capital, if we are not to do so, would be irreversible. More accurate, physical accounting is a necessary precondition for this policy change to take place.

to the regulating, cultural and supporting ecosystem services and critical for human well-being. Such degradation is not easily valued even with non-market valuation techniques (See Box 3). Moreover, the loss of natural capital in the case of land conversion of this kind is perhaps irreversible. In such cases, only an accurate physical accounting of land use change is recommended.

Valuing changes in water resources

Changes in water resources include changes in their quality and quantity. Water quality is affected as a result of pollution. Valuing these changes at a national level will be a complicated exercise. For example, when a river gets a little polluted, it may still be used a source for domestic water use despite adverse health effects, but when the pollution level exceeds some threshold, then it may no longer be used a source of domestic water. The loss in value depends on factors like these on which it would be difficult to get data. Accordingly, valuation of changes in water quality at the national level is likely to be a difficult exercise, and would need to be preceded by many local valuation exercises. Support for such studies that can be used to build up a knowledge base to be used in the future would be good step to take at this stage.

Changes in surface water quantities are not a major factor in India because there have been no significant changes in aggregate rainfall and river flows, although there have been changes in the temporal distribution of rainfall caused by climate change. Accordingly, it does not seem practical to attempt valuation of such changes.

Changes in groundwater stocks may be of considerable importance because groundwater is very important for agriculture in India. 60% of the value of farm output in India is served by groundwater with only 20% served by surface irrigation, and 20% being un-irrigated (Shah, 2000, pp 106-107).

Groundwater is currently nearly everywhere an open-access resource. So in each year or cropping season, it is extracted until the point when the marginal value of water pumped up has fallen to the marginal private cost of extraction, or until the aquifer is fully depleted, which may happen temporarily, within a cropping season, or permanently.

If extraction from the aquifer exceeds recharge, which is the case in many, but not all parts of the country, then next year's cost of extraction will be greater due to the extra energy needed to pump water to the surface. Thus the rent from the aquifer, the excess of total benefit over total cost, will fall. This decline in the rent will approximately equal to the rise in the marginal extraction cost times the quantity of water extracted (for a given aquifer). This is a measure of the loss of income in the current year as a result of aquifer depletion in the past year.

The decline in national wealth as a result will be greater, because it must factor in the fact that this process will happen every year into the future. If the aquifer is not likely to be fully depleted in the near future, then we would need to add the present discounted value of the rent decline in each future period.

This could be done by extrapolating past increases in marginal extraction costs to the future, assuming that the amount of water extracted will fall only slowly. This would suggest that the decline in wealth would be an order of magnitude greater than the year-to-year decline.

Data from monitoring wells can be used to track changes in the level of water in major aquifers, and the additional cost of extraction can be calculated from the additional energy requirement. In addition, estimates of the amount of water use in each aquifer would be required. These could be generated from sample surveys.

Mineral Resources

According to the Ministry of Mines mining and quarrying amounted to 2.10% of India's 2011-12 GDP. Most of these minerals come from a vast number of relatively small mining operations, but the public sector dominates with its production accounting for some 66% of the value of mineral extraction in 2010-11 (Ministry of Mines 2012). The main accounting problem with India's mineral wealth is that mined production is considered income and contributes to GDP; however, appropriate reductions are not made in asset accounts (Gundimeda 2012). Thus, the decline in natural capital or wealth as a result of mining goes un-accounted.

In order to incorporate changes in sub-soil wealth into national accounts, we need to a) have a good measurement of the quantity of India's mineral reserves; and, b) identify an accounting method for estimating resource rents. Resource rents reflect the value of a unit of mineral capital in the ground and are equal to the price of the mineral resource minus extraction costs. The net present value of resource rents multiplied by the quantity extracted until the stock is economically exhausted provides an estimate of total mineral wealth.[96] This value clearly depends on the discount rate used and the quantity extracted each year.[97]

A country's mineral wealth is never known with complete uncertainty. Reserves are generally classified into four categories – proven, probable, possible and potential reserves. Different countries treat these categories differently when they account for their national mineral wealth. Thus, one decision node for India's national accounts will be in agreeing on what category of reserves to consider as wealth. The two obvious candidates are proven reserves or proven plus probable reserves (SEEA 2003).

The next issue is estimation of resource rents. Mineral prices are internationally determined allowing any valuation exercise to use world prices. However, given volatility in prices and lack of clear information on extraction costs and extraction rates, it is not easy to establish either resource rents or the extraction path. Consequently, extraction rates are often assumed to be constant and resource rents are established by subtracting capital costs from gross operating surplus (SEEA 2003).

There are many careful details that need to be worked out in estimating mineral wealth. However, the accounting methods are well established and identified in the UNSEEA (see Chapters 7 and 8, SEEA 2003).

Conclusions

Valuation of India's environmental resources in order to create environment-economic accounts is possible. Changes in forest resources, ground water, mineral resources and some forms of land degradation can be measured and valued. SEEA (2003) provides detailed recommendations for valuation, which can be supplemented by some of the studies and methods discussed in this note. Any valuation exercise, particularly if there are changes in multiple ecosystem services, will necessarily be limited by data availability and methodological challenges.

Valuation, in some cases, will require sample surveys and testing of methods in diverse settings before embarking on national level accounting. In other cases, nationally available data can be used, but more thought needs to be given to how complimentary data can be generated. As a first step, physical accounts of key environmental and resource changes need to be established. Monetary accounts on a limited subset of physical accounts can follow.

[96]In rare cases, where markets for sub-soil deposits are available, it may be possible to obtain the market value of stocks. In the absence of this, the value of stocks is estimated based on the NPV of flows from this stock (SEEA 2003)
[97]See SEEA (2003) for details on how to incorporate discoveries and exploration.

CHAPTER 3

India's National Accounts and the System of Environmental Economic Accounting

India's National Accounts and the System of Environmental Economic Accounting

3.1 Introduction

The System of National Accounts (SNA) is an accounting framework for measuring the economic activities of production, consumption and accumulation of wealth in an economy during a period of time. The SNA was first introduced by the UN in 1953; it has since been revised multiple times with the latest version being the SNA 2008. The SNA is now followed by almost all countries around the world to measure indicators of annual change in economic activity such as Gross Domestic Product (GDP), Net National Product (NNP), and Gross Savings etc.

The SNA provides a comprehensive conceptual and accounting framework for analyzing and evaluating the performance of an economy. It also provides a structure for addressing emerging concerns related to the determinants of economic growth and their links to different sectors of the economy. The SNA, in fact, is a sequence of accounts, consisting of current accounts, accumulation accounts and a balance sheet for different sectors (SNA 1993/2008). Current Accounts record the production of goods and services and the generation, distribution and use of income. They reflect the flow of economic activity in any period of time and result in measures such as GDP. Accumulation accounts measure changes in assets, liabilities and net worth. Economic aggregates derived from the accumulation accounts include Gross Fixed Capital Formation (GFCF) and net lending and borrowing. The Balance Sheet is a static measure of wealth and shows the stocks of assets, liabilities and net worth of the country.

In order to measure whether a country is growing sustainably, Chapter 2 argued for the need to track changes in wealth or per capita, where the definition of wealth takes account of different forms of capital, including natural capital. Thus, there is sustainable development if net aggregate investment per capita is positive or, equivalently, net domestic product per capita exceeds consumption per capita. The SNA allows us to estimate these economic aggregates, which we further discuss in the section 3.2. Section 3.3 and 3.4 of this chapter describe India's national accounts system and United Nations (UN) prescribed methodologies for integrating environmental goods and services into the accounting framework.

3.2 Measuring Income and Wealth

There are three economic aggregates that are important for accounting for the environment: Net Domestic Product, Consumption Expenditures and Aggregate Net Investment.

We discuss the fundamentals of how these aggregates are measured, starting with the basic measurement of GDP.

3.2.1 Gross Domestic Product

GDP is the most used economic indicator worldwide and reflects a country's income through the production of goods and services. It measures the Gross Value Added (GVA) to the economy within a period of time. GDP is measured in three different ways: a) production approach; b) income approach; c) expenditure approach.

Production Approach: The gross value added in an economy is equal to the value of output less the value of intermediate consumption, i.e., products used up in the process of production.[98] All goods and services produced during the accounting period, whether they are marketed or produced for the own consumption of producers, are included in this measure.[99] The value of inputs of raw materials and services used in the process of production are excluded. Thus, GDP is measured as the sum of value added of all economic activities within a country's territory plus indirect taxes minus subsidies on products.

Income Approach: Since the production of goods and services is the result of the use of primary factors of production (capital, labour and raw materials), economic activity automatically generates income to the owners of these factors. Thus, GDP is also measured as the sum of factor incomes derived directly from the current production of goods and services within a country.[100] A related economic aggregate for the nation is Gross National Income (GNI) (previously referred to as GNP). Most of the national income in a country is derived from economic activities within the country. But some income arises from activities of residents outside the country and some income in the country may be due to the activities of the non-residents. The difference between these two flows is referred to as net factor income from abroad and GNP measures GDP plus net factor income from abroad. GDP, under the income approach, is the sum of compensation to employees, gross operating surplus and gross mixed income, plus taxes net of subsidies on production within the country.

Expenditure Approach: The production within an economy can also be measured by considering the expenditure of those who purchase final goods and services. National expenditure is the sum of expenditure on "final use" by the three institutional sectors in the national accounts viz., government, households and enterprises. Consumption expenditure is generally measured as final expenditures made by households, the government and non-profit institutions serving households. Final

[98]Thus, the goods cover all possible items produced, as for example, agricultural crops, livestock and livestock products, fish, forest products, mineral products, manufacturing of various consumer items for consumption, machinery, transport equipments, defense equipments etc., construction of buildings, roads, dams, bridges, etc. The services, similarly, cover a wide spectrum including medical and educational services, defence services, financial services, transport services, trading services, domestic services, sanitary services, government services, etc.

[99]While production of goods in the households are included in the production boundary of SNA, services produced in the households are excluded due to problems of measurement and their unsuitability for monitoring the economic parameters such as employment. For instance, services of house-wives are excluded.

[100]Other forms of income such as old age pensions, education grants, unemployment benefits, gifts etc., cannot be regarded as payments for current services to production. They are paid out of factor incomes and are called transfer incomes.

expenditures made by enterprises are labeled as Gross Capital Formation (GCF). This is that part of country's total expenditure which is not consumed but added to the nation's fixed tangible assets and stocks and includes 'fixed'[101] physical productive assets, (buildings, civil works, machinery, vehicles etc.) and stock accumulation (stocks of raw materials, fuels, finished goods and semi-finished goods awaiting completion)[102]. Thus, GDP through the expenditure approach is made up of: consumption expenditure of household's and Non-profit Institutions Serving Households (NPISHs), government consumption expenditure, and Gross Capital Formation (GCF), in addition to net exports.[103]

3.2.2 Net Domestic Product

One measure of the ability for a country to grow sustainably is whether its Net Domestic Product (NDP) per capita exceeds its consumption per capita on a continual basis (Chapter 2). Net Domestic Product is a standard economic aggregate and is measured as GDP minus depreciation on a country's capital. Depreciation is a business accounting term while in national accounts the related term is Consumption of Fixed Capital (CFC).

CFC reflects that part of gross product that is required to replace fixed capital used up in the process of production. Thus, CFC is defined as the decline during the course of the accounting period in the current value of the stock of fixed 'produced' assets owned and used by a producer, as a result of physical deterioration, normal obsolescence or normal accidental damage. CFC excludes the value of fixed assets destroyed by acts of war or exceptional events such as major natural disasters. CFC in the existing SNA does not include depletion of environmental assets. For further details on GFCF, capital stock and CFC see Appendix 1.

3.2.3 Measuring Aggregate Investment through Accumulation Accounts

As discussed in Chapter 2, improvements to inter-generational welfare are linked to the growth in wealth. Changes in the wealth of a country are established through the accumulation accounts, which include capital and financial accounts. Capital accounts record transactions linked to acquisitions of non-financial assets and capital transfers involving the redistribution of wealth,[104] while financial accounts record transactions for different financial instruments. Financial Accounts include changes in financial assets viz. net acquisition of financial assets like gold, SDR's, currency and deposits. They also include security other than shares, loans, share and equity etc. and record changes in liabilities and net worth.

Capital accounts deal with two kinds of non-financial assets: (a) Produced assets or non-

---

[101]Broadly two types of fixed assets viz. construction and machinery & equipment are covered.

[102]Technically, GCF is comprised: (a) gross fixed capital formation (GFCF), (b) consumption of fixed capital (CFC), (c) changes in inventories (in India this is referred to as change in stocks) and (d) acquisition less disposal of valuables.

[103]The expenditure on final goods and services may be purely for consumption purposes like consumption of food, clothing, shelter, services etc., or for capital formation such as addition to buildings, plant, machinery, transport equipment, etc. Some goods may not be immediately sold and may be kept aside as stocks. These goods which are added to stocks are also accounted for as final expenditure. Goods and services are also used for exports.

[104]The resources side of capital accounts show savings and the user side, the GFCF, Change in Inventories, and Capital transfers. The balancing item in both capital and financial accounts is net lending/net borrowing.

financial assets that are produced as outputs from production processes that fall within the production boundary of the SNA.[105] (b) non-produced assets, including non-financial assets that have come into existence by ways other than the processes of production. These are economic assets needed for production but are not produced through production process, including environmental assets such as land and certain uncultivated forests or mineral deposits.[106]

The components of Gross Capital Formation (see footnote 5 of this chapter) are recorded in the accumulation accounts. GCF depends on the savings of the nation. Thus, the link between current accounts and accumulation accounts is through savings.

Currently, several environmental or naturally accruing assets are not considered economic assets. Assets such as air and the ocean, whose contribution is not easily measurable, assets that are commercially inaccessible (eg. virgin forests or economically un-exploitable minerals), common property where it is not feasible to establish effective control, and assets that are not monetized (glaciers, the atmosphere) are currently excluded. We discuss below and in the Chapters that follow, ways in which ecosystem services and changes in the stocks of environmental assets can be included while accounting for changes in wealth in the accumulation accounts.

3.3 National Accounts in India

In India, the Central Statistics Office (CSO) in the Ministry of Statistics and Programme Implementation estimates national accounts and disseminates information on several macro-economic aggregates such as GDP, final consumption expenditure, savings, capital formation, capital stock, consumption of fixed capital etc. every quarter. The first official estimates of India's National Accounts were published by the CSO (referred to as Central Statistical Organisation at that time) in 1956, with prices held constant using 1948-49 as the base year.[107,108] These estimates along with the current estimates at current prices and the accounts of the Public Authorities were published in 1956. The latest revision of the National Account aggregates, based on SNA 1993 and 2008, was published in January 2010 with base year 2004-05.[109] (See Appendix 2 for details on changes in recent years based on

[105]Produced assets are further sub-divided into three types: (i) fixed assets, (ii) inventories and (iii) valuables. Fixed assets consist of (a) tangible or (b) intangible assets that are used repeatedly in production for more than one year. Valuables are works of art, precious stones and metals, jewelry, etc. which are not used in production or consumption. Their economic value lies in the expectation that their price will increase.

[106]Natural non-produced assets also include certain intangible assets such as patented entities, leases or other transferable contract, purchased goodwill, etc.

[107]With the gradual improvements in the availability of basic data, national income estimates were further revised and published in 1967 by taking 1960-61 as the new base. Simultaneously, related aggregates such as 'capital formation' and 'saving' for the years from 1960-61 were published in 1969. Subsequently, there have been several revisions of the national income series (with base years 1970-71, 1980-81, 1993-94 and 1999-2000) based on substantial improvements in the data base and use of the revised SNA 1993 guidelines.

[108]Base years are important for measuring the volumes of domestic product. The base year for India's national accounts is changed once in five years to capture structural changes that take place in the economy.

[109]The series of national account aggregates revised in January, 2010 with base year 2004-05 took into account the following three objectives: i) Revision of a base year to a more recent year for meaningful analysis of the structural changes in the economy. ii) Complete review of the exiting data base and methodology employed in the estimations of various macro-economic aggregates including choice of the alternative data bases on individual subjects, and, iii) Implementation of the recommendations of SNA 1993 as well as SNA 2008 to the extent feasible.

SNA guidelines).

3.3.1 India's National Accounts System

As Figure 1 shows, the National Accounts of India are based on current accounts, accumulation accounts and rest of the world accounts.[110] The rest of the world accounts refer to transactions between resident and non-resident institutional units and related stocks of assets and liabilities, where relevant.

The basic unit for measuring economic activities and compiling national accounts is the 'institution'. India's National Accounts (INA) include three major institutional sectors, i.e. the public or general government sector and public enterprises, households/un-organized sector and NPISHs, and the private corporate sector (see Appendix 3 for definitions and the correspondence between INA and the SNA). The 'Rest of the world' is also an institutional sector which is shown as part of current and accumulation accounts.

India's national accounts build the entire sequence of accounts for the total economy, but the accounts are not as complete for specific institutional sectors. Given available data, India constructs the following accounts and aggregates:

- for the total economy, the sequence of accounts (current accounts, accumulation accounts including only the capital and financial accounts, and the rest of the world account);
- for the total economy, the social accounting matrix which depicts all accounts in a single matrix;
- for different institutional sectors (general government, households and NPISHs, and financial and non-financial corporations) only the production and generation of income accounts (of the current accounts);
- for the general government and households (including NPISHs) sectors, the sequence of accounts up to financial accounts;
- GDP at basic prices;
- cross-classification of output and value added by industry;
- cross-classification of value added by industry and institutions;
- classification of the functions of the government;
- classification of individual consumption according to purpose.

The current accounts result in the aggregates such as GVA (gross value added), balance of primary income (national income), disposable income, and finally, the savings of the nation. As noted, the accumulation accounts comprise capital and the financial accounts. The capital account considers savings as resources of the nation used for capital formation. The difference between savings and capital formation (further adjusted for capital transfers) is the net borrowing/lending of the nation. We further note that current accounts do not give rise to the full expenditure measure of GDP, but only to one component of the GDP viz. the consumption expenditure. The other two components of GDP expenditure (GCF and net exports) are externally compiled and included

[110]Two accounts viz. 'Other changes in volume assets account' and 'Revaluation account' along with 'Balance Sheet' are not prepared in India.

into the capital account to leave the balancing item of net borrowing/lending. Thus, capital accounts do not feed into the current accounts, whereas current accounts feed into the capital accounts in the form of savings.

Figure 1 highlights the measurement of GDP as the most used national economic aggregate, even though other economic aggregates are also developed in addition to the sequence of accounts. India's accounts incorporate estimates of GDP compiled through the income, production and expenditure approaches. While the level of GDP estimated through the production and income approaches are identical, there are discrepancies between GDP measured by the production approach and by the expenditure approach, which, as noted, are recorded separately under the GDP expenditure components.[111]

The National Accounts Statistics (NAS) of India also includes a Social Accounting Matrix (SAM). The SAM captures transactions and transfers between different economic agents (institutions) in the system and represents national accounts in single matrix. The columns and rows show all the transactions taking place in the sequence of accounts. The SAM provides for: a) cross-classification of output and value added by industry; b) cross-classification of value added by industry and institutions; c) classification of the functions of the government; and d) classification of individual consumption according to purpose.[112]

India's national accounts are compiled based on information from several diverse data sources. Data, such as land records and collection of direct and indirect taxes, are generated as a by-product of public administration system, and other data collected directly through censuses and sample surveys conducted by official agencies of the Central and State Governments. For certain newly emerging activities, such as software, information available from selective non-official sources is used. While the underlying concepts and methodologies of compilation have been mostly standardized under the SNA, procedures and approximations are shaped by the country-specific data collection system.

3.4 Environmental Considerations in India's National Accounts Statistics

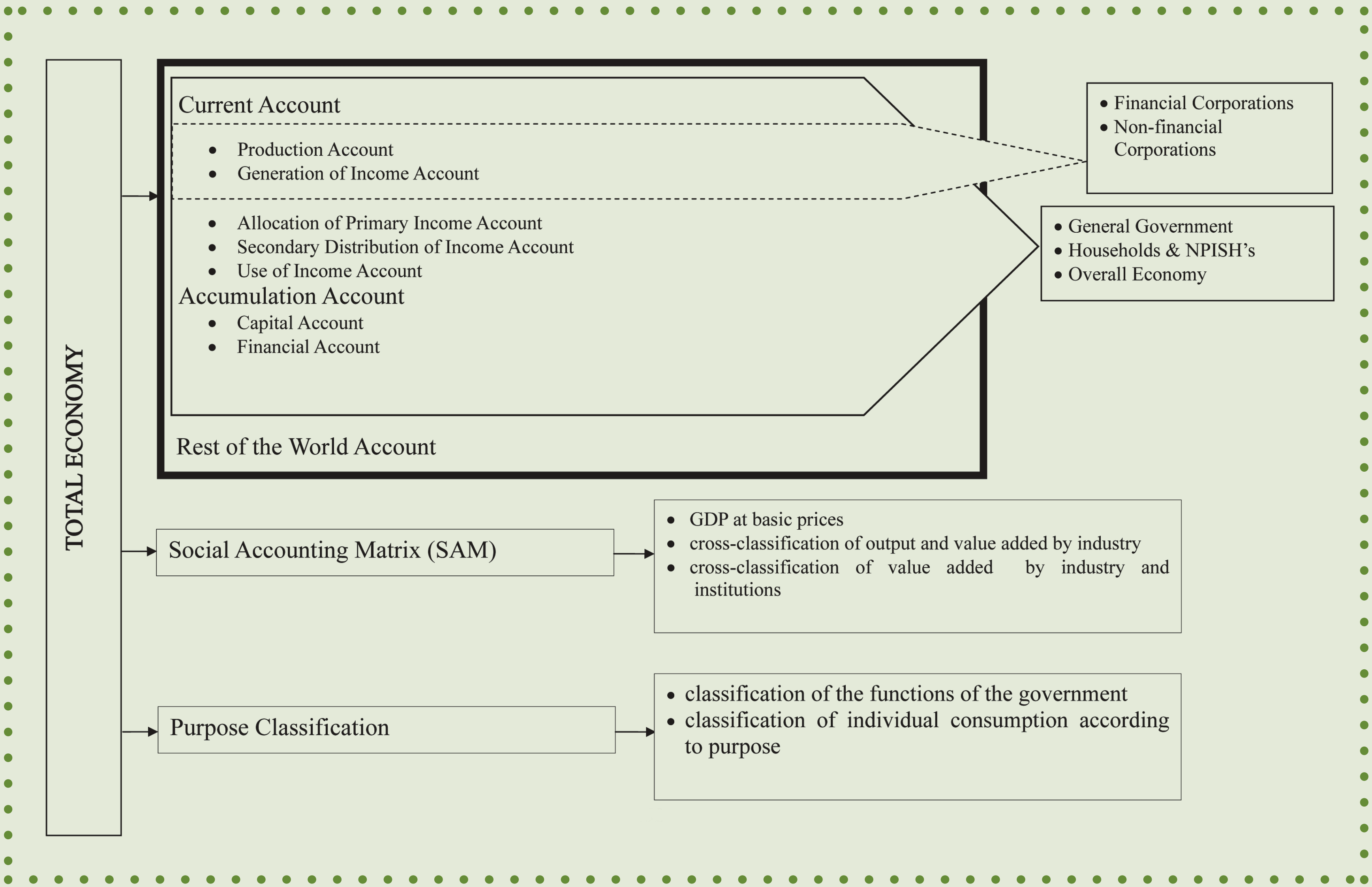
The NAS incorporates environmental goods and services in multiple ways within the current and accumulation accounts. While there is a lot to be done in terms of strengthening the environmental components of the NAS, Box 4 illustrates some measures that have already been taken.

GDP does not account for depreciation of natural capital stock as a result of economic exploitation and environmental degradation. In other words, GDP may increase even when the stock of natural capital, such as minerals, soils and forests, is being depleted. The NDP would more correctly measure these changes

[111]While the production approach of GDP is treated as a firmer estimate, any difference between the GDP measured by the production approach and the expenditure approach is shown as statistical discrepancy in the GDP estimates through the expenditure approach.

[112]Production activities in the National Accounts of India and the SAM are classified according to the National Industrial Classification (NIC), which is adapted to the International Standard Industrial Classification (ISIC). These activities comprise: (i) agriculture, forestry & fishing, (ii) mining & quarrying, (iii) manufacturing, (iv) electricity, gas & water supply, (v) construction and (vi) trade, hotels, transport & business services, and, (vii) community, social & personal services.

Figure 1: India's National Accounts



Box 4: Environmental considerations currently included in India's National Accounts

India's national accounts incorporate environmental considerations in different ways in estimating GDP and other aggregates such as GCF and GFCF

Gross Domestic Product (GDP) includes:

- value added in the electricity, gas & water supply sector through transmission and distribution of electric energy, manufacture of gas in gas works including gobar gas and distribution through mains to household, industrial, commercial and other users, production of LPG, and collection, purification and distribution of water excluding the operation of irrigation system.
- the value of minerals extracted (where minerals can occur in nature as solids, liquids or gases and in underground and surface mines) and income from quarries and oil wells with all supplementary operations (not depletion of minerals).
- the value of timber, fuelwood and non-timber forest products extracted from forests (to the extent that data are available on quantities and prices).
- the value of natural growth of cultivated assets for certain crops
- output of dung manure.

Gross Capital Formation (GCF) includes:

- capital transfers from the Government to corporations for the purposes of water supply.
- capital investment made by household sector in bio-gas plants and wind energy systems.
- capital expenditure incurred (estimated) in installation of wind energy systems (windmills, aero-generators and wind turbines) and unit prices of installation capacities.
- outlays on improvement of land and development or extension of mining sites, timber tracts and plantations.

Gross Fixed Capital Formation (GFCF) includes:

- estimates of improvement of land, irrigation works, flood control projects, laying of new orchards and plantations, forestry & logging and fishing.
- estimates of extraction of both major and minor minerals with respect to public sector, non-departmental enterprises, private corporate sector, and household sector.

Change in Stocks (CIS) includes:

- estimates of produced/unsold stocks of major and minor minerals (but not depletion of minerals).
- estimates in the agriculture sector for all the three institutional units (we note, that as the annual incremental data on species-wise livestock are not available, these are estimated by projection method at all India/State level using geometric growth rate based on latest available livestock census data).
- estimates of electricity, gas and water supply, only for public and private sectors
- changes in unsold timber extracted (GFCF does not include natural forests).

in natural stocks; however, CFC, the measure of depreciation, is currently not calculated for non-produced assets such as land, mineral and other deposits. Furthermore, GCF, the measure of changes in capital, does not include natural changes or improvements to non-reproducible tangible assets such as land and mineral deposits and natural growth of standing timber or crops.

GDP also under-estimates the value of natural resources. It does so even of those resources whose use is monetized. In the forestry sector, for example, while timber and NTFP use contribute to GDP, there is significant under-estimation of NTFP quantities and royalties may not reflect their true value. Non-monetized environmental goods and services are not reflected in the national accounts. The contribution of other forest services such as carbon or hydrological services, for example, is completely excluded. Also, changes in stock of ground water are currently un-accounted for.

Another anomalous property of GDP is that it will increase even when the quality of the environment is reduced by pollution. This is because it both ignores non-monetized degradation of environmental quality and includes monetized social costs associated with attempts to improve quality. For example, an increase in the consumption of potentially health-threatening goods such as alcohol, cigarettes and fatty foods will appear as an increase in GDP, although they may decrease individuals' welfare and impose a burden on the national health budget. Effects in air and water quality on health are ignored or included as consumption expenditure when they lead to the purchase of medical services. GDP also increases when expenditures are made on pollution abatement. This is another

[113]The environmental aspects relating to the sectors for which national accounts are compiled mainly pertain to economic activities involving use of natural resources that result in output which eventually lead to wastes and omissions and depletion of natural resources and natural assets. Presently, no environmental factors are accounted for under national accounts in terms of their use in the intermediate consumption or use of these natural resources as capital equipment, as core national accounts according to SNA do not consider these under production activities

distortion because environmental protection expenditures may actually be social costs of maintaining environmental quality (i.e., defensive expenditures).

Lastly, the national accounts are not yet able to examine fully the distributional implications of changes in natural or environmental goods and services.

3.5 SEEA – System of Environmental-Economic Accounting

In 1992, the UN Conference on Environment and Development "Earth Summit", as per Agenda 21 (UN 1992), recommended that countries implement environmental-economic accounts. In response, the United Nations

Table 1: Environmental goods and services not included in India's National Accounts

Environmental Factors and variables		Status regarding inclusion in NAS	Reasons for non-inclusion
LAND	Land Improvement	Included in GFCF	
	Change in Land Use	Not Included (Data available)	
	Depletion/Degradation of land	Not Included	Data need to be updated in National Bureau of soil survey (NBSS)
	Degradation of Soil	Not Included	Data need to be updated NBSS
	Impact of Disasters	Not Included	Non-availability of complete data
	Land Use, Cover Area, and Yield	Not Included (Data available)	
	Urban & Rural Land use pattern	Not Included (Data available)	
	Productivity of Land	Not Included	Updating of data in State Land Use Board (SLUB) will be required
	Real Estate prices	Not Included	Data available but the same to be disseminated by Registration offices
	Cropping Pattern	Not Included	Updating of data in Directorate of Economics & Statistics at State level will be required
	Output prices/ revenues	Included	
	Gross/Net sown area	Included	
	Soil depth, colour, salinity and drainage (Soil erosion, run-off and soil loss under the treated and un-treated micro-watersheds, soil loss prevented by dense forests)	Not Included	Data need to be updated in NBSS. Data on soil loss prevented by dense forests are not available.

Environmental Factors and variables		Status regarding inclusion in NAS	Reasons for non-inclusion
FOREST	Extraction of minerals in forests	Not Included (Data available)	
	Forest cover/Forest cover change	Not Included (Data available)	
	Accumulation of timber due to natural regeneration/natural growth	Not Included	Regular and complete data are not available
	Loss in timber volume due to insects, pests and diseases	Not Included	No data available after 1972
	Animal grazing	Not Included	Data not available regularly
	Shift in cultivation	Not Included	Data available, but more details are required
	Carbon stock	Not Included (Data available)	
	Asset valuation of forest & livestock	Not Included	Data not available
	Deforestation	Not Included (Data available)	
	Land area under forest	Not Included (Data available)	
	Physical volume of timber	Included	
	NTFPs	Included	
	Carbon sequestration potential	Not Included	Data not available
	Area of Sacred Groves	Not Included	Data not available
	Medicinal Plants	Included	
	Volume harvested for timber and fuel wood	Included	
	Volume of forest stock affected by forest fire	Included	
	Area regenerated/Area afforested	Not Included (Data available)	
	Mangrove cover	Not Included (Data available)	
	Biodiversity	Not Included	Limited data available
	Biomass: Litter Deadwood Solid organic carbon (below ground and above ground)/ Impact of worms	Not Included (Some data are available)	
MINERALS	Depletion of Minerals	Not Included (Data available)	
	Pollutant loads from mining	Not Included	Data not available

Environmental Factors and variables		Status regarding inclusion in NAS	Reasons for non-inclusion
WATER*	Surface and ground water quality	Not Included	Limited Data available
	BOD, COD and SS	Not Included	Data generated through primary surveys in case studies need to be updated
	Sedimentation in water ways and their treatment costs	Not Included	No reliable data available
AIR	CO2	Not Included	Limited data available
	SO2	Not Included	Limited data available
	SPM	Not Included	Limited data available
	N2O, Methane, HFCs, SF6	Not Included	Limited data available
	Carbon monoxide	Not Included	Limited data available
	Nitrogen dioxide	Not Included	Limited data available
	Fuel Consumption	Not Included	Data available through ASI, but not on a regular basis
	Ozone depleting substance; CFCs, Halgon, CTC	Not Included (Production/ consumption data available)	

Notes: a) Other Environmental factors include solid waste and energy that are not discussed in this Table. b) Changes in one indicator can change other indicators leading to changes in the sequence of accounts. c) * Purchase and Use of water

Statistics Division (UNSD) published the Handbook of National Accounting–Integrated Environmental and Economic Accounting (UN 1993), commonly referred to as the SEEA. The SEEA was revised in 2003 and then another revision was started in 2007 (for further details on SEEA's historical background, see Appendix 4). SEEA 2003 represented a significant step forward in terms of breadth of material and harmonization of concepts, definitions, and methods in environmental and economic accounting. It also provided a well accepted and robust framework for the compilation of environmental and economic accounting. The latest version of SEEA is comprised of three parts: the Central Framework, Experimental Ecosystems Accounts and Extensions and Applications. The 43rd Session of the UN Statistical Commission formally accepted the SEEA Central framework as an international statistical standard in 2012.

The System of Environmental–Economic Accounting (SEEA) Central Framework is a multi-purpose framework that describes the interactions between the economy and the environment, the stocks and changes in stocks of environmental assets. The SEEA allows us to examine various issues at the macro level such as resource efficiency and productivity indicators, decomposition analysis, analysis of net wealth and depletion, sustainable production and consumption, structural input-output analysis and general equilibrium modeling, consumption based input-output analysis and footprint techniques, analysis using geospatially referenced data etc.

The SEEA Central Framework provides a structure to compare and contrast source data and allows the development of aggregates, indicators and trends across a broad spectrum of environmental and economic issues. Particular examples include the assessment of trends in the use and availability of natural resources, the extent of emissions and discharges to the environment resulting from economic activity, and the amount of economic activity undertaken for environmental purposes. Melding different disciplines, it brings together information on water, minerals, energy, timber, fish, soil, land and ecosystems, pollution and waste, production, consumption and accumulation. It can be applied to all countries regardless of differences in economic & statistical development and environmental concerns or structure.

In addition to the SEEA Central Framework, two related parts are being developed: SEEA Experimental Ecosystem Accounts, and SEEA Extensions and Applications. The SEEA Experimental Ecosystem Accounts describes both the measurement of ecosystems in physical terms, and the valuation of ecosystems in so far as it is consistent with market valuation principles, noting that only those issues for which broad consensus has emerged will be included. In accounting terms, many of the structures for ecosystem accounting will be drawn from the structures in the SEEA Central Framework and, in this regard, the accounting conventions of the SEEA Central Framework will be applied consistently. For more details about ecosystem accounting, see Appendix 5. SEEA Extensions and Applications will present various monitoring and analytical approaches that could be adopted, and will describe ways in which SEEA data can be used to inform policy analysis which will be useful for official statisticians, researchers and policy makers. This part of SEEA will not be a statistical standard.

3.5.1 SEEA Central Framework

The SEEA Central Framework applies the accounting concepts and rules of the SNA to ecosystem goods and services. Broadly, the economy functions through the production and import of goods and services that in turn are consumed by enterprises, households or government; exported to the rest of the world; or accumulated to be consumed or use in the future. All goods and services (products) that are considered to be produced are effectively considered "inside the economy". Thus, the Central Framework consists of three parts: (i) physical flows of materials and energy within the economy and between the economy and the environment; (ii) stocks of environmental assets and changes in these stocks; and (iii) economic activity and transactions related to the environment.[114] The classification of different environmental assets within SEEA Central Framework is presented in Table 2.

Flows: Flows reflect creation, transformation, exchange, transfer or extinction of economic value and involve changes in volume composition or volume of the assets or

[114]Environmental stocks and flows are considered in a holistic way. The environment from stock perspective includes all living and non-living components that comprise the bio-physical environment, encompassing all types of natural resources and the ecosystems within which they are located, whereas the environment from flow perspective is seen as the source of all natural inputs to the economy including natural resource inputs like minerals, timber, fish, water, etc and other natural inputs absorbed by the economy such as energy from solar and wind sources and the air used in combustion processes.

Table 2: SEEA Central Framework classification of environmental assets

1	**Mineral and Energy resources**
1.1	Oil Resources
1.2	Natural gas resources
1.3	Coal and peat resources
1.4	Non-metallic mineral resources (excluding coal and peat resources)
1.5	Metallic mineral resources
2	**Land**
3	**Soil resources**
4	**Timber resources**
4.1	Cultivated timber resources
4.2	Natural timber resources
5	**Aquatic resources**
5.1	Cultivated aquatic resources
5.2	Natural aquatic resources
6	**Other biological resources (excluding timber resources and aquatic resources)**
7	**Water resources**
7.1	Surface Water
7.2	Groundwater
7.3	Soil water

liabilities of the institution. The SEEA Central Framework records physical flows of natural inputs, products and residuals. The flows from the environment to the economy are recorded as natural inputs (e.g. flows of minerals, timber, fish, water). Flows within the economy are recorded as product flows (including additions to the stock of fixed assets) and flows from the economy to the environment are recorded as residuals (e.g. solid waste, air emissions, return flows of water). Notably, many residuals also remain within the economy (e.g. solid waste collected in controlled landfill sites). We note that the definition of products aligns to the SNA definition of products, i.e., goods and services created through a production process and with economic value. Also the measurement boundary for physical and monetary flows aligns to the economic territory of a country, as defined in SNA.

Stocks: Environmental assets are defined as the naturally occurring living and non-living components of the Earth, together comprising the bio-physical environment that may provide benefits to humanity. The focus is on individual components of the environment that provide direct material benefits to enterprises and households. Broadly, assets are categorized into produced (from economic activity such as buildings and machines) and non-produced (land, mineral resources, water resources) which provide inputs to the productions of goods and services.[115] Changes in the economic value and quantity of stocks are either recorded as transactions (such as the acquisition of buildings and land) or as other flows. Many flows relating to non-produced assets (e.g. discoveries of mineral resources, and losses of timber resources due to fire) are considered to be flows outside the production boundary since the assets themselves are not the output from production processes undertaken by economic units.

Economic Activity and Transactions: In addition to the measurement of stocks of environmental assets and flows between the environment and the economy, the Central Framework records flows associated with economic activities related to the environment. Examples of economic activity related to the environment include expenditures on environmental protection and resource management, and the production of environmental goods and services such as devices to reduce air pollution. Environmental transactions such as taxes, subsidies, grants, and rent are also included. Using the measurement framework of the SNA, economic activity undertaken for environmental purposes are accounted for in the the sequence of economic accounts and also separately identified and presented in what are known as functional accounts (such as environmental protection expenditure accounts).

3.5.2. Differences between SNA and the SEEA Central Framework

The SEEA Central Framework adopts slightly different terminology in relation to environmental assets compared to the SNA. In the SNA, the term "Natural Resources" is used to cover natural biological resources (e.g. timber and aquatic resources), mineral and energy resources, and water resources and land. In the SEEA Central Framework, land is separated from natural resources recognizing its distinct role in the provision of space. Further, in the SNA, land and soil resources are considered as a single asset type whereas in the SEEA Central Framework, these are recognized as separate assets and soil resources are included as part of natural resources.

In physical terms, the asset boundary of the SEEA Central Framework is broader and includes all natural resources and areas of land of an economic territory that may provide resources and space for use in economic activity. Thus, in the SEEA, the scope in physical terms is not limited to those assets with economic value.

In terms of valuing environmental goods and services, the SEEA Central Framework adopts the same market price valuation principles as the SNA, i.e. in monetary terms, the asset boundary of the SEEA Central Framework

[115]The SEEA, in its stock accounts, does not consider the non-material benefits from the indirect use of environmental assets (for example, benefits from environmental services such as water purification, storage of carbon, and flood mitigation). Also coverage of individual assets does not extend to the individual elements that are embodied in the various natural and biological resources listed above. For example, the various soil nutrients are not explicitly considered as individual assets.

and the SNA are the same. Only those assets, including natural resources and land that have an economic value, following the valuation principles of the SNA are included in the SEEA Central Framework.

Both the SEEA Central Framework and the SNA recognize the change in the value of natural resources that can be attributed to depletion. In the SNA, the value of depletion is shown in other changes in the volume of assets and is not recognized as a cost against income earned from extracting natural resources. In the SEEA Central Framework, the value of depletion is considered a cost against income. Hence, in the sequence of economic accounts, depletion adjusted balancing items and aggregates are defined that deduct depletion from measures of value added, income and savings. The depletion deduction is made in addition to the deduction of CFC, which is already in the SNA. The differing treatment of depletion in SEEA Central Framework may require additional entries in the sequence of economic accounts at an institutional sector level.

Finally, the SEEA Central Framework applies two variations in the recording of product flows as compared to the SNA: a) In the SEEA Central Framework, all intra-enterprise flows (production and use of goods and services on own account within enterprises) are recorded depending on the analytical scope of the account being compiled, whereas in the SNA the recording of these types of flows is limited to the recording of the production of goods for own final use (e.g. own account capital formation) and intra-enterprise flows related to ancillary activities end.[116] b) In situations of goods sent to other countries for processing or repair, or in cases of merchanting, the SEEA Central Framework recommends recording the actual physical flows of goods in those cases where the ownership of those goods does not change but remains with a resident of the originating country. No change to the monetary recording of these flows is recommended.[117]

3.5.3 Accounts in the SEEA

The Central Framework organizes and integrates the information of the various stocks and flows of the economy and the environment in a series of tables and accounts. These tables and accounts can be linked to relevant employment, demographic and social information.

The Central Framework comprises the following types of tables and accounts (see Appendix 6):

(i) Supply and use tables in physical and monetary terms showing flows of natural inputs, products and residuals;

[116]For example, the recording of production of energy (through the incineration of waste) and the abstraction of water by an establishment for own intermediate consumption is to be done under SEEA. Similarly in the functional accounts of the SEEA Central Framework, recording of all production of environmental goods and services by an establishment (both for environmental protection and resource management depending on the scope of the account) for own intermediate consumption is to be done. The SEEA Central Framework also encourages the recording of own account production and final consumption by households (e.g. in relation to the abstraction or the production of energy). For such household own-account production, the production boundary used is the same as that described in the SNA. In all cases of own-account and intra-establishment production recorded in the SEEA Central Framework, the valuation of flows is consistent with the SNA valuation of own-account and ancillary production.

[117]This variation is particularly applicable in recording physical flows associated with the processing of raw materials (e.g. oil refining) where the physical flows may be largely invariant to the nature of the contractual relationships that are the focus of recording of monetary flows in the SNA and the Balance of Payments. Flows between the economy and the environment are determined by whether they cross the production boundary.

(ii) Asset accounts for individual environmental assets in physical and monetary terms showing the stock of environmental assets at the beginning and end of each accounting period and the changes in the stock;

(iii) A sequence of economic accounts that highlights depletion adjusted economic aggregates; and

(iv) Functional accounts which record transactions and other information about economic activities undertaken for environmental purposes.

Physical Supply and Use Tables (PSUTs) are used to assess how an economy supplies, uses and releases energy, water and materials and examine changes in production and consumption patterns over time. The Monetary Tables record flows of products in an economy between different economic units in monetary terms. Many of the flows of products recorded relate to the use of natural inputs from the environment (for example, the manufacture of wood products) or to expenditures associated with the environment (example, abatement or defensive expenditures). Separate Asset Tables record the opening and closing stock of environmental assets and the different types of changes in the stock over an accounting period. This information can be used to assist in the management of environmental assets and provide broader estimates changes in wealth. Basic forms of PSUT, Monetary Supply and Use Table (MSUT)[118] and Asset Account Table and Supply and Use Table as per the SNA are presented in Appendix 6 (Tables 6.1-6.4) and are further discussed in the next chapters.

The strength of the Central Framework comes from consistently applying definitions and classifications for stocks, flows and economic units across different types of environmental assets and different environmental themes (e.g. across water and energy). Further strength comes from different classifications being consistently applied in physical and monetary terms and because the same definitions and classifications are used in the SNA and economic statistics.

Implementation of the SEEA does not require compilation of every table and account for all environmental assets or environmental themes. Rather it can be implemented in a modular way taking into account those aspects of the environment of a country that are most important.

---

[118]In the compilation of supply and use tables in both physical and monetary terms, an important factor is the use of consistent classifications for the main economic units and products. Industries are consistently classified using the International Standard Industry classification of All Economic Activities (ISIC), products are classified using the Central Product Classification (CPC), and the determination of whether particular economic units are within a particular national economy is based on the concept of residence. The ISIC and the CPC are not only used in supply and use tables. They are also used in the other accounts and tables to classify industries and products. Other classifications, such as the Standard International Energy product Classification (SIEC), may also be used in specific situations.

[119]A Framework for Development of Environment Statistics (FDES) following the UNFDES was developed by the Central Statistics Office (CSO), Ministry of Statistics and Programme Implementation (MOSPI) in early 1990s and the first issue of Compendium of Environment Statistics was released in 1997.

Appendix I

Capital Formation, Capital Stock and Consumption of Fixed Capital

Gross Capital formation in the country is represented by GFCF and change in inventories and valuables. GFCF measures the additions to the capital stock of buildings, equipment and inventories, i.e. the additional capacity to produce more goods and income in the future. GFCF is the result of the following transactions on fixed assets:

(a) acquisition less disposal of new or existing tangible fixed assets which includes dwelling, other buildings and structures, machinery & equipment, and cultivated assets such as trees and livestock that are used repeatedly or continuously to produce products such as fruit, rubber, milk, etc.

(b) acquisition less disposal of new or existing intangible fixed assets like mineral exploration, computer software, entertainment, literary or artistic originals, and other intangible fixed assets;

(c) major improvements to tangible non-produced assets including land; and

(d) costs associated with the transfer of ownership of non-produced assets.

As per the guidelines issued by the United Nations Statistical Office in 1997, National Wealth is defined as the total of various kinds of net tangible and intangible non-financial assets of residence plus financial claims on non-residents less financial liabilities to non-residents. Tangible assets are classified into (i) reproducible tangible assets (capital stock) comprising fixed assets and stocks (inventories) and (ii) non-producible tangible assets comprising land, timber tracts and forests, sub-soil assets and extraction sites, fisheries, and historical monuments.

Reproducible fixed tangible assets (fixed assets used for the production of goods and services) consist of assets in the form of residential buildings, non-residential buildings, dams, irrigation and flood control projects, other construction works, transport equipment, machinery and equipment, breeding stock, drought animals, dairy cattle and the like, and capital expenditure on land improvement, plantations, orchard developments, and afforestation. Fixed assets also include un-completed construction assets.

Stocks refer to stocks of finished and semi-finished goods and young livestock except breeding stock, dairy cattle and the like which form part of the fixed assets. Durable goods in the hands of households which are not used for further production of goods and services such as automobiles, refrigerators, washing machines, furniture, sewing machines etc. as well as fixed assets mainly meant for defense purposes such as warships, fighter aircrafts and war materials do not form part of the fixed capital stock as these are assumed to have been consumed as soon as they are purchased. Construction works undertaken by the households including buildings and capital expenditure on residential dwellings for defense personnel, broader roads, ordnance factories etc. form part of the fixed capital stock.

Non-producible tangible assets are made up of land, timber tracts and forests, sub-soil assets and extraction sites, fisheries, and historical monuments.

As discussed in the SNA 1993, Gross Capital Stock is the value of all fixed assets still in use at the end of an accounting period at the actual or estimated current purchasers' prices for new assets of the same type, irrespective of age of the assets. The net or written-down values of all the fixed assets is equal to the actual or estimated current purchasers' price of new assets of same type less the cumulative values of CFC accrued at that point of time.

As per SNA 1993, estimates of CFC should be compiled in conjunction with the estimates of capital stock. This can be built up from the data on GFCF in the past combined with the estimates of the rate at which the efficiency of fixed assets declined over their service lives. This method of estimation of capital stock and changes in capital stock over time is known as the Perpetual Inventory Method (PIM). Estimates of CFC are obtained as a by-product of the PIM.

The CFC is calculated for all produced fixed assets i.e., tangible (buildings, other construction, roads and bridges, transport equipment and other machinery and equipment) and intangible fixed assets (software and mineral exploration) owned by producers. Fixed assets must have been produced as outputs from the process of production. The CFC is not calculated for (a) valuables that are acquired precisely because their value, in real terms, is not expected to decline over time, (b) livestock, (c) non-produced assets such as land, mineral and other deposits, (d) work in progress and (e) value of assets destroyed by acts of war or major natural disaster which occur very infrequently. It is, therefore, calculated using actual or estimated prices and not at historic costs, i.e., at prices originally paid for them.

Appendix 2

Changes in India's National Accounts based on SNA 1993 and 2008

A number of important recommendations of SNA 1993 have been implemented by India. Further, while introducing the new series of NAS in January, 2010 (base year 2004-05), the CSO attempted to implement some of the recommendations of the 2008 SNA, to the extent data were available. The changes relate to:

- valuation of non-market agricultural crops on the basis of prices of similar products made by market producers and their inclusion in the production boundary;
- inclusion of own-account production of housing services by owner-occupiers and of domestic and personal services produced by employing paid domestic staff;
- inclusion of premium supplements in respect of life and non-life insurance output estimates;
- inclusion of reinvested earnings of foreign direct investors in the rest of the world account; this treatment affects gross national product, saving and capital formation;
- imputed value of own-account labour treated as mixed income of self-employed;
- expenditures on mineral exploration treated as capital expenditure;
- allocation of financial intermediation services indirectly measured (FISIM) to the users of these services, as intermediate consumption to industries and as final consumption to final users;
- inclusion of expenditures on valuables, which are held as stores of value, and are treated as GCF;
- treatment of expenditures on software as GCF;
- inclusion of increment to livestock as GCF;
- inclusion of expenditures made on few tree crops during the gestation period as GCF;
- addition of capital expenditure incurred on installing the wind energy systems in the GFCF;
- estimation of CFC of all fixed assets including government buildings, roads, dams etc. as Perpetual Inventory Method (PIM);
- treating R&D expenditures in public sector as capital expenditures;
- adopting the declining balance (of life of assets) method for estimating the CFC and capital stock;
- adopting the user cost approach for estimating the services of owner occupied dwellings in rural areas as against the present practice of imputing these services on the basis of rent per dwelling;
- treating the construction component and machinery/transport outlay of defence capital account as capital formation, which was earlier being treated as intermediate consumption.

Appendix 3

Correspondence between the institutional sectors of SNA and the Indian Accounts

SNA Sector	INA Sector
General Government	Public Administration, Commercial Undertakings under Government called Departmental Commercial Undertakings (DCUs) and Autonomous Institutions.
Households	Households and Non-Profit Institutions Serving Households (NPISHs).
Non-Financial Corporations	All private non-financial institutions registered under Companies Act and registered public sector non-financial units called Non-Departmental Commercial Undertakings (NDCUs).
Financial Corporations	All private financial institutions such as banks, cooperative credit societies, etc. registered under Companies Act and financial NDCUs.

Appendix 4

Historical Background of SEEA

The Report of the Brundtland Commission, in 1987, made clear the capacity of the environment and links between economic and social development. In 1992, the UN Conference on Environment and Development "Earth Summit", as per Agenda 21 (UN 1992), recommended that countries implement environmental-economic accounts at the earliest date. In response, the United Nations Statistical Division (UNSD) published the Handbook of National Accounting–Integrated Environmental and Economic Accounting (UN 1993), commonly referred to as the SEEA. This handbook was issued as an "interim" version of work in progress since the discussion of relevant concepts and methods had not come to final conclusion. As a result of this publication, several developing and developed countries started experimenting on the compilation of SEEA based data.

The London Group on Environmental Accounting was created in 1994 under the auspices of the United Nations Statistical Commission (UNSC) to provide a forum for practitioners to share their experiences on developing and implementing environmental-economic accounts. Increased discussion on concepts and methods of environmental-economic accounting, accompanied with country experiences led to an increasing convergence of concepts and methods for various modules of the SEEA.

Another publication titled "Integrated Environmental and Economic Accounting- An Operational Manual (UN 2000)" was published by UNSD and the United Nations Environment Programme (UNEP) based on material prepared by the Nairobi group (a group of experts established in 1995 from national and international agencies and non-governmental organizations). This publication, while reflecting the on-going discussions following the 1993 publication of Handbook, provided step-by–step guidance on the implementation of the more practical modules of the SEEA and elaborated the uses of integrated environmental and economic accounting in policy making.

Simultaneously, the international agencies in cooperation with the London Group worked on a revision of the 1993 SEEA. The revision process was carried out through a series of expert meetings and was built upon a wide consultation process. The SEEA-2003, revision of SEEA 1993, represented a considerable step forward in terms of breadth of material and harmonization of concepts, definitions and methods in environmental and economic accounting. The SEEA-2003 also presented a number of different methodological options along with a range of country examples showing varying country practices, Thus the SEEA-2003 was never formally adopted as an international statistical standard and the SEEA was not recognized as a statistical system in its own right. Nonetheless, in general the SEEA -2003 provided a well accepted and robust framework for the compilation of environmental and economic accounts.

Recognizing the ever increasing importance of information on the environment and the need to place this information in an economic context understood by central policy makers, the Statistical Commission agreed at its thirty-eighth session in February 2007 to start a second revision process with the aim of adopting the SEEA as an international statistical standard for environmental-economic accounting within five years. This process was managed under the auspices of the newly formed United Nations Committee of Experts in Environmental and Economic Accounting (UNCEEA). It was recognized that the content of the SEEA -2003 was substantially agreed in terms of both scope and treatment and hence the focus of the revision was to remain largely on those specific areas of the SEEA-2003 in which the level of understanding and agreement needed to be increased and agreed treatments determined. The London Group was given carriage of the 21 issues identified for the revision of the SEEA. The newly formed Oslo Group on Energy Statistics was also involved in the discussion of issues pertaining to energy. The SEEA Central Framework represents the major outcome of the process.

Appendix 5

Ecosystem Accounting

The second perspective (which is dealt with in Ecosystem Accounts) covers the same environmental assets but instead considers the benefits obtained from environmental assets, including both material and non-material benefits. The measurement focus is on ecosystems. Ecosystems are areas containing a dynamic complex of biotic communities (for example, plants, animals and micro-organisms) and their non-living environment interacting as a functional unit to provide environmental structures, processes and functions. Examples are terrestrial ecosystems (e.g. forests) and marine ecosystems that interact with the atmosphere. Often there are interactions between different ecosystems at local and global levels.

For a given ecosystem or group of ecosystems, ecosystem accounting considers the capacity of living components within their non-living environment to work together to deliver benefits known as ecosystem services. Ecosystem services are the benefits supplied by the functions of ecosystems and received by humanity. Ecosystem services are supplied in many ways and vary from ecosystem to ecosystem. Ecosystem services may be grouped into four types (i) provisioning services (such as the provision of timber from forests); (ii) regulatory services (such as when forests act as a sink for carbon); (iii) supporting services (such as in the formation of soils); and (iv) cultural services (such as the enjoyment provided to visitors to a national park). Generally, provisioning services are related to the material benefits of environmental assets, whereas the other types of ecosystem services are related to the non-material benefits of environmental assets.

Economic activity may degrade environmental assets such that they are not able to deliver the same range, quantity or quality of ecosystem services on an ongoing basis. A focus on ecosystems that included both material and non-material benefits of environmental assets provides a basis for analyzing the extent to which economic activity may reduce ecosystem capacity to produce ecosystem services.

Appendix 6

SEEA Tables

Table 6.1 - Basic form of a Physical Supply and Use Table

SUPPLY TABLE						
	Industries	**Households**	**Accumulation**	**Rest of the World**	**Environment**	**Totals**
Natural inputs					Flows from the environment	Total supply of natural inputs
Products	Output			Imports		Total supply of products
Residuals	Residuals generated by industry	Residuals generated by household final consumption	Residuals from scrapping and demolition of produced assets			Total supply of residuals
USE TABLE						
	Industries	**Households**	**Accumulation**	**Rest of the World**	**Environment**	**Totals**
Natural inputs	Extraction of natural inputs					Total use of natural inputs
products	Intermediate consumption	Household Final Consumption	Gross Capital Formation	Exports		Total use of products
Residuals	Collection & treatment of waste and other residuals		Accumulation of waste in controlled landfill sites		Residual flows direct to environment	Total use of residuals

Table 6.2 -Basic form of a Monetary Supply and Use Table

	Industries	Households	Government	Accumulation	Rest of the world	Total
SUPPLY TABLE						
Products	Output	*	*	*	Imports	Total supply
USE TABLE						
Products	Intermediate consumption	Household Final Consumption expenditure	Government Final Consumption expenditure	Gross capital Formation (incl.changes In inventories)	Exports	Total use
Value added						

Note: * indicates Null by definition.

Table 6-3: Basic form of an asset account

Opening stock of environmental assets	
Additions to stock	
	Growth in stock
	Discoveries of new stock
	Upwards reappraisals
	Reclassifications
	Total additions to stock
Reductions in stock	
	Extractions
	Normal loss of stock
	Catastrophic losses
	Downwards reappraisals
	Reclassifications
	Total reductions in stock
Revaluation of the stock *	
Closing stock of environmental assets	

*Only applicable for asset accounts in monetary terms

Table 6.4 -Basic form of Supply & Use table as per SNA

SUPPLY TABLE													
	Industries	Total Domestic Production	Goods	Services	CIF / FOB adjustments on Imports	Total Imports	Total supply at basic prices	Total Trade & Transport Margin	Taxes less Subsidies on Products	Total Supply at Purchaser Prices			
Products													
USE TABLE													
	Industries	Total Intermediate Consumption	Household Consumption Expenditures	Total General Government	Total Final Consumption Expenditures	Gross fixed Capital Formation	Changes in Inventory	Acquisition less Disposal of Valuables	Total Gross Capital Formation	Goods	Services	Total Exports	Total Uses at Pur-chasers Prices
Products													
Value added													

Chapter 4

Sustainability and the SNA

Sustainability and the SNA

4.1 Sustainability and the SNA

The conceptual framework developed in Chapter 2 lays out the conditions for sustainability under the assumption that information is not a serious constraint for evaluating and aggregating the diverse elements that compose an economy. In making the framework operational, the effective limiting factor is in fact the availability of information – particularly reliable and internally consistent data. There are no doubt important methodological issues which arise in the full implementation of the conceptual framework, but these are secondary to the data issues. The purpose of this chapter is to describe a step-by-step process for generating the appropriate data for eventual realisation of the objective.

Although all economic systems produce data of varying reliability, and for a wide variety of purposes, the only data set which currently meets the minimum standards of internal consistency is the National Income Accounts produced by most countries using the United Nations System of National Accounts (SNA). The SNA provides the organising principles by which data from diverse sources can be compiled to yield a consistent set of accounts. Thus, whatever the limitations of the SNA, and there are many, it is at present the best that is available. More importantly, the organising principles of the SNA provide a useful template for the considerations that need to be taken into account in the process of evolving a more complete description of the economy than the SNA itself provides.

Therefore, this chapter takes the SNA as its starting point. It explicitly recognises that the process of extension needs to be informed by three broad considerations:

(a) The extension does not violate the internal consistency of the SNA.

(b) It progressively reflects a better understanding of the economy.

(c) It is based on data that either exists or can be generated with a reasonable degree of accuracy.

4.1.1 Measuring 'Inclusive Wealth'

The key condition for assessing the sustainability of a particular growth path is encapsulated in Proposition 2 of Chapter 2, which states:

"An economy's development is sustainable over any brief period of time if and only if its wealth increases over the interval."

In the proposition, 'wealth' is of course defined in its most inclusive sense. Nevertheless, this proposition is extremely attractive in that it appears to demand the least violence to the SNA as it exists today. It may be recalled, inclusive wealth has within its ambit all produced (or reproducible) capital, natural capital and human capital. The SNA already provides for all produced and a large component of natural capital within its asset boundary.

The balance sheet of the nation as provided under the SNA captures the value of all produced assets, but is incomplete even with respect to the natural assets that are counted within the asset boundary. A natural starting point, therefore, would be for a more complete evaluation of such natural assets. Beyond this, there are other natural assets which are not within the SNA asset boundary and human capital which is missing in its entirety.

Since the focus is on the balance sheet of the Nation, it is not essential to integrate all other forms of wealth into the flow accounts of the SNA. Separate asset accounts can possibly be developed to yield the values of natural and human assets. These combined with the asset valuation for produced assets given by the SNA could perhaps then be used to evaluate the application of Proposition 2.

Although this approach may seem straight forward enough, there are some serious impediments to its application. At the most mundane level, most developing countries, including India, do not have national balance sheets as yet. In such cases this approach is inapplicable until the standard SNA valuation is developed first. A more fundamental problem is that it is not at all clear that the valuations used for natural and human wealth would be consistent with the valuation used for produced assets. Since Proposition 2 requires that all forms of wealth be evaluated on a consistent basis, this problem has to be evaluated carefully if the aggregated measure of wealth is not to give a misleading interpretation.

It may be recalled from Chapter 2 that the only consistent basis for evaluating for all forms of wealth is on the basis of their shadow prices. In the case of produced assets, the stock is usually valued at historical prices. But there is provision for revising those values to current prices through the evaluation account. Nevertheless, this procedure in principle assumes that the current market price of produced assets is equivalent to its shadow price at all points in time. This is by no means obvious. The problem of obtaining shadow prices for both natural and human capital is more daunting. In the case of natural assets, even where market prices exist, they are almost never equal to their respective shadow prices. In the case of human capital, for particular types of human assets, such as education, market prices do exist and can be used in the same manner as is done for produced capital. However other forms of human capital, particularly health, such valuation does not really exist.

Indeed, the problems encountered in valuing the health component of human assets lead to another serious issue in the application of Proposition 2. There are assets whose stocks are not easy to measure. So it's especially hard to measure their social worth. In such cases it is usually easier to define flows and to evaluate the value of such flows. Whether it is at all possible to convert such flow values into stock estimates would need to be examined in each case.

The need to value wealth in terms of assets' shadow prices creates another hurdle in creating what may be called "stand-alone asset accounts" for natural and human capital. It may be recalled from Chapter 2, estimating shadow prices requires forecasting of the variables into the future. Since all models used for forecasting are necessarily based on flows and usually require integration between the variables, it is not possible to derive shadow prices in the absence of the flow accounts and without integrating these flow accounts with the existing SNA.

Thus, despite its elegance, Proposition 2 does not lend itself to easy application in most countries of the world. Fortunately, Chapter 2 offered an alternative method to judge the sustainability of growth processes.

4.2 Expanded Net Investment

The concept of wealth can be naturally extended to a more complete characterisation of the notion of investment, and thereby to the "consumption" of assets. In Section 2.8 of Chapter 2 we described sustainable development in terms of flows. The conceptual basis was provided in Proposition 7:

"Intergenerational well-being averaged over the generations increases over a period of time if and only if per capita net aggregate investment over the period is positive".

Here again the notion of investment is inclusive in the same sense as it was for wealth. The distinct advantage that Proposition 7 has over Proposition 2 is that it cannot only accommodate such elements of wealth which can be measured in terms of stocks, but also those for which only flow measures are possible. It is also applicable to such countries which do not as yet have balance sheets.

As a starting point, the asset boundary needs to be expanded to include non- produced assets. It should be clear however that in practice there are important environment variables and some human ones that are not easy to classify as assets. Pollution and morbidity come to mind. To be sure, techniques have been developed by environmental and health economists, respectively, for estimating losses that are incurred owing to atmospheric pollution and morbidity. Those losses would enter as depreciation in the measure of aggregate net investment. Integrating those methods to the SNA will, however, prove to be a difficult, though by no means impossible, task.

However, mere expansion of the asset boundary is not enough. Since changes in the various components of net investment originate in economic activities, it is necessary to integrate them with the other flows in the economy. Thus the production boundary and the institutional sectors of the SNA need to be brought in explicitly.

Since the objective of this Report is to adapt the SNA structure to inform a wider set of issues, it may be wise to hold the SNA production boundary unchanged and examine the extent to which environmental and intergenerational concerns can be captured. It is clear that a fairly substantial component of environmental damage occurs in the act of consumption rather than in production. However, there is nothing in the present institutional sectors of the SNA to which those effects can be allocated. It becomes necessary then to introduce a new "institutional" sector that can accommodate those flows. Whether such a sector, let us call it "nature", should be an independent sector or a subset of Government, doesn't really matter. We could view that sector as custodian of the rights of future generations. The "custodian" would provide services to the rest of the economy and would receive flows to it either in the form of preservation or augmentation expenditures or of the negative flows arising out of degradation and depletion.

In order to fully integrate environmental flows with the SNA, it would be necessary to develop the supply and use tables for the expanded set of institutional sectors. The first step of course would be to develop PSUT, but this clearly would not be enough for the purpose. In converting the PSUT into MSUT care will need to be taken. As has been mentioned earlier, there are a number of environmental variables for which market values exist. Valuation techniques for the remainder are also available and have been used variously. However, in order to generate the requisite data for evaluating Proposition 7, which requires shadow prices, a careful choice has to be made in order to ensure consistency between the available prices and valuation techniques.

It is important to note that accounting for environmental assets and flows in this manner and deriving the environmentally adjusted net investment runs the risk of misestimating the extent of increase in net investment. The evaluation of the change in human assets is essential to ensure that wrong conclusions are not arrived at. There is however a complication in making the necessary adjustments to accommodate human capital. If natural capital and human capital could be assumed to be separable, there would not be a mission in that the changes in the two could be worked out separately and built in to the definition of net investment. This however is not the case. Degradation of the environment, for instance, is a direct input into morbidity and technological knowledge is a direct input into environmental improvements. Accommodating such considerations will require the development possibly of a new set of tables which embody the interrelationships between the set of variables.

4.3 On Re-defining the NDP

Although the inclusive notion of aggregate net investment is a coin that can be used to assess the sustainability of the growth process, it does not readily lend itself to replacing GDP as the primary objective of economic policy. Chapter 2 suggests an alternative which may prove to be a more effective substitute. Recall Proposition 8:

"Intergenerational well-being averaged over the generations increases over a brief interval of time if and only if aggregate consumption per capita is less than net domestic product per capita".

The NDP in the above Proposition is more inclusive than is commonly understood from the national accounts. It not only takes into account the CFC but also the depletion of natural resources and the cost incurred in preserving the natural capital. Properly defined and measured, such net domestic product can potentially be even more useful in planning and policy formulation than the GDP. It also has great virtue: like GDP, it can be used as a compact descriptor of the growth in immediate well being.

In making NDP operational, the initial step could be to leave the GDP unchanged as in the current SNA and to take into account only such components of environmental degradation that arise out of production. The environmental damage arising out of consumption will prove to be more difficult. Since there are components of consumption which affect the environment simply as a by product of human existence, it would be necessary to first have an estimate of the normal or steady state values and take into account only the deviations.

Using Proposition 8 to judge sustainability over the long run is a lot more difficult. There needs to be clarity in the classification of what constitutes investment and what constitutes consumption. This is particularly important in the case of human capital, which in the SNA is currently treated almost entirely as consumption. It is shown why that is bad practice. There is no doubt that substantial component of both education and health expenditures are investments. In the spirit of Proposition 8 these should be deleted from consumption in evaluating sustainability.

Chapter 5

Environmental Accounting: Illustrations

Environmental Accounting: Illustrations

Chapter 2 discusses how we derive our well-being from different assets and the changes in wealth (defined as the social worth of any economy's array of capital assets) as the prime object of interest to understand the sustainability analysis. The proposition 2 postulates "An economy's development is sustainable over a period of time if and only if over the period its wealth increases". In this part of the report we illustrate the feasibility of examining changes in wealth and integrating this into the national accounts for selected set of assets: land, forests and minerals. We use the theoretical construct discussed in chapter 2 to develop the wealth accounts and explore the feasibility of the development of supply, use and asset accounts to ensure consistency with the existing national accounts. The chapter is structured as follows: In section 5.2, we discuss the framework to analyze the changes in selected assets. Section 5.3 links with the physical supply use tables to make it more compatible with the existing national accounts in India. In section 5.4, we discuss the data availability from different agencies in India.

Our objective in this report is not to develop accounts using the latest values but use the existing studies as a sort of illustration to discuss the framework, methodology, valuation techniques, and then the feasibility of integration into supply use tables. The estimates in this chapter are based on earlier work carried out by Gundimeda (1998, 2000, 2001) and Gundimeda et al (2005, 2006, 2007). However, where feasible and possible the estimates have taken into consideration latest available data.

5.1 Framework for analyzing changes in wealth

We suggest evaluating the changes in natural wealth using the format suggested in Table 1 for the selected assets under consideration in physical terms. The opening stock and closing stocks are the economically exploitable quantity of reserves or stocks available at the beginning and end of the accounting period. Changes in quantity are brought about by direct economic use/exploitation of the asset, including the extraction of minerals, logging, water abstraction etc. The term depletion measures the exploitation of the resource beyond long-term sustainable levels or yields (the quantity exploited above the accumulation of the asset). Changes in quality of the resources affect the productivity and economic value. As the quality changes are difficult to incorporate into physical quantitative asset accounts, they are shown separately below the closing stocks for completeness. Other accumulation refers to changes in assets due to economic decisions or interest and other volume changes are the changes due to non-economic causes or natural events or disasters. They therefore do not affect value added and income-generation, but are important elements in the assessment of the availability of natural resources.

Table 1: Framework for the Physical Asset Accounts for the selected assets

	Land/soil (sq.km)	Subsoil assets (metric tonnes)	Forests (economic functions) (m3, mt)
Opening stock	Area of land underlying buildings, land under cultivation, recreational land	Proven reserves	Volume of standing timber
Economic use		Extraction of minerals	Logging (tons/m3) Clearing of forests (loss of timber)
Other accumulation	Changes in land use - Transfer of land from the environment to economic use - Land reclamation (asset increase)	Discoveries Reassessment of reserves due to changes in technology and relative prices	Natural growth Natural mortality Transfers from the environment to economic use like shifting cultivation, transfer to non-forest uses
Other volume changes	Changes in land use and land area due to natural, political or other non-economic causes Transfer of land from economic use to the environment	Reduction in volume due to natural disasters or other non- economic factors	Reduction in volume due to natural disasters or other non- economic factors (fires, floods, earthquakes) Transfer of forest from economic use to the environment
Closing stocks	Area of land underlying buildings, land under cultivation, recreational land	Proven reserves	Volume of standing timber

The specific accounting categories will slightly vary. Below we discuss and compile the physical asset accounts for each resource.

5.2. Land and soil accounts

Opening and closing stocks consist of the land area over which ownership rights are enforced, including land underlying buildings and works, agricultural land, forest and other wooded land, recreational land, and associated surface water, and other open land and areas of artificial water bodies. Land area can increased through land reclamation, which is treated as other accumulation. The losses of land due to natural disasters (like Tsunamis, wars, land submergence due to permanent flooding etc) are recorded in other volume changes. This category includes also changes in land use and transfers of non-economic land from the environment into the economy for purposes of economic land use (cultivation, construction and so forth). The economic return to land in many cases depends on the quality of topsoil. Under the land accounts one can consider the degradation of land due to soil erosion, deforestation, industrial development, natural erosion and for other reasons separately. In principle one could develop separate accounts for soil but the stock estimate is difficult. Hence, for the time being we consider that quality of land is indicative of quality of topsoil.

Table 2 gives the asset accounts for land based on the nine-fold classification. The reporting area is classified into the following nine categories:

1. Forests include all lands classed as forest under any legal enactment dealing with forests or administered as forests, whether state-owned or private, and whether wooded or maintained as potential forest land. The crops raised in forest and grazing lands or areas open for grazing within the forests should remain included under the forest area.

2. Area under non-agricultural Uses: This includes all lands occupied by buildings, roads and railways or under water, e.g. rivers and canals and other lands put to use other than agriculture.

3. Barren and un-cultivable Land: The category includes all barren and uncultivable land like mountains, deserts etc. Land, which cannot be brought under cultivation except at an exorbitant cost, should be classed as uncultivable whether such land is in isolated blocks or within cultivated holdings.

4. Permanent pastures and other grazing Lands: They include all grazing lands whether they are permanent pastures and meadows or not. Village common grazing land is included under this head.

5. Land under miscellaneous tree crops, etc.: This category includes all cultivable land, not included in 'Net area sown', but put to some agricultural use. Lands under Casuarina trees, thatching grasses, bamboo bushes and other groves for fuel, etc. which are not included under 'Orchards' should be classed under this category.

6. Cultivable wasteland includes land available for cultivation, whether not taken up for cultivation or taken up for cultivation once but not cultivated during the current year and the last five years or more in succession for one reason or other. Such lands may be either fallow or covered with shrubs and jungles, which are not put to any use. They may be assessed or unassessed and may lie in isolated blocks or within cultivated holdings. Land once cultivated but not cultivated for five years in succession should also be included in this category at the end of the five years.

7. Fallow lands other than current fallows: This includes all lands, which were taken up for cultivation but are temporarily out of cultivation for a period of not less than one year and not more than five years.

8. Current Fallows represent cropped area, which are kept fallow during the current year. For example, if any seeding area is not cropped against the same year it may be treated as current fallow.

9. Net area Sown represents the total area sown with crops and orchards. Area sown more than once in the same year is counted only once.

The physical accounts for agricultural and pastoral lands include items such as opening and closing stocks, other accumulation, and other volume changes (Table 2). Opening and closing stocks refer to the quantity of

Table 2: Framework for land resources accounting

Area in 000 Ha			Causes of changes			
Categories	Opening Reported Area in 000 Ha	Changes	Additions	Classification change	Reductions	Closing Reported Area (2008-09)
Opening reporting area for land utilization statistics	305636.46	50.23		50.23		305686.69
Economic uses						
Forests	69688.25	-53.46			-53.46	69634.78
Area under non agricultural uses (A)	25568.32	739.19	739.19	0.00		26307.51
Barren and uncultivable land (B)	17396.69	-380.15		-380.15		17016.54
Land not available for cultivation (A+B)	42965.01	358.90				43323.91
Permanent Pastures and other grazing lands	10418.14	-75.27		-75.27		10342.87
Land under Misc. tree crops& groves not included in net sown area	3361.81	40.41	40.41			3402.23
Culturable wasteland	13269.63	-508.09		508.09		12761.54
Fallow lands other than current fallows	10510.11	-194.07		194.07		10316.04
Current fallows	15425.44	-884.75	0.00	-884.75		14540.69
Net area sown	139998.07	1366.42	1366.42		0.00	141364.49
Closing stocks	7					9

Source: Opening and closing stock figures are based on Agricultural statistics 2012, published by Ministry of Agriculture, Directorate of Economics and Statistics. Figures reported under causes of changes have been derived based on the land use change statistics published by Ministry of Agriculture.

land (area in hectares) at the beginning and end of the accounting period. The land area under agricultural and pastoral lands can be increased (artificially) for economic reasons by means of land reclamation (from the sea or river beds). Increase or decrease in the quantity of land comes under the other accumulation category, which simply pertains to the changes in the quantity of land (additions or reductions in areas devoted to specific use) caused by economic decisions. Included in this category are changes in land use and/or transfer of non-economic land from the environment to the economy for production purposes and vice versa. Lands under shifting cultivation involve areas opened up for agriculture from forestry and thus, represent additions to the inventory. On the other hand, conversions from agricultural to non-agricultural uses would decrease agricultural areas and increase other types of land. Quantitative losses of land due to economic uses can be due to: i) the partition of states or the transfer of districts to some states; ii) natural disasters (for example river/ sea coastal erosion. For instance in states such as Assam, the area lost due to river erosion is not inconsiderable; similarly, in December 2004 tsunami submerged large portions of arable land.

As such, these changes are entered in the category other volume changes. An adjustment was included in the physical accounts to balance the resulting closing stock of the previous year to the opening stock of the following year. Changes in land and soil quality affect land productivity and economic value, the most notable of which is topsoil erosion measured in tonnes of soil lost, which affects the productivity of agricultural land. The physical extent of land for general and specific uses was accounted for in the supplementary accounts and expressed in hectares. Specifically, the land use account represents the physical area by specific type of land use and land utilization.

5.3. Forest Accounts

The framework and unit of accounts vary across stakeholders. To a minister of the

Table 3. Physical accounts for forests for the years 2009 – 11 *

	Area in (Sq.km)	Volume accounts (Million cum)	Carbon accounts (Million tC)
Opening stock (A)	6,92,394	4498.66	6813.16
Depletion/degradation due to economic activities (-) (B)	-2689	17.47	26.46
Afforestation (+) (C)	4972	32.10	48.92
Accumulations due to Natural or Artificial Regeneration in forested land (+ (D)	3830	24.88	37.69
Transfer to non-forest purposes (E)	5339	34.69	52.54
Other volume changes (F)	175	0.21	1.72
Changes in stock (A – G) = (C – E) for area accounts (A – G) = (C + D – B – E – F) for volume and carbon accounts	-367	-16.26	-9.335
Closing stock (G)	692027	11877.502	6822.495

* - Quick estimates. These assessments are done during the years 2007 – 2009 respectively by FSI.
Source: Area accounts based on SFR (2009, 2011). Growing stock data from FSI (2009, 2011). Carbon per hectare taken from FSI (2011). The rest of the figures are derived based on the assumptions specified in the text.
Note: B, D, F though have an impact on the volume will not lead to addition or decrease in forested area because degradation can change dense to open forest or scrub but the area officially still remains under the forest department. Hence, forest area would not change though tree cover might change. Hence, changes in forest area can only be due to additions in forest area and deductions in forest area. However, for volume and carbon stocks they have to be added or subtracted because
Note: Changes in stock are the difference between opening and closing stocks. This should also equal the additions and reductions in the detailed accounts.

environment, perhaps the area under forests is more important, whereas to a forester the volume of timber matters more. For a conservation activist it is the number of species of resident fauna that is useful. Hence, physical accounts can be constructed in alignment with the users of this information. Accordingly, the forest accounts are expressed in volume (standing timber), weight (biomass), carbon (tons), hectares (area) or number (species). Nevertheless, the general format is same as that indicated in Table 1.

The detailed components are slightly different for area, volume and carbon accounts etc., which follow format given in Table 3. Opening and closing stocks are defined as the total standing volume of timber or area or tonnes of carbon. The volume of timber logged, above the long-term net growth of the forest, is considered non-sustainable and termed depletion. Sustainable use refers to the volume of timber logged without impairing the long-term capacity of the forest to yield economic products. The sustainable yield is usually estimated through models but given the level of detail required we can assume it as the volume logged above the net natural growth. As illegal logging is a reduction in the asset, it is recorded under changes due to economic activity. If the forests are cleared for non-forest uses or shifting cultivation, it is recorded as an economic activity. Forest increases due to afforestation are also considered as an economic activity. Reforestation and natural growth are recorded as other accumulation. Other accumulation thus includes increase in volume due to net natural growth (after accounting for natural mortality) and transfers from the environment to economic use. If the forests are transferred from, economic use to protected forests or forest affected by natural fires etc is recorded as other volume changes. Further forests can be classified based on the economic function. If the forest is used for purely commercial purposes (plantations) and ownership rights are clearly enforced, it is recorded under produced economic asset. Otherwise it is classified under non-produced economic asset or non-produced natural asset.

Table 3 shows the opening stocks in 2009 and closing stocks for the year 2011[120], by state, for forestland as open or closed forests, based on statistics from the State of Forest Report (FSI, 2009, 2011) . The opening stock can change due to

- Natural expansion: The stock of forested land may increase because of silvicultural measures, or natural expansion (natural regeneration).
- Afforestation: The stock of forested land may increase because of economic activity resulting in establishment of new forest on land, which was previously not classified as forested land. The afforested area and compensatory afforestation in India is available from various forest statistical reports.
- Losses due to deforestation and degradation. Forestland may be lost when transferred to non-forest purposes or as the result of shifting cultivation (a specific form of land transfer), or when the forested land is degraded to a point, where tree cover falls below 10 per cent and the land thus

[120]Open forests include all land with a forest cover of trees with a canopy density between 10 to 40 percent. Dense or closed forests include all lands with a forest cover of trees with a canopy density over 40 percent.

becomes classified as other wooded land. Sources of degradation include logging damage and forest encroachment, and heavy grazing by livestock. Although the total area of forestland may not change, some closed forests may become open forests because of excessive harvesting. The area transferred for non-forest purposes has been compiled from the star questions of the Parliament and from the land-use change matrices. Regarding shifting cultivation, data from Wasteland Atlas (2011), Forest Sector Report of India has been used.

Table 4 and Table 5 give the accounts for timber and carbon. The opening stocks represent the growing stock of timber present in 2009 (assessment carried out during 2007-08). To convert this estimate into units of carbon, earlier studies used estimates of biomass based on a study by Gundimeda (2000b, 2002a), which used the volume inventory data to estimate the carbon content of the biomass in different states and different types of forests. The earlier papers converted biomass into carbon by assuming a carbon content of 0.5 Mg C per Mg oven dry biomass. However, the latest report of FSI estimated the carbon in forests in different states and we have used this estimate for this report. Only the aggregate carbon content of forest biomass was included but not the stock of carbon in soils as the element of interest is only the change in carbon because of current disturbance. The closing stocks are computed as opening stocks less reductions plus additions.

Economic activities affecting area, volume and stock of carbon can be:

Logging (both recorded and unrecorded): The recorded volume of timber harvested/logged has been derived from the production statistics of timber and fuel wood obtained from the CSO for the year 2009-2011. National Account statistics also considers production of timber from trees outside the forests in consultation with the Ministry of Environment and Forests. According to the Forest Sector Report of India published in 2010, the annual production of timber at present is only about 2.4 million m3 which is 5% of the total timber produced and consumed in the country, of which around 60% is harvested by the State Forest Development Corporations. According to the report, most of the timber produced in the country comes from Trees outside Forests (TOF) grown in private lands under agro-forestry, along the roads, canal, homesteads etc. However, reliable data of timber produced from TOF is not available. Based on the growing stock of TOF and average rotation of the tree species, the annual production of timber from TOF has been estimated by the Forest Survey of India (FSI) to be 44.3 million m3 in the country.

In case of fuelwood, the production of fuelwood is estimated indirectly from the consumption side. The data is obtained by the CSO from the National Sample Survey Organization (NSSO) survey data carried out every five years. Based on the survey, the fuelwood consumption in household sector for 2010 is estimated at 248 million m3 and 13 million m3 in hotels and restaurants, cottage industries and cremation of dead human bodies, giving a total annual consumption in 2010 of around 261 million m3. The production of fuelwood from forests is estimated at 52 million m3, and the remaining 209 million m3 came from farmland, community land, homestead, roadside, canal side and other wastelands. Still a considerable amount of timber and fuel wood goes unrecorded due to illegal felling of trees. In order to account for unrecorded production[121], the CSO used an estimate of 10% of the total recorded production of industrial round wood as the value of unrecorded production of industrial round wood (which is an approximate estimate).[122] Despite accounting for unrecorded production based on the norms set by CSO, on tallying the volume accounts at the end, if some growing stock is still missing, this can be attributed to unrecorded production.

Logging damage: Damage due to logging was assumed to be 10% of the volume of timber logged from both recorded and unrecorded production.[123] The assumption made in this study is that some of the damaged timber leaves the forested land because deadwood is collected for use as fuel. The remaining timber is left on-site but is assumed that it is an economic loss.

Forest encroachments and shifting cultivation: In India forests are encroached every year illegally. As a result, though that land is legally classified as forests, in reality the forestland is occupied by humans or put to use for some human activity. This results in loss of tree cover in that area. Similarly, in some of the Indian states forests are cleared for agriculture and after few years the land is left for trees to grow. Such practice is very often seen in some of the northeastern states. The volume of timber lost due to shifting cultivation and forest encroachment is obtained by multiplying the area subject to this disturbance with the growing stock per hectare in open forests.[124]

Afforestation: The statistics on afforestation (reported by FSI, 2010) does not indicate various species planted, the survival rate of these plantings, how much area actually ends up forested and the growing stock per ha in these afforested areas. The latest FSI reports have improved the data on afforestation but as detailed estimates on the nature of species afforested, volume of afforested species, the study estimated the volume additions due to afforestation by multiplying the area afforested with the mean annual increment per sq. km and assumes that the same conditions prevail at the existing sites.[125]

Damage from heavy grazing: Only the area subject to heavy grazing is considered and the volume lost due to grazing is derived by multiplying naturally regenerated volume and the afforested volume with the percentage of area subject to heavy grazing. However, no carbon loss is assumed from grazing because the carbon increases due to regeneration (if any) on the grazed land is assumed offset by loss in carbon due to surface fires and grazing.

Other Accumulations

Other accumulations due to natural processes consist of the natural growth (mean annual increment) and natural regeneration. The mean annual increment of different species is taken from the statistics published by the FSI

[121]Unrecorded production refers to extraction of timber without proper records, illegally and detected theft.
[122]Due to ban on clear felling this assumption may need to be revised. It is recorded that in some states like Rajasthan the logging figure is as high as 2.5 times of the recorded production.
[123]The figure is based on the information provided by the state forest department of Maharashtra (visited on May 28th 1997)
[124]We assumed that forest encroachments and shifting cultivation usually happen on the periphery of open forests. Therefore, the growing stock in open forests needs to be used for calculations.
[125]The assumption was made, as the information on volume of stock growing in afforested area is not available.

(1995). This volume estimate is converted to units of carbon using the FSI estimates (latest draft report circulated but not published) as discussed earlier. The area regenerated (naturally and artificially) is obtained from SFR (2010), but only for some states. The volume added is computed by multiplying the area regenerated with the mean annual increment per hectare of different species.[126]

Changes in forest stock due to reclassification

Changes in forest stock due to reclassification include the transfer of forestland for non-forest purposes (for example, for agriculture, residential or industrial purposes) or transfer from agriculture to forests. The volume reduction due to transfer of land for non-forest purposes is derived by multiplying the area transferred with the growing stock per hectare. Here we assume that there is some standing timber left on the forestland before the land is converted to non-forest purposes. This timber may be used in various wood products from which the carbon will be released depending on the use to which it is put to.

Other Volume Changes

Other volume changes comprise reductions due to forest fires; stand mortality, insect infestation, and degradation due to heavy grazing. The area subject to forest fire has been given by SFR (2010). Multiplying the naturally regenerated volume and the afforested volume with the percentage area affected by the forest fire gives the volume of forest stock affected by forest fire.[127] Gundimeda (2003) estimated that when the forest is affected by fires, only 20% of the stem biomass remains, 50% is burnt and the carbon transferred to the soils (immediate and releases that eventually occur in future as a result of fires today) and 30% is released into the atmosphere.

- Insect and pest infestation. The latest statistics available about insect induced mortality at the time of the analysis carried out by Gundimeda (1998, 2000, 2001), Gundimeda et al (2005) are estimates from Indian Forest Statistics (various years between 1947 to 1972) for various states. These statistics reveal that the average volume rendered unusable annually due to attack of insects/pests is around 0.031% for broad-leaved species and 0.005% for coniferous species. From this the average volume lost due to insects and pests has been derived for the years 1947-70[128] and the same proportion has been used for the study period. The volume estimates are converted to carbon estimates as discussed before.

5.4. Accounting framework for Agricultural and Pasture Lands

The physical accounts for agricultural and pastoral lands include items such as opening and closing stocks, other accumulation, and other volume changes (Table 1). Opening

[126]Because of frequent fires and heavy grazing only 18.3% of the total forest, area has regeneration potential of important species (FSI, 1995a).

[127]Only the forest area that is prone to frequent fires is considered as affected by fire annually in this study.

[128]During the period 1947-72 the forests were classified as deciduous and broad-leaved forests. The area, volume of growing stock and volume of timber lost because of pests and diseases was available for that period. From this we computed the proportion of timber (volume of timber affected/total growing stock) affected annually and used the same proportion for the latest year.

and closing stocks refer to the quantity of land (area in hectares) at the beginning and end of the accounting period. The land area under agricultural and pastoral lands can be increased (artificially) for economic reasons by means of land reclamation (from the sea or river beds). Increase or decrease in the quantity of land comes under the other accumulation category, which simply pertains to the changes in the quantity of land (additions or reductions in areas devoted to specific use) caused by economic decisions. Included in this category are changes in land use and/or transfer of non-economic land from the environment to the economy for production purposes and vice versa. Shifting cultivation areas are the lands opened up for agriculture from forestry and thus, represent additions to the inventory. On the other hand, conversions from agricultural to non-agricultural uses would decrease agricultural areas and increase other types of land. Quantitative losses of land due to economic uses can be due to partition of states or the transfer of districts to some states or sometimes due to natural disasters. For example river/sea coastal erosion—in the case of river erosion, in states such as Assam, the area lost is not inconsiderable; or, for example, the December 2004 tsunami that submerged large portions of arable land etc. are all recorded under other volume changes. An adjustment was included in the physical accounts to balance the resulting closing stock of the previous year to the opening stock of the following year.

In the current system of national accounts in India, additions to agricultural land due to economic activity are included in output. If the increase in agricultural area came because of land improvements or reclamation, the expenditures involved are included in output on the supply side and treated as Gross Fixed Capital Formation/Gross Capital Formation of produced asset on the use side. If the agricultural land is converted to non-agricultural use, it indicates decrease in the capital in the agricultural sector but increase in value in the other sector, which would be accounted in that sector. In SNA, the agricultural land (non-produced asset) is acquired by the institutional sectors from other institutional sectors and recorded in their accounts. The net acquisition of non-produced assets is zero as one institutional sector acquisition is balanced by another institutional sector's disposal. The acquisition of non-produced assets is not included in the output either of institutional sectors or at the national level. It is only the produced assets (which included additions to non-produced assets, whose output and GFCF gets included in the overall estimates).

The most important limitation is that the changes in land and soil quality affect land productivity and economic value. However, the impact is not shown. Similarly, land degradation impacts other sectors due to intensive use of land but is not reflected in the current system of national accounts. We need to show this impact clearly through a proper accounting framework.

Table 4 gives the physical accounts for agricultural and pasturelands for the year 2001-2009. The reason why such a long time frame has been considered is to capture the extent of land degradation. Land usually degrades over a period. Hence, sufficient time span has been allowed for assessing quality changes.

Table 4. Physical Accounts for Agricultural and Pasture Lands (2000-2009) (in 1000 ha)

	Agricultural land	Pasture land	Changes in Degraded Land	Soil erosion* (Mt/yr)	Water sedimentation	N Loss	K Loss	P Loss
Opening stock	141461.34	14877						
Changes in quantity	-96.850	-614						
Closing stocks	141364.49	14263						
Total			-23185.3	611.31	120.56	6.60	142.57	22.9
Degraded land categories	2001	2008-09	Change					
Gullied and/or Ravenous land	2055.3	741.2	-1314.1					
Land with scrub	19401.4	18001.3	-1400.11					
Waterlogged and marshy land	1656.85	870.34	-786.51					
Land affected by salinity/alkalinity coastal/inland	2047.7	680.56	-1367.14					
Degraded forest scrub, pastures and land under plantation crops	2597.89	9081.74	6483.85					
Shifting cultivation (abandoned+ current Jhum)	25703.84	902.51	-24801.3					

Source: Opening and closing stock figures are based on Agricultural statistics 2012, published by Ministry of Agriculture, Directorate of Economics and Statistics. The waste land data is taken from Wasteland Atlas (2005, 2010 and 2011), Department of Land Resources.

a – No time series data on soil erosion available for this period

5.5. Accounting framework for Minerals

The physical accounting framework should include information on the opening stocks (i.e. stocks present at the beginning of the accounting period), changes during the period and the closing stocks (stocks present at the end of the accounting period). The changes during the period can be due to extractions, new discoveries, other volume changes, which includes redefinition of reserves due to changes in price or extraction technology. An issue, which is critical to the construction of physical accounts, is definition of physical stock. Different ways to measure physical stock exist – The most commonly used system of classification is based on what is known as McKelvey box, which classifies mineral resources based on the two combined criteria i.e. the degree of uncertainty (proved, proven and probable or classified as measured, indicated, inferred, potential

Table 5. Physical Accounts for Minerals 2000-2010 (all-India) (Million tonnes)

	Coal	Iron ore	Bauxite	Limestone	Copper ore	Oil	Natural gas
Total Opening stock	245583	17712	5052.9	169941	712.52	732	763
of which proven	91596	8571	1080.69	21861	224.6		
Probable	116133	3929	896.5	29402	222.14		
Possible	37854	5213	3075.72	118678	265.78		
Extractions (-)	4341.61	1532.35	129.98	1747.47	28.431	332.38	324.3
Other accumulations due to new discoveries (+)	36345	4370	2397.09	94701	317.29	282140	393943
of which Proven	24209.83	-4105.335	-889.412	-14629.887	-119.64		
Probable	0	-1811.713	-624.82	-23454.191	38.844	0	0
Possible	5501.27	15197.86	-189.038	51330.72	898.31	0	0
Other volume changes due to changes in classification	5053	329	224.1	108	0	-41359	-61066
Net stock changes (+/-)	81185.1	10814.1	-1573.3	5403.90	845.94	25.44	477.92
of which proven	28551.44	-2572.985	-759.432	-12882.417	-91.212	0	0
Probable	0	-1811.713	-624.82	-23454.191	38.844	0	0
Possible	5501.27	15197.86	-189.038	51330.72	898.306	0	0
Total Closing stock	326768.1	28526.15	3479.62	175344.901	1558.46	757.44	1240.92
of which proven	120147.4	5998.015	321.258	8978.583	133.388		
Probable	116133	2117.287	271.68	5947.809	260.984		
Possible	43355.27	20410.85	2886.682	170008.72	1164.09		

Source: Opening and closing stock of assets are based on Indian Mineral Year Book, 2011 and previous years. Data on extraction has been taken from CSO for the respective years. For copper, data is based on Copper Market survey report (2011) published by IBM. The rest are derived.

and speculative) and economic feasibility of extraction (economic, marginally-economic, sub-economic). If a mineral resource is both known and economically profitable to exploit with existing technology and price it is categorized as 'reserve'. This is the most commonly used measure for the stock of subsoil assets. India, since 1981 and prior to 2003 has followed a modified McKelvey classification and considered two categories: recoverable resources and in-situ resources. Reserves include proved, probable and possible corresponding to the measured, indicated inferred classification of the McKelvey Box. Resources include prospective and prognostic reserves corresponding to the hypothetical and speculative classification of the McKelvey box. The parameters are also very few and, largely, subjective. However, after 2003 a decision was taken to shift to UNFC classification. UNFC is a 3 dimensional system, the 3 axes being economic, feasibility and geological. The categories of resource estimation are denoted by digital codes. The codes of categories can vary from the highest (111) to the lowest (334). The development of physical accounts for minerals depends on the accuracy of estimates under different categories.

Though India has several minerals, the most important minerals in terms of gross value added are coal, iron ore, oil, natural gas and limestone and others contribute less than 18% of the value in the national accounts. In this report, we illustrate the asset accounts for these minerals. The data for construction of physical accounts were obtained from the collection of "Indian Minerals Year books" published by Indian Bureau of Mines. Table 5 gives the physical asset account for minerals for the period 2000-2010.

In the national accounts the extraction of minerals is treated as intermediate consumption. There is also a debate on the treatment of new discoveries and whether they should be treated as capital accumulation. Here we have shown that in the integrated accounting framework but have not deducted/added to the NDP expression.

5.6. Valuation of the Stock of Assets and its changes

Estimating the value of changes in stock of assets necessitates monetizing the physical accounts for which valuation is essential. The assets and their changes can be valued using different approaches depending on whether the asset is renewable or nonrenewable. These approaches are discussed below:

The conceptual framework behind the net present value approach is as follows. A piece of land can be characterized by several attributes like soil quality, soil texture, soil fertility measured in terms of nutrients, associate water resources etc. With the help of these natural factors and other inputs like seeds, rainfall, fertilizers etc. some marketable output is produced. Economic rent is obtained by deducting the value of these produced inputs from produced output, which can be considered as payment for the use of natural resources and this can vary every year with changes in output/inputs, prices and discount rates. Land rents may vary due to the difference in the quality of the land and inputs. Since the resource unit is expected to contribute to the production of one or more resource commodities over a period of time, the asset value for any one land use, say agriculture, will be equal to the present value of the stream of land rent over the economic life of the resource over the relevant planning period. The land rent is obtained by estimating the annual net returns from the use of the resource over time, less a reasonable allowance for profit, which can be represented by:

$$\text{NPV} = \sum_{T=1}^{N} \frac{LR_T - C_T}{(1+r)^T}$$

Where, NPV is the net present value of the asset.

T is the length of the planning horizon/or economic life of the resource;

r is the discount rate;

LR_T is the gross rent in year T; and

C_T is the cost of input in year T

The change in the value of assets (depreciation) is the differences in asset values during the accounting period.

5.7. Valuation of natural resources for accounting

Chapter 2 discussed the purpose of valuation and various techniques available to place a value on the changes in natural assets. In this section we discuss some of the techniques adopted by earlier studies discussed in sections 5.1 and 5.2 to place a monetary value on the physical resource accounts to be able to integrate them in the form of supply use tables. Below we discuss the methods adopted in valuing different resources considered in the study.

5.7.1. Land

Valuation may seem straightforward, as market prices exist for land. However the complications arise due to the following reasons: 1) The number of transactions carried in a particular year is not much: 2) Even where prices are recorded, they are seldom available for all locations (e.g. remote rural areas) and if available are quite distorted; 3) The land has bequest value which is higher than that of market price. 4) Market transactions seldom take place for certain categories of land like forests and wastelands. 5) Bundling of resources may often take place. For example, agricultural land fetches higher value if the soil quality is good and water is available in plenty. In such instances, where market prices are often not a good indicator, net present value of the future benefits accruing from holding or using the asset is used as proxy for market prices. In the absence of market prices due to which net present value may not be used, the cost of production may be used as a lower bound on its value.

5.7.2. Forests

As forested land is seldom marketed, forests may be best valued based on their total economic value. It may be difficult to value each component. This chapter reports some of the values, which have been considered by earlier studies but by no means, are a complete representation of all the values.

Timber and Fuelwood

The prices realized per cubic meter of timber for different states were obtained from the CSO who in turn compiles the figures based on the information provided by various state forest departments. The most common form of revenue generation is through royalties or auctions. From this the costs of logging are deducted to obtain the resource rent. The costs include logging, pre-logging and post-logging costs, transportation costs and overhead costs, some of which differ by the extractable log volume and the logging methods (see Gundimeda, 1998 for more details on different costs).

Carbon

For valuing the carbon sink services, marginal social damage or abatements cost approaches have been used. Marginal social damage costs refer to the economic value of the damage caused by the emission of an additional metric ton of carbon to the atmosphere. Abatement costs refer to the costs of maintaining/ reducing carbon emissions, which can vary depending on the abatement measure used. Frankhauser (1994,1996), Frankhauser and Tol (1996), and Tol (1999) discuss the wide range of marginal social damage costs estimated by various authors, which average approximately US $20/MTC. There are well-established carbon markets now, and one can use this estimate as well. However, as the carbon prices fluctuate depending on the volume of trade, one can use an average price. Further, to avoid double counting forests can be valued for either timber or carbon and not both. Assumptions about the proportion of forests valued for timber and carbon have to be made, which in the earlier papers were assumed to be the percentage area under protected and reserved forests respectively.

NTFPs

In addition to timber, forests yield non-timber forest products (NTFPs) like bamboo, sandalwood, lac, honey, fodder, resin, gum, tendu leaves etc. These are also referred to as minor forest products. NTFPs are valued by multiplying the forest area accounts with the discounted value per hectare of the products computed from the statistics provided by the CSO (see Gundimeda 2001). As the only input required in collecting NTFPs are the labor and it is mostly those who have no opportunity to work elsewhere are involved in collection, the cost of inputs are considered to be zero and the entire output value is considered resource rent. Like timber and fuelwood, the value of NTFPs is severely under-reported; the CSO estimates the value of unrecorded NTFP production as 10 times the value recorded by the State Forest Departments, which are based on a nominal 'royalty' charged to forest users for collecting NTFPs, but which is largely unenforceable.

Fodder

The forests also provide fodder for the livestock. The fodder has market value but it is considered to be largely undervalued. The central statistical organization includes the value of fodder in their national account estimates based on the information provided by the Ministry of Environment and Forests but it is considered to be grossly underestimated.

Ecotourism

As forests provide tourism benefits, the best way to approximate the value of protected areas is through exploring their potential value as a source of nature recreation (also called eco-tourism). The ecotourism value can be captured through estimating the consumer surplus per hectare per tourist either through contingent valuation method or travel cost method which involve collecting information from different sites and tourists. Consumer surplus is referred to as net willingness to pay or willingness to pay in excess of the cost of the good and can be viewed equivalent to a virtual market price for a recreation activity. A study by Gundimeda et al. (2006b) used an approach called benefit transfer method to estimate the value of ecotourism in Indian forests. "Benefit transfer" refers to the use of existing information and knowledge to new contexts, i.e., adapt and use information from already existing secondary studies in India on ecotourism to different protected parks in India. In this paper, the values have been taken from the study by Gundimeda et al (2006b).

Bioprospecting Value of Forests

One of the most important services that biodiversity provides to the economy is in the form of provision of genetic material. For the genetic materials, which are already discovered values exist but are mostly undervalued due to market imperfections. If we want to know whether the conservation of a species is worthwhile, we need to know the value of undiscovered genetic material. The study by Gundimeda et al. (2006b) used an approach called the value of marginal species, i.e. the contribution that one more species makes to the development of new pharmaceutical products (termed as marginal value). The marginal value is the incremental contribution of a species to the probability of making a commercial discovery. This approach is based on a paper by Rausser and Small (2000).

Change in value of forest assets

Once the value of different goods and services are established, asset value of forests has been derived using net price of timber and fuelwood. In contrast to timber which once harvested is lost forever unless replanted, the tree grows to maturity again (hence, can be valued only once), the value from NTFPs, fodder, ecotourism and bioprospecting can be generated every year, Hence, for these benefits the present value, obtained by dividing the net price with the social discount rate of 4% has been used.

5.7.3. Agriculture and Pasture Lands

Estimating the value of land degradation

If the land is used sustainably, it has an infinite life therefore no adjustment for degradation is required and the whole resource rent can be considered as income. However, as discussed earlier the use of land for agriculture using unsustainable practices would mean degradation of land due to salinization, soil erosion etc.

Cost of soil erosion

Soil erosion is a natural process and only when it erodes beyond the tolerable rate, does this have an impact. Under the natural condition, whatever soil lost is replenished back. However, when the natural rate is exceeded a physical depreciation of soil resources takes place. Thus any loss of soil erosion beyond a tolerable level can be considered as human induced. Soil erosion has two effects: 1) erosion of topsoil leading to productivity loss 2) Sedimentation of waterways thereby reducing the reservoir capacity. At the aggregate level, the costs of soil erosion can be estimated through the yield losses from production and fertilizer equivalent of soil nutrient lost (replacement cost method). The soil yield loss function can be derived from empirical studies relating productivity level of soils for a given land use/crop to varying rate of erosion. Using this technique the yield response functions measures the difference in yields between each soil type as compared to the normal fertile soils. However, given the large number of crops that are grown in various parts of the country, it is difficult to come up with damage functions for all the crops in different states taking into account the specific conditions like the land use, crop management factor, altitude, slope etc. Though some studies have been done, these studies are hardly available for entire country thus limiting the use of this method.

The on-site cost of soil erosion has been estimated using replacement cost method, which estimates the value of lost nutrients through erosion. The idea behind this is that eroded soil carries with it soil nutrients that could have been used up for plant growth. An estimated fertiliser equivalent of the nutrients in eroded soils and percentage nutrient uptake by different crops can be used to convert to an inorganic fertilizer equivalent. The value of fertilizer can be taken as a measure of the depreciation of the soil resource base because of economic activities. For estimating the off-site effect of erosion, one can look at the cost of cleaning up reservoirs or the reduced capacity of the reservoirs due to siltation or sedimentation.

Estimating the cost of land degradation

Land degradation can happen in the form of salinity or erosion of topsoil. Salinity directly affects the productivity of soils by making the soil unfavorable for good crop growth and indirectly lowers productivity through adverse effects on the availability of nutrients and on the beneficial activities of soil micro flora. Apart from salinity the deposition of heavy metals or industrial effluents and indiscriminate use of agro-chemicals such as fertilizers and pesticides are also responsible for land degradation. To estimate the cost of land degradation, once again two approaches can be used: productivity loss method and treatment cost method, i.e. costs incurred in treatment of degraded lands to restore the lands back to their original capacity.

5.7.4. Estimating the value of depreciation of Mineral Resources

The physical stock of minerals can be valued using market prices. However, in case of minerals it is difficult to get accurate market prices due to market distortions and depends on institutional arrangements. Once the per unit value of the mineral is known, one can calculate the value of stock of a natural resource (RV) as the net present value of the stream of the future resource rents the resource will yield until it is exhausted and is expressed as follows.

In case of non-renewable resources like minerals, one can calculate the value of stock of natural resource as the net present value of the stream of the future resource rents the resource will yield until it is exhausted and is expressed as follows.

$$RV = RR\sum_{k=1}^{n} \frac{1}{(1+r)^{K}} = RR\left[\frac{(1+r)^{n}-1}{r(1+r)^{n}}\right]$$

where RR is the total resource rent (the unit resource rent rr = RR/E, where E is the annual rate of extraction), n the life length of the deposit (i.e. time for which the resources will last until exhaustion), given by n = S/E where S is the stock of the resource and E is the annual rate of extraction, r is the discount rate

Five sets of assumptions are critical in this estimation procedure.

1) First assumption relates to prices, costs and yield data as a function of time. Under the assumption of constant prices, any changes in asset values can only be attributed to the changes in productivity of the resource and the time-value of money.

2) Second assumption relates to the expected value of the resource at the end of the planning horizon.

3) The third assumption refers to the choice of the discount rate. In general, a lower discount rate favors future consumption, while a high discount rate gives more preference to present consumption.

4) The cost of production is assumed to include the value of all material and labour inputs along with normal return on capital (i.e. profit).

5) Another important assumption to be made is regarding the variable n, the economic life of the resource.

Owing to the difficulties in using the present value approach, various alternative methods have been proposed to value mineral depletion by various researchers (see Atkinson and Hamilton, 2007). The first approach called the total rent approach (also called net price method) proposed by Repetto et al. (1989) assumes an optimal extraction path. Using this method, the value of the resource at the beginning of the period t, Vt is the volume of the resource Rt multiplied with the difference between the average market value per unit of the resource Pt and the per-unit (marginal cost of extraction, development and exploration, including a normal return to the capital Ct). The user cost here would be the total rents

$$UC_t = (P_t - \bar{c})R_t$$

Ideally, this net price ideally would be the Hotelling rent accruing to the owner of the resource, in which case the expected rate of growth of the unit rent would be equal to the discount rate. The main problem with this approach is that the marginal extraction is fixed and for optimality, the total rent approach required a rising price path to hold.

The second variation, marginal rent (or current scarcity rent) proposed by Hartwick and Hageman (1993), states that under the assumption of constant resource prices and increasing marginal extraction costs, the user cost is given by

$$UC_t = (P_t - c'(q_t))q_t$$

This approach assumes that the mineral extraction program is on the optimal path.

A third variant to the approach proposed by Hartwick and Hageman (1993) is given by the exhaustion condition for the optimal extraction path. Using this approach, the user cost is computed as

$$UC_t = \frac{pq_t}{(1+r)^N}$$

Where, N is the number of years until the resource is exhausted.

A fourth approach proposed by ElSerafy (1989) imposed no optimization of the extraction path for the resource and assumed that total rents in each period are constant at level pq – c. Using this approach the user cost can be calculated as:

$$UC_t = \frac{pq - c_t}{(1+r)^N}$$

This approach is referred to as the 'simple present value (PV) method', where N declines in each period as the resource is exhausted (assuming no discoveries).

A fifth approach has been proposed by Vincent (1997). He assumed an iso-elastic extraction cost function with increasing marginal costs defined by

$$UC_t = \frac{\varepsilon(pq - c)}{1 + (\varepsilon - 1)(1+r)^N}$$

Where N is defined to be reserves-to-production ratio

Table 6 gives the summary monetary estimates of the physical accounts for different assets considered above. We used net price method in case of forests and minerals and estimated the cost of associated degradation due to agricultural practices.

5.8. Integration with the supply use accounts

The whole objective of this exercise is to integrate these estimates with the national accounts. The integration should ensure that all of the following three components are addressed: 1) figures for the production of natural resources should adjust for unreported production. 2) Capital accounts should be adjusted to expand

Table 6: Accounting prices and wealth of forests, agricultural land and minerals for the year 2009

Accounting price of timber/m^3 (Rs/m3)	13,390
Accounting price of fuelwood (Rs/m3)	1943
Accounting price of NTFPs (Rs/Ha)	6289
Accounting price of carbon (Rs/ton)	1000
Accounting price of recreation (Rs/Ha)	96355
Accounting price of genetic material (Rs/ha)	33471
Weighted net price of minerals considered in the study (Rs/tonne)	916.2
Loss in value of timber, carbon and NTFPs (million Rs)	-19859.95
Loss in ecotourism and genetic diversity (million Rs)	-4765
Total loss in forest wealth (million Rs)	-24624.56
Total adjustment for depletion and degradation per rupees of agricultural GDP	0.0037 Rs/unit of agricultural GDP
Adjustment for depletion and degradation of agricultural GDP	-28384.3

Source: Timber, fuel wood, ntfps based on National account statistics from MOSPI
Carbon, recreation, genetic materials from secondary sources (mentioned in the text)
Value of minerals based on IBM data and net price is derived after deducting the costs based on earlier study (mentioned in the text)
Loss in forest wealth: computed

a. Capital formation to include accumulation of natural assets and their depletion or degradation. In the conventional accounts, only accumulation of produced capital is included. Other Natural assets are categorized as non-produced assets and are excluded. The value of this accumulation of natural capital should be added to investment, which increases GDP and NDP.

b. Consumption of capital to include the cost of depletion and degradation of natural resources, which decreases NDP.

The result of these adjustments is the environment adjusted state domestic product (ESDP)

$$ESDP = NSDP + (A_{np} - D_{np})$$

Where Dnp is the depletion of non-produced natural assets and is obtained from the asset accounts.

The asset accounts are constructed as follows:

Closing stocks – Opening stocks = changes due to economic activities ± other accumulations ± other volume changes ± omissions and errors

Depletion = other accumulations ± changes due to economic activities

The second term captures the net effects of

Table 7: Integration of supply use tables and the natural assets

	Economic activities			Economic assets		Environment
	Production	Rest of world	Final cons.	Produced assets	Non-produced assets	Other non-produced natural assets
Opening stock of assets (i)				Kop.ec	Konp.ec	
Supply (ii)	P	M				
Economic uses (iii)	Ci	X	C	Ig		
CFC (iv)	CFC			−CFC		
net domestic product* (v)	NDP	X – M	C	I		
Use of Nonproduced natural assets	Usenp				−Usenp.ec	−Usenp.env
Other accumulation of non-produced natural assets (vii)					Inp.ec	−Inp.env
Environmentally adjusted aggregates (viii)	EDP	X − M	C	Ap.ec	Anp.ec	−Anp.env
Holding gains/losses (ix)				Rev p.ec	Rev np.ec	
Other changes in volume of assets				Volp.ec	Vol np.ec	Vol np.env
Closing stock of assets (xi)				Kl p.ec	Kl np.ec	Kl np.env

accumulation natural forests (non-produced assets, A_{np}) minus depletion (D_{np}).

Table 7 represents this integration in a simplistic form for the assets considered in this paper. However, this should be expanded for all the sectors.

5.9. Conclusions and data needs

This chapter analysed both the changes in wealth and flows using the framework consistent both with wealth accounting approach as well as SEEA framework. The estimates shown in this chapter are the quick estimates at the national level for only three resources: forests, land and minerals, and did not come from a bottom up exercise. We start of measuring stock of the assets at the beginning of the accounting period and account for all the changes which occurred during that period to give the stock level at the end of the accounting period. Physical account flows can represent the stocks and the changes therein during the accounting period, in physical measures (square kilometres (Km2); cubic metres (m3); metric tonnes). Opening and closing stocks are measured as the economically exploitable quantity of reserves or stocks available at the beginning and end of the accounting period. Changes in quantity are brought about by the direct economic use/exploitation of the asset. For renewable resources, economic use is a gross concept

Table 8. Greening of National accounts: an illustration for the resources considered in the study (Units in Rupees Crores) for the year 2009

	Economics activities			Economic assets					Environmental assets
	Production	Rest of world	Final cons.	Produced assets	Errors & Omissions	Non-produced assets (forests)a	Non-produced assets (agricultural land)b	Non-produced assets (minerals)c	Other non-produced natural assets
Opening stock of assets (i)				Kop.ec		6966158	4310843.2	36912824	
Supply (ii)	13102022	1639872							
Economic uses (iii)	6551751	1298371	4567456	2016186		13526.9		132266	
Other accumulations of assets (iv)				113374		17420.58		5905953	−Inp.env
Holding gains/ losses (v)				214619		-	35934.02	Rev np.ec	
Other changes in volume of assets(vi)				Volp.ec		160.97	-748.11	-855184	Vol np.env
Errors and omissions (vii)				45034					
GDP (viii)	6550271	-341501	4567456	2389213	-64897				
CFC (ix)	-655673			−655673					
Net domestic product (NDP (x)_	5894598	-341501	4567456	1733540	-64897				
Use of Non produced natural assets (xi)	-3893.6					-13526.9			−83397
Environment adjusted domestic product (EDP) (xii)	5807307.4	-341501	4567456	1733540	-64897	-3893.6		5892726	−83397
Closing stock of assets (xiii)						6962465	4470173	43812493	

Source: National Account statistics (2011)

a- the stock changes for forestland are for the assessment year 2007-09 but the flows are annualised

b- the stock changes for agricultural land are for the period 2000-2009 but the flows are annualised

c – the stock changes for minerals are for the period 2000-2009 but the flow of minerals is annualised. Extraction of minerals is recorded under intermediate consumption (economic use). However, the appreciation or depreciation might have to be adjusted in the EDP expression.

that includes sustainable use made possible by natural regeneration or replenishment, as well as "depletion" which represents exploitation of the resource beyond long-term sustainable levels or yields. This can be represented in the following equation:

Opening stock (+) Additions to stock [renewable resources] (–) Depreciation of stock [economic use/exploitation] (+/-) Other stock changes[revaluations/natural processes] = Closing stock

There are also quality changes that are relevant (physical) aspects of environmental costs but they are difficult to incorporate into physical quantitative asset accounts.

The monetary accounts are derived from the physical accounts by applying monetary unit values, that is to say, market prices or estimated market values, to the physical stocks and stock changes of natural resources. Different valuation methods are used to place a monetary value on the impacts imposed to the environmental assets covered. Finally, the monetary estimates are integrated with the main national accounting aggregates.

The aim of this integration is to allow for the computation of depreciation of the resource in question by adjusting the NSDP (net state domestic product) to reflect that depreciation. This new adjusted value is termed ESDP (environmentally- adjusted state domestic product), which is then used as a useful indicator for policy makers to evaluate the wealth impact of previously unaccounted damage. It is also useful in evaluating trade-offs in land use and resource use.

However, it should be noted here that the results produced here are quick estimates for illustrative purposes. The good news is that some data is available for carrying out green national accounting for India, though it does suffer from some limitations. However, one could look for some approximations or proxy variables to be able to come up with a meaningful estimate reflecting the county conditions. Below we also discuss the data availability to implement the green national accounting framework discussed in the earlier sections along with possible data sources for India. Where information is not available, we need to compile this data.

Data	Source
Forest cover change in different states of India	Data is available for year 2001, 2003, 2005, 2009, 2011 in the state of forest reports by FSI
Forest cover in different states of India	State of Forests Reports, Published by Forest Survey of India
Volume of timber harvested/logged	Various state forest departments, Production Statistics can be obtained from CSO – but these are under estimates. There is gross underestimation. Further, timber and fuelwood comes from trees outside forests, private plantations as well. However, detailed periodic data is not avaiable
Area afforested in India state-wise	State of forest report various years. – But we need more details and clarity on species wise afforestation in different states. We have information on afforestation under various scheme, However, the relation between various schemes is not clear. Further, more information is required on the stocking of species, volume, whether afforested in forested area or outside the forest, name of species afforested, survival rate of these plantations etc.
Accumulation of timber due to natural growth (mean annual increment)	The original publication in "Extent composition and density of growing stock" published in 1995. We need to know if any other publication is available. But the latest FSI reports still use the information published in 1995
Accumulation of timber due to natural regeneration	Area regenerated was available in one of the documents of Forest Sector Report of India 2010– but we still need more details on the species composition and regeneration rates and volume regenerated.
Area subject to forest fire	Area subject to forest fires was available from Forest Sector Report India 2010. However, regular statistics are not available – even where available we need more detailed information on the type of species destroyed, the loss in trees due to fires, volume of timber lost, value of forest crop destroyed etc.
Loss in timber volume due to insects, pests and disease	No data is available after 1972
Animal grazing	Infrequent and inadequate data available from state of forest reports regarding extent of animal grazing
Shifting cultivation	Infrequent data from state of forest reports. Wasteland Atlas (2011, Department of Land Resources) now publishes the information on shifting cultivation. Yet, more information is required on the composition of species and volume lost because of shifting cultivation.
Encroachments	State of forestry report published by ICFRE published this information before 2000 but the information is not regularly provided. Data for encroachments sometimes is available from the starred parliament questions.
Carbon stock	FSI now publishes carbon stock and changes in carbon stock in forests in India. However, we still need more details on the density-wise and state-wise carbon stock in forests.
The value of NTFP, fodder from forests	Mainly from state forest departments and other secondary studies. CSO is also able to get this information from state forest departments. However, the data is still not reliable. Mostly we need to update this from secondary studies. Further, more details on whether ntfps, fuelwood and fodder are coming from trees outside forests are from the area within the forest department.
Forest dependent population in different states	National sample survey data and secondary studies However there are no official census figures for the forest dependent population in the country.

Biodiversity status of the species in India	Environment statistics, FRLHT, IUCN, WCMC publishes this information but not periodically. This data moreover is not available state-wise.
Centers of plant biodiversity and endemic bird areas, species of conservation importance, rare, vulnerable and endangered species	WCMC, IUCN but periodicity of data is an issue
Area under national parks and sanctuaries	MOEF, FSI – state of forest report
Medicinal Plants species in different bio-geographic zones of India	FRLHT, National Medicinal Plants development board publishes this information but no periodic information is available
Total flowering plants	Botanical survey of India publishes this information
Amount sanctioned under different schemes for protection, maintenance and upkeep of national parks and wildlife sanctuaries	Data is available from the annual reports of the ministry of environment and forests
Estimates of medicinal value of plants	Available from forest department statistics but is a gross under estimate
R&D expenditure of firms	Can be compiled from annual reports of firms
Soil erosion and sediment estimates	Centre for soil and water conservation research training institute (CSWCRTI), Indian council for agricultural research (ICAR) publishes this information but state-wise data is not available, Moreover, the data is not periodic. We also need information
Run-off and soil loss under treated and untreated micro-watersheds	CSWCRTI publishes sporadic information but we require state-wise and more periodic data
Concentration of nutrients in run-off	Did not come across any data except for few secondary studies
Soil loss prevented by dense forest	No data available for this. We came across some field experimental studies
Likely hydrological changes following deforestation	National institute of hydrology is one possible source but not sure what kind of information is available and its periodicity
Ground water recharge figures	Central water commission, National ground water board

	Data	Source of Data
Agriculture	Land use change across categories	Nine fold classifications is available but this is not consistent across data sources – Department of land resources gives the data, Ministry of Agriculture also publishes this information but there is some variation across the data sources. Data is available till 2008-09
	Agricultural land area	Planning commission publishes area under major crops, Data can also be obtained from agricultural statistics
	Contribution of agriculture to economy	Data is available from the Economic survey of India
	Fertilizer consumption	Fertilizer Association of India, Directorate of Economics and Statistics, value of fertiliser consumed available with CSO
	Crop Yield	Reserve Bank of India. Agricultural statistics, Agricultural bulletin
	Pesticide consumption	Directorate of economics and statistics but the data is not periodic, value of pesticide consumed available with CSO
	Total sown area and share of irrigated area in gross sown areas is available for major crops;	Data is available for major crops from Directorate of economics statistics
	Land use data	Data not periodic but can be found from planning commission documents and Directorate of economics statistics
	Area under different croplands	Reserve Bank of India, Indiastat, Directorate of economics and statistics
	Area under wasteland	NRSA report on wastelands for different states is available; Wasteland Atlas 2011 published by Department of Land Resources for different states is the latest data available. However, some of the wasteland is improved and used for different purposes. These details are required. The data is available after every 5 years
	Data on various crops and their prices	Directorate of economics and statistics, agricultural statistics, agricultural bulletin, RBI
	Sedimentation in water ways and their treatment costs	The Central water commission publishes time series data on sedimentation load in different rivers.
	Extent of run-off	No data available
	State-wise loss in productivity due to various land degradation	No reliable data is available. Only few secondary sources are available.
	On-site and offsite impacts of land degradation	Can only be inferred from secondary studies if available but no systematic data is available.

Minerals	Mineral resources and mineral reserves	Indian Bureau of Mines (Minerals year book). The data on reserves can be found in National Mineral inventories and is available with Indian Bureau of mines for various years. However, due to change in classification before and after 2003, time series data is not consistent. The latest data available is for the year 2011
	Data on extraction	Data is available with CSO and also IBM for various years
	Price	IBM publishes the information on quantity and value of minerals extracted from which the prices can be computed. Export and import prices are also available from the export statistics.

Water	Surface Water quantity accounts and Water quality accounts	Central Water Commission (CWC) publishes data on various hydrological basins. The data on volume of water, run-off, extraction, turbidity etc. are available for different years. Sediment load in different river basins is available too. Basin wise water quality data is also available with CPCB and CWC
	Data on extraction	Data on surface water supplied is available with CSO and also with research organizations for various years
	Price	Good reliable information on prices is not available

Chapter 6

Implementing Environmental Accounting in India

Implementing Environmental Accounting in India

The conceptual foundations of a comprehensive system of national accounts were developed in Chapter 2 and its Appendices. Chapter 3 reviewed the structure of the SNA and that of the satellite environmental accounts SEEA. In Chapter 4 we noted, however, that in putting the framework advocated in Chapter 2 into operation, particular difficulties will arise owing to limitations of information, in particular reliable and internally consistent data. We noted as well the salience of the SNA despite the absence of resource accounting within it. The purpose of this, final chapter is to describe a step-by-step process for generating the appropriate data for an eventual realization of the objective of "greening" India's national accounts. In doing so it is as well to remind ourselves of the strictures that ought to be followed in the process of extending national accounts to recognise the environment:

(a) The extensions should not violate the internal consistency of the SNA.

(b) The development process should reflect an increased understanding of the economy.

(c) The extensions should be based on data that either exist or can be generated with a reasonable degree of accuracy.

6.1 A Short History of Environmental Accounting in India

Although the SNA tidily neglects to account for our use of environmental resources, environmental accounting have not been entirely absent in India. It will prove useful to present a short history of that endeavour before discussing what now needs to be done.

In parallel to a reliance on the SNA, the Statistical Organizations in India have for several decades discussed the possibilities of introducing environmental data into national accounts. Following the Stockholm Conference on the Environment in 1972, environmental accounting was discussed at several annual conferences of Central and State Statistical Organizations. A Framework for the Development of Environmental Statistics (FDEA) was developed by the CSO of India in the early 1990s. The first issue of a Compendium of Environmental Statistics was released in 1997. Since then the CSO has been regularly publishing the Compendium of Environmental Statistics, which provides in turn a general introduction to the state of the environment, their changing character, and the impact of health owing to their deterioration. The Compendium then focuses on biodiversity, the atmosphere, land and soil, water, and human settlements. The 13th Compendium was released in January 2013, covering data up to 2011-12. The CSO organizes National Workshops and Seminars on Environmental Statistics. It also holds training workshops on the subject for State/UT Government and data compilers.

One of the CSO's early attempts to incorporate the use of environmental resources in national statistics was the establishment of a Technical Working Group on Natural Resource Accounting in the later 1990s. The recommendations of that Group led to a pilot project in 1999-2000 in the State of Goa. The study was undertaken by the Energy and Resources Institute (TERI).

In order to develop sector-specific but uniform methodologies for resource accounting, the Ministry of Statistics and Programme Implementation (MOSPI) commissioned a set of studies on land, forests, air, water, and sub-soil resources in eight Indian states between 2000 and 2006 (Appendix 1). It was noted in Chapter 3 that the SEEA prescribes two types of ways for valuing changes in the environment: maintenance costs and methods that involve non-market valuation (e.g., stated preferences). The studies in question used both types of methods. In parallel, the CSO undertook a study entitled "Post Clearance Environmental Impacts and Cost Benefit Analysis of Power Generation in India". The study was conducted by the National Environmental Engineering Research Institute (NEERI), in Nagpur. A synthesis report based on those studies was developed under the technical guidance of a Technical Advisory Committee, which was Chaired by Dr. Kirit Parikh (Member of the current Expert Group). The report recommended the preparation of a National Accounting Matrix that would include environmental accounts. The establishment by MOSPI in 2011 of the present Expert Group reflected the natural and obvious next step in the process.

Some of the issues discussed in this Report have found place in the Twelfth Five Year Plan of the Government of India. For example, a complete mapping of ground water resources is a goal of the Plan. If successful, it will enable the Government to prepare a ground water Physical Supply and Use Table (PSUT) and the corresponding asset accounts.

6.2 Recommendations

Chapters 3 and 4 concluded that the transition from the existing SNA to a comprehensive set of national accounts that was identified in Chapter 2 and its Appendices can only occur in a step-by-step manner. Bearing that in mind the following possibilities suggest themselves:

1. Prepare PSUTs and Asset Accounts for: (i) land, (ii) forest and timber, and (c) minerals. This can be completed within a year or so.

2. Develop a medium-term plan (extending to a period of, say, 5 years) that would include (i) the preparation of MSUT for land, forest and timber, and minerals for implementing the SEEA in those sectors; (ii) the development of PSUTs and Asset Accounts for soil, water, carbon, and energy; and (iii) planning and collecting data for the purposes of valuing changes in water, carbon, and energy sectors. We note here that MSUTs for minerals can probably be prepared more quickly than those for the other sub-sectors because of the availability of market prices for minerals and data on extraction costs.

3. Develop a medium-term plan for estimating NDP. In addition to adjusting for depletion of reproducible and the types of natural capital that were identified in 1-2 above, the move would require subtracting defensive expenditure on the environment from GDP and identifying better ways to

account for human capital as investment.

4. Initiate exploratory research in two areas: (i) the development of a more complete set of national accounts, including a balance sheet for the nation; and (ii) the identification of principles for valuing and periodically collecting and compiling data on environmental assets and flows. This would culminate in a valuation-and-data manual that can be used for making adjustments to the SNA.

5. Develop a long-term plan (extending, say, to a period of ten years) for (i) institutionalizing mechanisms for periodic collection of data and for organizing periodic studies and surveys for environmental accounts; (ii) collecting and compiling data for valuation and preparation of MSUTs for aquatic resources, air, and biodiversity.

6. The Planning Commission could fruitfully put in place a mechanism for estimating shadow prices and their natural ranges.

6.3 A Word of Caution

Our strategy in this Report has been to begin by providing an outline of an ideal system of accounts (an "ideal SNA", so to speak) and from there to show step by step how very far the current system is from the ideal and how far it can be expected to remain from it. We present a feasible transition path to an ever-improving system, but caution that even if figures for physical stocks were available, the deep problem of estimating shadow prices would remain. The issue isn't merely one of uncertainty about the role environmental resources play in production and consumption possibilities, it is also a matter of differences among people in their ethical values. Wealth estimates should be presented as bands, not exact figures. That people may never agree on the wealth of nations is however no reason for abandoning wealth as the object of interest in policy and sustainability analyses.

Appendix 1: State-level studies on Natural Resource Accounting commissioned by the CSO

Name of study/Organisation	Areas Considered
NRA of Air and Water Pollution in Andhra Pradesh & Himachal Pradesh Institute of Economic Growth, New Delhi	Physical accounts of Environmental Pollution consisting of source specific accounts and ambient accounts of water (industrial water pollution, water pollution loads for agricultural sector) and air pollution (road transport). Monetary accounts using relevant methods for valuing the pollution at source and ambient air and water pollution.
NRA of Land and Forestry for Madhya Pradesh & Himachal Pradesh Indian Institute of Forest Management (IIFM), Bhopal	Methodologies and framework for NRA for forest and land. Generated various resource accounting tables for land and forestry sectors (land resource accounting, soil resource accounting, land-use accounting, physical asset accounting, monetary asset accounting, flow accounting, degradation and depletion accounting, etc.).
Environmental Accounting of Land and Forestry of Meghalaya North East Hill University (NEHU), Shillong	Generation of data pertaining to various components of land and forest resources of Meghalaya. Identification of goods and services rendered by forest and land, and their annual output. Valuation of the resources in economic terms. Identification of ecologically sensitive areas and various natural and anthropological threats to land and forest resources. Developed – Physical Accounting of timber and fuel wood (both area and volume) Valuation of timber and fuel wood Monetary accounting of timber, fuel wood and NTFP's Accounting of Land Resource

Name of study/Organisation	Areas Considered
NRA in Goa Integrated Research and Action for Development (IREDe), Delhi	Worked out loss incurred due to solid waste and economic/environmental loss due to uncollected solid waste. Methodology developed for air pollution abatement costs, and water pollution status. Did economic valuation of forests and indirect benefits from forests. Worked out environmentally adjusted SDP.
Environmental Accounting of Land and Water in Tamil Nadu Madras School of Economics (MSE), Chennai	Physical accounting for land, forest land, timber and carbon. Monetary accounting for forests and water. Valuation of stock of assets in respect of land and estimation of value of land degradation. Asset accounts for water and water quality accounting. Accounting for interaction between the economy and the environment in the conventional accounts.
NRA for Air and Water Sectors in West Bengal Jadavpur University, Kolkata	PSUTs for water. Water related indicators based on primary survey. Marginal/Average abatement costs and tax rates for water. Monetary valuation for water based on damage cost method. Physical and Monetary accounting of air.
Accounting for unsustainable mineral extraction in Madhya Pradesh & West Bengal The Energy and Resources Institute (TERI), Delhi	Physical accounting for coal resources. Valuation of coal resources. Environmental costs of coal mining. Impact and abatement measures in respect of coal mining and environment.
NRA for Land and Forestry (excluding mining) in Karnataka Centre for Multi-Disciplinary Development Research (CMDR), Dharwad, Karnataka	Developed methodology for physical accounting and valuation of land and forest sectors.

References

1. Abramovitz, M. (1986), "Catching Up, Forging Ahead, and Falling Behind," *Journal of Economic History*, 56, 385-406.
2. Acemoglu, D. and Robinson (2006), *Economic Origins of Dictatorship and Democracy* (Cambridge. MA: Cambridge University Press).
3. Adelman, I. and C.T. Morris (1965), "A Factor Analysis of the Interrelationship between Social and Political Variables and per Capita Gross National Product," *Quarterly Journal of Economics*, 79, 555-78.
4. Adelman, I. and C.T. Morris (1967), *Society, Politics and Economic Development* (Baltimore, MD: Johns Hopkins University Press).
5. Adhikari, Bhim (2005). Poverty, Property Rights and Collective Action: Understanding the distributive aspects of common property resource management. *Environment and Development Economics* 10:7-31.
6. Aldy, J.E., A.J. Krupnick, R.G. Newell, J.W.H. Parry, and W.A. Pizer (2010), "Designing Climate Mitigation Policy," *Journal of Economic Literature*, 48(4), 903-934.
7. Anderson, R.M. and R.M. May (1991), *Infectious Diseases of Humans: Dynamics and Control* (Oxford: Oxford University Press).
8. Arrow, K.J. (1965), *Aspects of the Theory of Risk-Bearing* (Helsinki: Yrjö Jahnssonin säätiö).
9. Arrow, K.J. (1971), "Political and Economic Evaluation of Social Effects of Externalities," in M. Intriligator, ed., *Frontiers of Quantitative Economics, Vol. 1* (Amsterdam: North Holland).
10. Arrow, K.J. (2000), "Observations on Social Capital," in P. Dasgupta and I. Serageldin, eds., *Social Capital: A Multifaceted Perspective* (Washington, DC: World Bank).
11. Arrow, K.J. and A. Fisher (1974), "Preservation, Uncertainty and Irreversibility," *Quarterly Journal of Economics*, 88, 312-19.
12. Arrow, K.J. and M. Kurz (1970), *Public Investment, the Rate of Return and Optimal Fiscal Policy* (Baltimore: Johns Hopkins University Press).
13. Arrow, K.J. and P.S. Dasgupta (2009), "Conspicuous Consumption, Inconspicuous Leisure," *Economic Journal*, 2009, 119 (541), F497-F516.
14. Arrow, K.J., B. Bolin, R. Costanza, P. Dasgupta, C. Folke, C.S. Holling, B.-O. Jansson, S. Levin, K.-G. Mäler, C. Perrings, and D. Pimentel) (1995), "Economic Growth, Carrying Capacity, and the Environment," *Science*, 268(5210).
15. Arrow, K.J., G. Daily, P. Dasgupta, P.R. Ehrlich, L. Goulder, G.M. Heal, S. Levin, K.-G. Mäler, S. Schneider, D.A. Starrett, and B. Walker (2007), "Consumption, Investment, and Future Well-Being: Reply to Daly *et al.*," *Conservation Biology*, 21(5), 1363-1365.
16. Arrow, K.J., P. Dasgupta, and K.-G. Mäler (2003), "The Genuine Savings Criterion and the

Value of Population," *Economic Theory*, 21(2), 217-225.

17. Arrow, K.J., P. Dasgupta, L. Goulder, G. Daily, P.R. Ehrlich, G.M. Heal, S. Levin, K.-G. Mäler, S. Schneider, D.A. Starrett, and B. Walker (2004), "Are We Consuming Too Much?," *Journal of Economic Perspectives*, 18(1), 147-172.
18. Arrow, K.J., P. Dasgupta, L.H. Goulder, K. Mumford, and K. Oleson (2012), "Sustainability and the Measurement of Wealth," *Environment and Development Economics*, 17(3), 317-353.
19. Arrow, K.J., P. Dasgupta, L.H. Goulder, K. Mumford, and K. Oleson (2012a), "Sustainability and the Measurement of Wealth," *Environment and Development Economics*, 17(3), 317-353.
20. Arrow, K.J., P. Dasgupta, L.H. Goulder, K. Mumford, and K. Oleson (2012b), "Sustainability and the Measurement of Wealth: Further Considerations," *Environment and Development Economics*, forthcoming, 2013.
21. Atkinson, A.B. and J.E. Stiglitz (1980), *Lectures in Public Economics* (New York: McGraw Hill).
22. Atkinson, G. and H. Gundimeda (2006), 'India's forest wealth', *Ecological Economics* **59**(4): 462-476.
23. Balmford, A., B. Fisher, R.E. Green, R. Naidoo, B. Strassburg, R. Kerry Turner, and A.S.L. Rodrigues (2011), "Bringing Ecosystem Services into the Real World: An Operational Framework for Assessing the Economic Consequences of Losing Wild Nature," *Environmental & Resource Economics*, 84(2), 161-175.
24. Barrett, S. (2003), *Environment & Statecraft: The Strategy of Environmental Treaty-Making* (New York: Oxford University Press).
25. Barro, R.J. and X. Sal-i-Martin (2003), *Economic Growth* (Cambridge: MIT Press).
26. Bateman, I.J., G.M. Mace, C. Fezzi, G. Atkinson, and K. Turner (2011), "Economic Analysis of Ecosystem Service Assessments," *Environmental & Resource Economics*, 84(2), 177-218.
27. Becker, G.S., T.J. Philipson, and R.S. Soares (2005), "The Quantity and Quality of Life and the Evolution of World Inequality," *American Economic Review*, 95(1), 227-291.
28. Bok, D. (2009), *The Politics of Happiness: What Government Can Learn from the New Research on Well-Being* (Princeton NJ: Princeton University Press).
29. Bongaarts, J. and S.C. Watkins (1996), "Social Interactions and Contemporary Transitions," *Population and Development Review*, 22(4), 639-682.
30. Bourdieu, P. (1984), *Distinction: A Social Critique of the Judgment of Taste* (London: Routledge and Kegan Paul).
31. Bourdieu, P. and J.C. Passeran (1990), *Reproduction in Education, Society, and Culture* (London: Sage).
32. Brander, M.S. and J.A. Taylor (1998), "The Simple Economics of Easter Island," *American Economic Review*, 88(1), 119-138.
33. Carlsson, F. and O. Johansson-Stenman (2012), "Behavioural Economics and Environmental Policy," in G.C. Rausser, W.M. Hanemann, and D. Zilberman, eds., *Annual Review of Resource Economics, Vol. 4* (Palo Alto, CA: Annual Reviews).
34. Carpenter, S.R. (2001), "Alternate States of Ecosystems: Evidence and Its Implications," in M.C. Press, N. Huntly, and S. Levin, eds., *Ecology: Achievement and Challenge* (London: Basil Blackwell).

35. Chakravarty, S. (1969), *Capital and Development Planning* (Cambridge, MA: MIT Press).

36. Chopra, K. and P. Dasgupta (2008). Assessing Economic and Ecosystem Services Contribution of Forests: Issues in Modeling and An Illustration, *International Forestry Review, Special Issue*.

37. Clark, A.E., P. Frijters, and M.A. Shields (2008), "Relative Income, Happiness, and Utility: An Explanation for the Easterlin Paradox and Other Puzzles," *Journal of Economic Literature*, 46(1), 95-144.

38. Coase, R. (1960), "The Problem of Social Cost," *Journal of Law and Economics*, 3(1), 1-44.

39. Daly, H.E., B. Czech, D.L. Tranger, W.E. Rees, M. Grover, T. Dobson, and S.C. Trombulak (2007), "Are We Consuming Too Much - for What?," *Conservation Biology*, 21(5), 1369-1382.

40. Das, S. and J. Vincent (2009). Mangroves protected villages and reduced death toll during Indian super cyclone, PNAS, 106 (18) 7357-7360.

41. Dasgupta, P. (1982), *The Control of Resources* (Cambridge, MA: Harvard University Press).

42. Dasgupta, P. (1990), "The Environment as a Commodity," *Oxford Review of Economic Policy*, 6(1), 51-67.

43. Dasgupta, P. (1993), *An Inquiry into Well-Being and Destitution* (Oxford: Clarendon Press).

44. Dasgupta, P. (2001), *Human Well-Being and the Natural Environment* (Oxford: Oxford University Press), 2nd ed. (2004).

45. Dasgupta, P. (2009), "The Welfare Economic Theory of Green National Accounts," *Environmental and Resource Economics*, 42(1), 3-38.

46. Dasgupta, P. (2011), "A Matter of Trust: Social Capital and Economic Development," in J. Lin and B. Plescovik, eds., *Annual World Bank Conference on Development Economics, 2009: Lessons from East Asia and the Global Financial Crisis* (New York: World Bank and Oxford University Press).

47. Dasgupta, P. (2012a), "Sustainability and the Determinants of Personal Consumption," Discussion Paper, Sustainable Consumption Institute, University of Manchester.

48. Dasgupta, P. (2012b), "Personal Histories and Poverty Traps", in J. Lin and B. Plescovik, eds., *Annual World Bank Conference on Development Economics, 2010* (New York: World Bank and Oxford University Press). Translated into French in *Revue d'Economie Dudeveloppement*, 2011, 4(December), pp. 87-114.

49. Dasgupta, P. (2013), "Sustainability and the Determinants of Personal Consumption," in D. Southerton and A. Ulph, eds., *Sustainable Consumption: Multi-Dimensional Perspectives: Essays in Honour of Sir Partha Dasgupta* (Oxford: Oxford University Press), forthcoming, 2013.

50. Dasgupta, P. and G.M. Heal (1974), "The Optimal Depletion of Exhaustible Resources," *Review of Economic Studies*, 1974 (Special Number), 3-28.

51. Dasgupta, P. and K.-G. Mäler (2000), "Net National Product, Wealth, and Social Well-Being," *Environment and Development Economics*, 5(1), 69-93.

52. Dasgupta, P., S.A. Marglin, and A. Sen (1972), Guidelines for Project Evaluation (New York: United Nations).

53. Dasgupta, S., B. Laplante, H. Wang, and D. Wheeler (2002), "Confronting the Environmental Kuznets Curve," *Journal of Economic Perspective*, 16(1), 147-168.

54. Diamond, J. (2005), *Collapse: How Societies Choose to Fail or Survive* (London: Allen Lane).

55. Dinda, S. (2004), "Environmental Kuznets Curve Hypotheis: A Survey," *Ecological Economics*, 49(4), 431-455.

56. Dixit, A., P. Hammond, and M. Hoel (1980), "On Hartwick's Rule for Regular Maximin Paths of Capital Accumulation and Resource Depletion," *Review of Economic Studies*, 47(3), 551-556.

57. Donati, P. (2011), *Relational Sociology: A New Paradigm for the Social Sciences* (London: Routledge).

58. Easterlin, R. (1974), "Does Economic Growth Improve the Human Lot? Some Empirical Evidence," in P.A. David and M. Reder, eds., *Nations and Households in Economic Growth: Essays in Honor of Moses Abramowitz* (New York: Academic Press).

59. Easterlin, R. (1995), "Will Raising the Incomes of All Increase the Happiness of All?" *Journal of Economic Behaviour and Organization*, 47, 35-47.

60. Easterlin, R. (2001), "Income and Happiness: Toward a Unified Theory," *Economic Journal*, 111, 465-484.

61. Ehrlich, P.R. and L.H. Goulder (2007), "Is Current Consumption Excessive? A General Framework and Some Indications for the United States," *Conservation Biology*, 21(5), 1145-1154.

62. El Sarafy, S. (1989), "The Proper Calculation of Income from Depletable Natural Resources," in Y. Ahmed, S. El Sarafy, and E. Lutz, eds., *Environmental Accounting for Sustainable Development* (Washington DC: World Bank).

63. Fankhauser, S. (1994) "Evaluating the Social Costs of Greenhouse Gas Emissions", The Energy Journal, 15(2): 157-184.

64. Fankhauser, S. and R. S. J. Tol (1995), The Social Costs of Climate Change: The IPCC Second Assessment Report and Beyond, Working Paper W-95/34, Institute for Environmental Studies, Vrije Universiteit, Amsterdam

65. Fankhauser, S. Tol, R.S.J. and Pearce, D.W. (1997) "The Aggregation of Climate Change Damages: A Welfare Theoretic Approach", Environment and Resource Economics, 10(3): 249-266.

66. Ferraro, P.J., K. Lawlor, K.L. Mullan, and S.K. Pattanayak (2012), "Forest Figures: Ecosystem Services Valuation and Policy Evaluation in Developing Countries," *Review of Environmental Economics and Policy*, 1-26.

67. Forest Sector Report of India (FSRI) (2010), Forest Sector Report of India, Indian Council for Forestry Research and Education, Dehradun.

68. Forest Survey of India (FSI) (2003), *State of Forest Report 2003*, Dehradun: Government of India, Ministry of Environment and Forests.

69. Forest Survey of India (FSI) (2005), *State of Forest Report 2005*, Dehradun: Government of India, Ministry of Environment and Forests.

70. Forest Survey of India (FSI) (2009), *State of Forest Report 2009*, Dehradun: Government of India, Ministry of Environment and Forests.

71. Forest Survey of India (FSI) (2011), *State of Forest Report 2011*, Dehradun: Government of India, Ministry of Environment and Forests.

72. Freeman III, A.M. (2002), *The Measurement of Environmental and Resource Values: Theory and Methods* (Washington, D.C.: Resources for the Future), 2nd Edition.

73. Freeman, A.M. III (1993). *The Measurement of Environmental and Resource Values: Theory and*

Methods, (Washington D.C.: Resources for the Future.

74. Report of CSO, GOI (2012), *Generalized National Income Accounts for Measuring Green GDP for India: A Review of Indian and International Experience.*

75. Graham, C. (2009), *Happiness Around the World: The Paradox of Happy Peasants and Miserable Millionaires* (Oxford; Oxford University Press).

76. Gundimeda, H. (2012). Is current pattern of growth sustainable - analysis for Indian states. Note sent to the Expert Committee on greening India's national accounts.

77. Gundimeda, H., P. Sukhdev, R. Sinha, and S. Sanyal (2007), 'Natural resources accounting for India: illustration for Indian states', *Ecological Economics* **64**(4): 635-49.

78. Gundimeda, H., S. Sanyal, R. Sinha, and P. Sukhdev (2005), 'The Value of Timber, Carbon, Fuelwood and Non-timber Forest Products in India's Forests', Monograph 1, Green Accounting for Indian States Project, India.

79. Gundimeda, H., S. Sanyal, R. Sinha, and P. Sukhdev (2005). The value of timber, carbon, fuelwood and non-timber forest products in India's forests, Monograph 1, Green Accounting for Indian States Project, Green Indian States Trust, New Delhi: TERI Press.

80. Gundimeda, H., S. Sanyal, R. Sinha, and P. Sukhdev (2006), 'Value of India's biodiversity', Monograph 4 for the Green Accounting of Indian States Project, Green Indian States Trust, published by TERI press.

81. Gundimeda, Haripriya (2000a), 'Integrating forest resources into the system of national accounts in Maharashtra, India', *Environment and Development Economics* **5** (1 & 2): 143 - 156 (special issue on Advances in Green Accounting).

82. Gundimeda, Haripriya (2000b), 'Estimation of biomass in Indian forests', *Biomass and Bioenergy*, **19**(4): 245-258.

83. Gundimeda, Haripriya (1998), Forest Resource Accounting: Preliminary Estimates for the State of Maharashtra in India. *Development Policy Review*, Vol. 16, No.2, pp. 131-51.

84. Gundimeda, Haripriya (2002), 'Estimation of biomass from the truncated stand tables in India', *Forest Ecology and Management* **168** (1-3): 1-13.

85. Gundimeda, Haripriya (2003). 'Carbon budget of the Indian forest ecosystem', *Climatic Change* **56**(3): 291-319.

86. Gundimeda, Haripriya, (2001), 'Accounting for the Forest Resources in the National Accounts in India', *Environmental and Resource Economics,***19** (1): 73-95.

87. Hall, R.E. and C.I. Jones (1999), "Why Do Some Countries Produce So Much More Output Per Worker Than Others?," *Quarterly Journal of Economics*, 114, 83-116.

88. Hamilton, K. and M. Clemens (1999), "Genuine Savings Rates in Developing Countries," *World Bank Economic Review*, 13(2), 333-56.

89. Harbaugh, W.T., A. Levinson, and D.M. Wilson (2002), "Ambient Air Pollution in Cities: Re-examining the Empirical Evidence for an Environmental Kuznets Curve," *Review of Economics and Statistics*, 84(3), 541-551.

90. Hardin, G. (1968), "The Tragedy of the Commons," *Science*, 162, 1243-8.

91. Hartwick, J.M. (1977), "Intergenerational Equity and the Investing of Rents from Exhaustible Resources," *American Economic Review*, 66(5), 972-974.

92. Hausman, J. (2012), "Contingent Valuation: From Dubious to Hopeless," *Journal of Economic Perspectives*, 26(4), 43-56.

93. Heal, G.M. (1998), *Valuing the Future: Economic Theory and Sustainability* (New York: Columbia University Press).

94. Helpman, E. (2004), *The Mystery of Economic Growth* (Cambridge, MA: Belknap).

95. Henry, C. (1974), "Investment Decisions under Uncertainty: the Irreversibility Effect", *American Economic Review*, 64, 1006-12.

96. Hicks, J.R. (1940), "The Valuation of Social Income," *Economica*, 7(2), 105-124.

97. Hirsch, F. (1977), *Social Limits to Growth* (London: Routledge).

98. Homer-Dixon, T.E. (1999), *Environment, Scarcity, and Violence* (Princeton, NJ: Princeton University Press).

99. Hotelling, H. (1931), "The Economics of Exhaustible Resources," *Journal of Political Economy*, 39(2), 137-175.

100. IBM 2004, Handbook of Minerals, Indian Bureau of Mines (IBM), Nagpur.

101. Jensen, R. and E. Oster (2009), "The Power of TV: Cable Television and Women's Status in India," *Quarterly Journal of Economics*, 124(3), 1057-1094.

102. Jones, C.I. and P.J. Klenow (2010), "Beyond GDP? Welfare across Countries and Time," Working Paper, Stanford University.

103. Jorgenson, D.W. and B.M. Fraumini (1989), "The Accumulation of Human and Non-Human Capital, 1948-1984," in R.E. Lipsey and H.S. Tice, eds., *The Measurement of Savings, Investment, and Wealth* (Chicago: Chicago University Press).

104. Jorgenson, D.W., J.S. Landefeld, and W.D. Nordhaus, eds. (2006), *Architecture for the National Accounts* (Chicago: University of Chicago Press).

105. Klenow, P.J. and A. Rodriguez-Clare (1997), "The Neo-Classical Revival in Growth Economics: Has It Gone Too Far?", in B. Bernanke and J. Rotemberg, eds., *NBER Macroeconomics Annual 1997* (Cambridge, MA: MIT Press).

106. Krutilla, J.V. (1967). Conservation Reconsidered, *American Economic Review,* 57: 777–786.

107. Kumar, P., ed. (2009), *The Economics of Ecosystems and Biodiversity* (Nairobi: United Nations Environment Programme).

108. Landes, D. (1969), *The Unbound Prometheus* (Cambridge: Cambridge University Press).

109. Layard, R. (2005), *Happiness: Lessons from a New Science* (New York: Penguin), 2nd edition.

110. Lindahl, E.R. (1933), "The Concept of Income", in G. Bagge ed., *Economic Essays in Honour of Gustav Cassel* (London: Allen & Unwin).

111. Little, I.M.D. and J.A. Mirrlees (1974), *Project Appraisal and Planning for Developing Countries* (London: Heinemann).

112. Little, I.M.D. and J.A. Mirrlees (1991), "Project Appraisal and Planning Twenty Years On," *Proceedings of the Annual World Bank Conference on Development Economics 1990* (Washington, DC: World Bank), 351-382.

113. Lomborg, B. (2001), *The Skeptical Environmentalist* (Cambridge: Cambridge University Press).

114. Luce, R.D. and H. Raiffa (1957), *Games and Decisions* (New York: John Wiley).

115. Lutz, E., ed. (1993), *Toward Improved Accounting for the Environment* (Washington, DC: World Bank).

116. Mäler, K.-G. (1991), "National Accounts and Environmental Resources," *Environmental and Resource Economics*, 1(1), 1-15.

117. Mäler, K.-G. and R.E. Wyzga (1976), *Economic Measurement of Environmental Damage* (Paris: OECD).

118. Martin, S. and N. Grube (2008), *Chronicles of the Maya Kings and Queens* (New York: Thames & Hudson).

119. MEA - Millennium Ecosystem Assessment - eds., D. Capistrano, C. Samper K., M.J. Lee, and C. Randsepp-Hearne - (2005d), *Ecosystems and Human Well-Being, IV: Multiscale Assessments* (Washington, DC: Island Press).

120. MEA - Millennium Ecosystem Assessment - eds., K. Chopra, R. Leemans, P. Kumar, and H. Simmons - (2005c), *Ecosystems and Human Well-Being, III: Policy Responses* (Washington, DC: Island Press).

121. MEA - Millennium Ecosystem Assessment - eds., R. Hassan, R. Scholes, and N. Ash - (2005a), *Ecosystems and Human Well-Being, I: Current State and Trends* (Washington, DC: Island Press).

122. MEA - Millennium Ecosystem Assessment - eds., S.R. Carpenter, P.L. Pingali, E.M. Bennet, and M.B. Zurek (2005b), *Ecosystems and Human Well-Being, II: Scenarios* (Washington, DC: Island Press).

123. Meade, J.E. (1955), *Trade and Welfare* (Oxford: Oxford University Press).

124. Meade, J.E. (1973), *The Theory of Externalities* (Geneva: Institute Universitaire de Hautes Etudes Internationales).

125. Mincer, J. (1974), *Schooling, Experience, and Earnings: Human Behaviour and Social Institutions No. 2* (New York: National Bureau of Economic Research).

126. Ministry of Mines (2012). National Mining Scenario. (Last modified 11/05/2012). http://mines.nic.in/index.aspx?lid=73&level=2&chk=24dfe45y5edf5e3

127. Mirrlees, J.A. (1969), "The Evaluation of National Income in an Imperfect Economy," *Pakistan Development Review*, 9(1), 1-13.

128. Murphy, K.M. and R.H. Topel (2006), "The Value of Health and Longevity," *Journal of Political Economy*, 114(5), 871-904.

129. National Accounts Statstics - Sources and Methods, 2007 by CSO,MOSPI (a Govt. of India publication)

130. National Accounts Statstics - Sources and Methods, 2012 by CSO,MOSPI (a Govt. of India publication)

131. National Accounts Statistics (In the Accounting Framework of System of National Accounts 1993), 2010 by CSO,MOSPI (a Govt. of India publication)

132. Nordhaus, W.D. (2008), *A Question of Balance: Weighing the Options on Global Warming Policies* (New Haven: Yale University Press).

133. Nordhaus, W.D. and J. Tobin (1972), "Is Economic Growth Obsolete?," in *Economic Growth*, 5th Anniversary Colloquium of the NBER (New York: Columbia University Press).

134. Oswald, A.J. (1997), "Happiness and Economic Performance," *Economic Journal*, 107, 1815-1831.

135. Parikh K. and U. Ghosh (1991). Natural Resource Accounting for Soils: Towards an Empirical Estimate of Costs of Soil Degradation for Cultivated Land in India, IGIDR-DP-48, Indira Gandhi Institute of Development Research, Mumbai.

136. Parikh, Kirit (2012). "Role of Ecological Economics in Policy Making" in Bandhopadhyaya, J. Chopra, Kanchan and Ghosh, Nilanjan (forthcoming) *Environmental Governance: Approaches, Imperatives, and Methods.*

137. Pattanayak, S.K. (2004), "Valuing Watershed Services: Concepts and Empirics from Southeast Asia," *Agriculture, Ecosystems & Environment*, 104(1), 171-184.

138. Perrings, C. (2012), "The Road to Wealth Accounting," in UNU-IHDP/UNEP, *Inclusive Wealth Report 2012* (Cambridge: Cambridge University Press).

139. Putnam, R.D., with R. Leonardi and R.Y. Nanetti (1993), *Making Democracy Work: Civic Traditions in Modern Italy* (Princeton, NJ: Princeton University Press).

140. Raiffa, H. (1968), *Decision Analysis* (MA: Addison-Wesley).

141. Rausser, G. and A. Small (2000). Valuing research leads: bioprospecting and the conservation of genetic resources. Journal of Political Economy 108(1), 173–206.

142. Rawls, J. (1972), *A Theory of Justice* (Oxford: Clarendon Press).

143. Reid, W.V., H.A. Mooney, A. Cropper *et al.* (2005), *Ecosystems and Human-Wellbeing: Synthesis* (Washington, DC: World Resources Institute).

144. Repetto, R., W. Magrath, M. Wells, C. Beer, and F. Rossini (1989), *Wasting Assets: Natural Resources and the National Income Accounts* (Washington DC: World Resources Institute).

145. Richard. R. S. Tol (2005). The marginal damage costs of carbon dioxide emissions: an assessment of the uncertainties. *Energy Policy* 33: 2064–2074

146. Romer, D. (1996), *Advanced Macroeconomics* (New York: McGraw Hill).

147. Sachs, J.D., J.L. Gallup, and A. Mellinger (1998), "Geography and Economic Development," in B. Pleskovic and J.E. Stiglitz, eds., *Annual World Bank Conference on Development Economics* (Washington DC: World Bank).

148. Samuelson, P.A. (1961), "The Evaluation of 'Social Income': Capital Formation and Wealth," in F.A. Lutz and D.C. Hague, eds., *The Theory of Capital* (London: MacMillan).

149. Scheffer, M. (2009), *Critical Transitions in Nature and Society* (Princeton, NJ: Princeton University Press).

150. Schor, J. (1998). *The Overspent American*. New York: Basic Books.

151. Schultz, T.W. (1974), *Economics of the Family: Marriage, Children and Human Capital* (Chicago: University of Chicago Press).

152. SEEA Central Framework of UN, 2012 (UNSD Website)

153. Sen, A. (1976), "Real National Income," *Review of Economic Studies*, 43(1), 19-39.

154. Shah, T. (2008). Taming the anarchy: groundwater governance in South Asia, RFF and IWMI.

155. Smith, V.K. (1997), "Pricing What is Priceless: A Status Report on Non-Market Valuation of Environmental Resources," in H. Folmer and T. Tietenberg, eds., *The International Yearbook of Environmental and Resource Economics 1997/1998* (Cheltenham: Edward Elgar).

156. Solow, R.M. (1957), "Technical Change and the Aggregate Production Function," *Review of Economics and Statistics*, 39, 312-20.

157. Solow, R.M. (1974), "Intergenerational Equity and Exhaustible Resources," *Review of Economic Studies*, 41 (Symposium Issue), 29-45.

158. Solow, R.M. (2000), "Notes on Social Capital and Economic Performance," in P. Dasgupta and I. Serageldin, eds., *Social Capital: A Multifaceted Perspective* (Washington, DC: World Bank).

159. Southerton, D. and A. Ulph, eds., *Sustainable Consumption: Multi-Dimensional Perspectives: Essays in Honour of Sir Partha Dasgupta* (Oxford: Oxford University Press), forthcoming, 2013.

160. States Trust, New Delhi: TERI Press.

161. Steffen, W., A. Sanderson, P.D. Tyson, J. Jäger, P.A. Matson, B. Moore III, F. Oldfield, K. Richardson, H.J. Schellnhuber, B.L. Turner II, and R.J. Wasson (2004), *Global Change and the Earth System* (Berlin: Springer).

162. Stern, D.I. (2004), "The Rise and Fall of the Environmental Kuznets Curve," *World Development*, 32(8), 1419-1439.

163. Stern, N.H. (2006), *The Stern Review of the Economics of Climate Change* (Cambridge: Cambridge University Press).

164. Stiglitz, J.E., A. Sen, and J.-P. Fitoussi (2009), *Mismeasuring Our Lives: Why GDP Doesn't Add Up* - Report to President Sarkozy on the Measurement of Economic Performance and Social Progress (Paris).

165. Sunderlin, William D., Anne M. Larson, Amy Duchelle, Erin O. Sills, Cecilia Luttrell, Pamela Jagger, Subhrendu K. Pattanayak, Peter Cronkleton, Andina D. Ekaputri (2010). Technical guidelines for research on REDD+ project sites. Global Comparative Study on REDD+. Bogor, Indonesia: CIFOR.

166. Supreme Court Expert Committee (2007). Net present value of forest land for non-forest uses.

167. Tilman, D. (2012), "Biodiversity and Environmental Sustainability Human Domination of Global Ecosystems," *Daedalus*, Summer, 108-120.

168. Tilman, D., P.B. Reich, and J. Knops (2006), "Biodiversity and Ecosystem Stability in a Decade-Long Grassland Experiment," *Nature*, 441, 629-632.

169. Tol, R.S.J. (1999) 'The Marginal damage costs of Greenhouse Gas Emissions', The Energy Journal, 20(1), 61-81.

170. Tomich, T.P., C.A. Palm, S.J. Velarde, H. Geist, A.N. Gillison, L. Lebel, M. Locatelli, W. Mala, M. van Noordwijk, K. Sebastian, D. Timmer, and D. White (2005), *Forest and Agroecosystem Tradeoffs in the Humid Tropics* (Nairobi: Alternatives to Slash-and-Burn Programme).

171. Tomich, T.P., M. van Noordwijk, and D.E. Thomas, eds. (2004), "Environmental Services and Land Use Change: Bridging the Gap between Policy and Research in Southeast Asia", *Agriculture Ecosystems & Environment*, 104(1).

172. Umamaheswari, L. K. Omar Hattab, P. Nasurudeen andP. Selvaraj (2011). Should shrimp farmers pay paddy farmers? The Challenges of examining salinization externalities in South India, in Haque, A. K. E., M.N. Murty and Priya Shyamsundar (Eds), *Environmental Valuation in South Asia*, Cambridge University Press.

173. UNDP (1990, onward), *Human Development Report* (New York: Oxford University Press).

174. UNU-IHDP/UNEP (2012), *Inclusive Wealth Report 2012: Measuring progress toward sustainability* (Cambridge: Cambridge University Press).

175. United Nations System of National Accounts,2008 (UNSD Website)

176. van der Werf, G.R., Morton, D.C., De Fries, R.S., Olivier, J.G.J., Prasad S. Kasibhatla, Jackson, R.B., Collatz, G.J. and Randerson, J.T. (2009). CO2 emissions from forest loss. *Nature Geoscience* 2:737-738.

177. Veblen, T. (1899, [1925]), *The Theory of the Leisure Class: An Economic Study of Institutions*. Originally published in 1899. Reprinted (London: George Allen & Unwin), 1925.

178. Vermeulen, F. (2012), "Foundations of Revealed Preference: Introduction," *Economic Journal*, 122(566: Conference Papers), 287-294.

179. Vincent JR (1997) Resource depletion and economic sustainability in Malaysia. Environ Dev Econ 2: 19–37

180. Vincent, J.R., R.M. Ali, and Associates (1997), *Environment and Development in a Resource-Rich Economy: Malaysia Under the New Economic Policy* (Cambridge, MA: Harvard Institute for International Development).

181. Viscusi, W.K. and J.E. Aldy (2003), "The Value of a Statistical Life: A Critical Review of Market Estimates Throughout the World," *Journal of Risk and Uncertainty*, 27(1), 5-76.

182. Vouvaki, D. and A. Xepapadeas (2009), "Total Factor Productivity Growth When Factors of Production Generate Environmental Externalities," Working Paper No. 20.2009, FEEM, Milan.

183. Weisbrod, B.A. (1964), "Collective Consumption Services of Individual Consumption Goods," *Quarterly Journal of Economics*, 77, 71-7.

184. Weisbrod, B.A. (1964). Collective Consumption Services of Individual Consumption Goods', *Quarterly Journal of Economics,* 78: 471–477.

185. Weitzman, M.L. (2003), *Income, Wealth, and the Maximum Principle* (Cambridge, MA: Harvard University Press).

186. Williams, B. (1985), *Ethics and the Limits of Philosophy* (London: Fontana/Collins).

187. World Bank (1992), *World Development Report* (New York: Oxford University Press).

188. World Bank (2006), *Where is the Wealth of Nations*? (Washington, DC: World Bank).

189. World Bank (2011), *The Changing Wealth of Nations* (Washington, DC: World Bank).

190. World Commission on Environment and Development (1987), *Our Common Future* (New York: Oxford University Press).

191. Yaeger, J. and D.A. Hodell (2008), "The Collapse of Maya Civilization: Assessing the Interaction of Culture, Climate, and Environment," http://publications.esc.cam.ac.uk:8080/2468/1/yaeger_hodell_2008.pdf

M-12012/15(2)(1)/2011 (SSD)
Government of India
Ministry of Statistics and Programme Implementation
Central Statistics Office
(Social Statistics Division)

West Block-8, Wing -6,
R.K.Puram,
NewDelhi-110066
Dated: 4th August, 2011

OFFICE MEMORANDUM

SUBJECT: Expert Group on Green National Accounting for India

In accordance with the directions of the Hon'ble Prime Minister, an Expert Group to develop a framework of "green " national accounts and prepare a roadmap for India to implement the framework is hereby constituted.

2. **The Constitution and Terms of Reference of the Expert Group are as under:**

I **Constitution of the Group.**

(i) Prof. Sir Partha Dasgupta, FBA FRS — **- Chairman**
Frank Ramsey Professor Emeritus of Economics,
Faculty of Economics,
University of Cambridge,
Sidgwick Avenue,
Cambridge CB3 9DD, UK

(ii) Dr. Pronab Sen, — **- Member**
Principal Adviser,
Planning Commission,
Government of India,
Yojana Bhavan, Parliament Street,
New Delhi

(iii) Dr. Kaushik Basu, — **- Member**
Chief Economic Adviser,
Ministry of Finance,
Government of India,
North Block, New Delhi

(iv) Dr. Nitin Desai, — **- Member**
B-63, Defense Colony,
1st Floor, New Delhi-110024

(v) Dr. Vijay Kelkar, - Member
Chairman, National Stock Exchange,
Bandra –Kurla Complex, Bandra, Mumbai

(vi) Dr. Kirit Parikh, - Member
Former Member, Planning Commission,
Integrated Research and Action for Development (IRADe),
C-50, Chhota Singh Block,
Asian Games Village Complex,
Khelgaon, New Delhi-110048

(vii) Dr. Kanchan Chopra, - Member
(Former Director & Professor,
Institute of Economic Growth, Delhi),
Y-155, Regency Park II, DLF Phase IV,
Gurgaon

(viii) Prof K. Sundaram, - Member
B-103, Belwada Park,
DLF City, Phase III,
Gurgaon- 122002

(ix) Shri. Ramesh Kolli, - Member
Ex-Additional Director General (NAD, CSO),
109, Inder Enclave, Jahaaz Appartment
Rohtak Road, New Delhi-110087

(x) Dr. Haripriya Gundimeda, - Member
Indian Institute of Technology,
Powai P.O, Mumbai

(xi) Dr. Priya Shyamsundar, - Member
Programme Director,
South Asian Network for
Development and Environmental Economics, (SANDEE)
32/25 Sukhumvit Soi 67,
Bangkok, Thailand, 10110

(xii) Dr. E. Somanathan, -Member
Professor, Indian Statistical Institute,
7-SJS Marg, Katwaria Sarai, New Delhi

(xiii) Dr. T.C.A. Anant, - Member Convenor
Chief Statistician of India & Secretary,
M/o Statistics &Programme Implementation,
Sardar Patel Bhavan, NewDelhi-110001

II Terms of Reference

(i) To develop a framework for 'Green National Accounts ' of India keeping in view the previous work done on the subject, internationally and in India including the Reports of the Technical Advisory Committed of CSO headed by Dr. Kirit Parikh.

(ii) To identify the data requirements for the implementation of the recommended framework for ' Green National Accounts', identify data gaps and give suggestions for filling the data gaps and to develop sector specific methodologies.

(iii) To develop a roadmap for the implementation of the framework .

3. The Expert Group may co-opt members and also can call special invitees for the meetings as required.

4. The Expert Group will have a term until 1st October, 2012 and submit an interim report by 1st April, 2012.

5. The Official members will be entitled to draw TA/DA from their respective organizations for attending the meetings of the Group. The Non-Official members will, however, be reimbursed TA/DA. as per SR 190(a) by the Ministry of Statistics and Programme Implementation, from the funds available under object Head 'Domestic/Foreign Travel Expenses' under the plan Scheme " Capacity Development (Capacity Development of CSO and Institutional Development & Capacity Building)".

6. This issues with the concurrence of AS&FA vide No.- 528/AS & FA dated 27/7/11.

(V. Parameswaran)
Deputy Director General

To
All members of the Expert Group.

Copy to:

1. PS to Principal Secretary, PMO, South Block, Raisina Hill, New Delhi-1
2. PS to Deputy Chairman, Planning Commission, New Delhi
3. PPS to MOS(IC), Ministry of Statistics and Programme Implementation, Sardar Patel Bhavan, New Delhi-110001
4. PPS to MOS(IC), Ministry of Environment & Forests, Paryavaran Bhavan, CGO Complex, Lodhi Road, New Delhi-110003
5. Director General, CSO, Ministry of Statistics and Programme Implementation, Sardar Patel Bhavan, New Delhi-110001
6. Additional Director General, Social Statistics Division, West Block-8, R.K.Puram, New Delhi-66
7. Director (IFD), Ministry of Statistics and Programme Implementation, Sardar Patel Bhavan, New Delhi-110001
8. Cash & Accounts Section, Ministry of Statistics and Programme Implementation, Sardar Patel Bhavan, New Delhi-110001
9. Budget & Finance Section, Ministry of Statistics and Programme Implementation, Sardar Patel Bhavan, New Delhi-110001

(V. Parameswaran)
Deputy Director General

F. No. 12012/15(2)(1)/2011-SSD
Ministry of Statistics and Programme Implementation
Central Statistics Office
(Social Statistics Division)

West Block-8, Wing -6,
R.K. Puram, New Delhi – 110 066.
Dated: 30th October, 2012

Office Memorandum

Subject: Extension of tenure of Expert Group on Green National Accounting for India - reg:

In accordance with the directions of the Prime Minister of India, an Expert Group on Green National Accounting for India' was constituted under the chairmanship of Prof. Sir. Partha Dasgupta, Professor-Emeritus, Cambridge University, UK to develop a framework of 'green' national accounts for India and to prepare a roadmap for its implementation vide OM no. of even number dated on 4th August, 2011, for a tenure up to 1st October, 2012.

2. The tenure of the Expert Group is hereby extended till 30th June, 2013 under the same terms as stated in the OM dated 4th August, 2011.

3. This issues with the concurrence of AS&FA vide diary No. **911** dated **26-10-2012**.

(V. Parameswaran)
Deputy Director General

Copy forwarded for information / necessary action to:

1. All members of the Expert Group on Green National Accounting for India
2. Sr. PPS to Secretary, MOSPI for information
3. PPS to DG, CSO for information
4. Director (IFD), MOSPI
5. Cash & Accounts Section
6. Budget & Finance Section, CSO, SP Bhavan, New Delhi
7. Concerned File

Summary record of the first meeting of the 'Expert Group on Green National Accounting for India' under the Chairmanship of Prof. Sir Partha Dasgupta, University of Cambridge, UK held on 23rd August, 2011 at National Institute of Public Finance and Policy, 18/2, Satsang Vihar Marg, Special Institutional Area, New Delhi.

An 'Expert Group on Green National Accounting for India' has been constituted on 4th August, 2011 as per the directions of Hon'ble Prime Minister of India to develop a framework for 'Green National Accounts' and to prepare a roadmap for implementation of the same. The first meeting of the Expert Group was held on 23rd August, 2011 under the Chairmanship of Prof. Sir Partha Dasgupta, Professor Emeritus of Economics, University of Cambridge, United Kingdom at National Institute of Public Finance and Policy (NIPFP), 18/2, Satsang Vihar Marg, Special Institutional Area, New Delhi at 10.30 AM. The list of participants is enclosed.

Dr. T. C. A. Anant, Secretary and Chief Statistician of India, in his introductory speech gave a background of the constitution of the Group. Sri. Jairam Ramesh, the then Hon'ble Minister of State for Environment and Forest felt the need for a green accounting for the economy and took initiative to get the approval of the Prime Minster of India and identified the key members to be present in the Group. The Group has a mandate for suggesting a Methodology and a framework for preparation 'Green National Accounts' India and prepare a roadmap for the implementation of the same. CSO could be coordinating the activities of the Group with Chief Statistician of India (CSI) as the Member Convenor. The 'Green National Accounting is a new area of research and the data availability is one of the major issues and hence will need to be examined. CSI indicated that the Group may take stock of the work done until now and identify steps to fill up data gaps and also areas which need more research. CSO has already conducted 8 studies on Natural Resource Accounting and the Centre of Economic and Social Studies (CESS), Hyderabad has brought out a Synthesis Report of the 8 studies and is also preparing a report on comprehensive methodology for NRA. During the course of the functioning of the Group, the government departments and other agencies that collect data as part of their administrative work may be identified and involved with the work.

Representatives from such institutions may be invited to the next meeting. The Group is to submit an interim report by April, 2012. The duration of the Expert Group will be till October, 2012.

Dr. Partha Dasgupta, the Chairman of the Expert Group, in his address narrated the distinction between the state of the economy and the need for valuation of the economy. He explained two types of evaluation techniques. The first kind of evaluation is based on the notion of Sustainable Development and tries to gauge whether the economy is going in the right direction. The second type of evaluation is based on Cost-Benefit Analysis and tries to bring out wealth of the economy through some measurements. The measurement of sustainable development looks into the changes in stocks, net investments, valuation of stocks, valuation of amenities available for the people, measuring the monetary values through shadow prices etc., and create a system consistent with existing practices. The Chairman also explained why sustainable development should form part of national accounts.

Dr. Kaushik Basu said that a Climate Change Unit has been set up in Ministry of Finance. He further mentioned that climate change and environment are being separately dealt with in the Economic Survey and he would look for inputs from this Group so that the subject under consideration of this Expert Group can be included in the Economic Survey of the Government of India.

Thereafter, there were four presentations as per details given below:

Shri. V. Parameswaran, DDG, CSO presented the status paper on Natural Resource Accounting. In this presentation, SEEA, present position of the process of revision of SEEA, brief of the 8 studies commissioned by CSO and some salient features of the interim Synthesis Report were explained. The studies undertaken by CSO broadly covered the natural assets like Air, Water, Land, Forestry and Minerals for the states like Andhra Pradesh, Himachal Pradesh, Madhya Pradesh, Meghalaya, Goa, Tamil Nadu, West Bengal and Karnataka. He also mentioned about data availability and gaps.

Dr. Manoj Panda, Director, CESS, Hyderabad in his presentation, covered alternative indicators of GDP and the findings of the eight studies in the respective states. The studies employed a host of market and non-market valuation techniques to highlight the pollution abatement costs and the respective reduction in the State GDPs, the extend of change in the air quality due to policy changes, the contribution of forestry sector in the state GDP, depletion of forest assets, the extend of land degradation etc. The methodological aspects, data issues in terms of availability, scalability and reliability and standardization were brought out in the presentation.

Dr. Haripriya, in her presentation, tried to examine whether the current pattern of growth in Indian states is sustainable. She considered forests, renewable natural capital, minerals (non-renewable natural capital) and human capital to find out whether the total stock of wealth is declining or not. She showed with empirical analysis that the states of the union of India are following a weak sustainable path to development, though the capital accumulation is positive in almost all the states. The environmental capital has been decreased in most of the states showing that the critical capital is declining.

Dr. Priya Shyamsundar gave a presentation on the environmental valuation in South Asia. Various aspects of pollution, agriculture and productive systems, ecosystem services and the needed policy interventions were explained. She gave ideas on health cost of air and water pollution, agrarian externalities, and ecosystem services. The challenges in the valuation of green accounts were also covered.

The Group had brief discussions before the presentations and detailed discussions throughout the sessions of presentations in which the following points/issues emerged:

1. Welfare being the underlying concept of sustainable development, it should be measured over a period of time rather than considering the present time. Movement of time could be seen as the pixels and not as continuous.

2. Measurement of wealth is a topic being dealt with since the time of classical economists. A number of alternatives have been proposed over time for the measurement of wealth.

3. Though GDP would be a predominant measure, there is a problem with GDP when environment aspects are to be linked. The Group should look into alternate data which could be easier to get rather than hypothetical valuation.

4. Based on the new series of National Accounts, national aggregates seem to indicate availability of whole lot of disaggregated data. However, aggregate data could be obtained directly on the basis of studies/surveys.

5. At national level all externalities are captured which may not be the case at sub-national level.

6. Growth vs. Environment was the major point of origin of this Expert Group and hence GDP should reflect the environment concern. As policy concerns are not adequately measured in the existing system of national accounts, macro level estimates of national accounts have to reflect the policy concerns of the Government.

7. Valuation should be based the descriptive framework and it depends on what kind of valuation is being adopted. It may be apt to start the valuation at the macro level and a macro perspective is desirable to arrive at National accounts as the present system captures a part of the environmental expenditure. It is also desirable to look into the larger policy issues and its implications.

8. The exercise of asset management needs collection of necessary additional data. Enlarging the existing NSSO questionnaire with a view to collect more household information is not advisable as it would affect the quality of data and hence alternative ways of collecting the required information need to be considered.

9. More studies are to be encouraged to asses the states' resources and to obtain information at the micro level. Emphasis need to be given at the sectoral level.

10. A beginning has to be made to estimate the wealth of the states following the conceptual measure of Dr. Partha Dasgupta.

11. Epidemiological data which can be used by environmental economists are not organized properly. Therefore, collection of additional data for better reflection of GDP measure needs to be planned and periodical coverage of such data needs to be ensured.

12. One should begin the valuation with forest and to be extended to other assets like minerals. The non-productive assets like air quality data to be deferred till an appropriate methodology is devised. There are also concerns about case studies on the assumption they may lead to differing outcomes.

13. The framework suggested by SEEA could be made use of for preparation of the green national accounts. The focus should be on NRA and compilation of stocks/flows of NRA assets and valuation and to identify data needs with a time frame for implementation.

14. The method of evaluation depends on what type of evaluation one thinks of. Firstly, which areas of green national accounts are required for larger policy issues need to be identified. Then what aspects of environment are captured in perverse way and what dimensions need to be considered are to be identified.

15. Presently, the national accounts do not capture non-marketed goods/services and made a point one should decide whether these affect macro-level policy and also whether to be captured.

16. Newly added items under forestry in National Accounts and also manpower requirements for collection of data were highlighted.

17. A beginning has to be made with a conceptual framework and then to identify important sectors, issue of valuation in each sector and ways of filling up the missing data.

18. A query was posed whether forest to be treated as one asset or as 3 or 4 assets.

19. Areas of air and water quality need to be included along with forest, land and minerals.

20. Input-Output table may be extended by including natural resources as inputs and emissions as by-products and required data may be captured either through NSSO surveys or by other means.

The detailed discussions and exchange of different views of the Group members have culminated into following decisions:

(1) The report of the Group should have a descriptive at the beginning indicating the policy background and the objective of this exercise.

(2) The principal focus of this exercise is to develop a framework for Green National Accounts i.e. for arriving at national level economic dimensions adjusted for environmental damages.

(3) While capital produced by human efforts forms part of national accounts, the natural capital is not accounted for in the national accounts and therefore, green accounting measure of capital is necessary which has to adequately address the policy concerns of the Government. It is also required to make an assessment of the natural wealth of the nation and the depreciation of these assets ought to be accounted for. In fact till green accounting gets stabilized and becomes a widely accepted measure, the existing national accounts paradigm will continue. Thus the exercise of computing the green national accounts will be complementary to the existing established system of national accounts.

(4) There is a need to identify national level indicators which are used in computation of national accounts and generate the correction factors to be applied on them, to account for the degeneration caused to the environment due to the development processes. It is necessary to segregate these into two categories into (a) those indicators which are doable and (b) in principle doable but not in the near future.

(5) The Group must look into the feasibility of developing accounts for natural resources. The natural resource accounting may be started with forest, land and mineral resources. In case water and air, the challenges are more both in the areas of data and concepts, particularly with regard to conversion into capital. There is a need to deal with resolving the issues related to concepts during the course of the work of the Group. Dr. Haripriya's research paper may be considered as the starting point. With respect to each area of the natural resource, data systems for accounting need to be identified, the existing data sets will be described, missing data sets will be identified and action will be proposed for filling up the gaps taking into account the constraints within data collection machinery. Consultations with Ministries/ Departments / Organizations may be done with regard to missing data and filling up the gaps.

(6) In each area of natural resource accounting, as there would be a need for more detailed studies for integrating the natural resource accounting into the national accounts, the requisite type studies may be recommended . There may be a need to generate replicable studies which can be scaled up for getting national level proportions/ratios. Also out of 8 studies commissioned by CSO, those studies can be replicated may be identified. The newly suggested studies could be taken up during the 12th five year plan period.

(7) It is needed to identify and document agencies and the data which are brought out by them (assessment of quantity of assets, valuation procedures). These agencies may also be consulted in the next meeting which may be organized some time in the last quarter of 2011-12 either in end of January, 2012 or during March, 2012

The venue may be a suitable place other than Delhi. It is required to institutionalize the system to fill data gaps.

(8) The important question is whether fugitive resources such as air, surface water, fish moving in water, etc., can be called as assets (capital). The Chairman offered to prepare a note on the aspect of formalizing the fugitive assets similar to other assets. The Chairman has also agreed to draft the introduction chapter on conceptual framework.

(9) All the members would give a one-page write-up giving their views in addition to what were discussed in the meeting.

The meeting ended up with a vote of thanks to the chair.

List of participants

Sr. No	Name	Designation	
1	Prof. Partha Dasgupta	Professor Emeritus, Cambridge University	In Chair
2	Dr. Pronab Sen	Principal Advisor, Planning Commission	Member
3	Ms. Priya Shyamsundar	Prog. Director, SANDEE, Bangkok	Member
4	Prof. K. Sundaram	Retd. Prof.	Member
5	Dr. Kaushik Basu	Chief Economic Advisor, M/o. Finance	Member
6	Prof. E. Somanathan	ISI, Delhi	Member
7	Dr.. Haripriya Gundimeda	Associate Prof., IIT, Mumbai	Member
8	Prof. Ramaprasad Sengupta	Prof., JNU	Special Invitee
9	Dr. Manoj Panda	Director, CESS, Hyderabad	Special Invitee
10	Dr. Nitin Desai	Honorary Professor	Member
11	Dr. Kanchan Chopra	Former Director, IEG, New Delhi.	Member
12	Mr. Ramesh Kolli	ADG (Retd.)	Member
13	Mr. Ashish Kumar	ADG NAD	Special Invitee
14	Dr. T.C. A. Anant	Secretary	Member convener
15	Mrs. S.Jeyalakshmi	ADG SSD	
16	Mr. V. Parameswaran	DDG	
17	Dr..S. Durai Raju	DDG	Special Invitee
18	Mr.S. Suresh Kumar	DD	
19	Mr.R.K. Panwar	SSO	

Summary Record of the Second Meeting of the Expert Group on Green National Accounting for India held during 16-17 April, 2012

The Second meeting of the Expert Group on Green National Accounting for India was held during April 16-17, 2012 at National Institute of Public Finance and Policy, New Delhi under the chairmanship of Prof. Sir Partha Dasgupta, Professor Emeritus, Cambridge University, U.K. As decided in the first meeting of the Expert Group in August, 2011, the Central Ministries/Departments/Central Government Organizations which deal with the subjects related to environment were also invited to participate in the meeting.

The list of participants in the meeting is enclosed.

Dr. T.C.A. Anant, Chief Statistician of India and Secretary and Member Convenor of the Group, after welcoming all, mentioned briefly about the progress in the work of the Expert Group after the first meeting and also about the purpose of the second meeting. During the course of his address, Dr. T.C.A. Anant also covered the salient features from the paper titled 'Developments in International Environmental Economic Accounting' sent by Mr. Peter Harper, Chair, UN Committee of Experts on Environmental Economic Accounting and Deputy Australian Statistician for the meeting of the Expert Group and touched upon System of Environmental Economic Accounting (SEEA) Central Framework and recognition of SEEA as a standard document by UN Statistical Commission.

Thereafter, Prof. Partha Dasgupta, Chairman of the Expert Group mentioned about the importance of human capital as a component of wealth of a nation and said that presently wide discussions are going on among the academics and international organizations on this. He was of the view that the present meeting would be an excellent one as it would give an opportunity to the Expert Group to listen to presentations and to have interaction with the participating organizations in the area of environment which would throw light on the available data structures, how the same would be feasible to meet the requirements of environmental accounting and what changes would be required so that the available data could be converted for the purpose of the environmental accounting framework.

Thereafter, there were presentations from the following organizations. The presentations were made by senior officers representing the respective organizations. The subjects covered in the presentations have been indicated in brackets.

(i) Indian Council of Agricultural Research, New Delhi (land, soil and agriculture and allied sector)

(ii) Forest Survey of India, Dehradun (forests)

(iii) Central Pollution Control Board, New Delhi (air/water pollution)

(iv) Prof. Janakarajan, Madras Institute of Development Studies, Chennai (overall environmental accounting with regard to surface water – rivers)

(v) Botanical Survey of India, Kolkata (flora)

(vi) Zoological Survey of India, Kolkata (fauna)

(vii) Ministry of Earth Sciences, New Delhi (activities of the Ministry from the environmental accounting point of view)

(viii) Geological Survey of India, Jaipur (activities of GSI from the environmental accounting point of view)

(ix) Indian Bureau of Mines, Nagpur (Minerals)

(x) Central Water Commission, New Delhi (Surface and Ground water and Irrigation)

(xi) Prof. Haripriya, IIT, Bombay (Data Requirements and availability in respect of sectors forests, land and mines)

(xii) National Natural Resources Management Systems, MOEF, New Delhi (Projects on environment subjects)

(xiii) Social Statistics Division, CSO, MOSPI, New Delhi (Way Forward)

All the presentations were mainly on existing data structures with regard to the respective Departments/Organizations from environmental accounting point of view in order to give a board picture to the Expert Group to be able the Group to decide on the sectors/sub-sectors of environment to be included in the accounting framework from the angle of feasibility and implementation. All the presentations were well appreciated by the Expert Group. Each presentation was followed by a discussion .

The various points/issues emerged out of the discussions held during the course of the presentations and afterwards are as under:

Indian Council of Agricultural Research

(i) Conversion of degraded land into productive land is an important aspect and it would be useful to have some estimates of investments required to maintain the requisite area of land productive.

(ii) The data on land degradation were based on the available data with various state governments (may not pertain to the same period) and consolidation of the same was an one-time exercise. It would not be feasible to update this information frequently. However, data on land capability classes are available. Using sampling of land classes, it could be possible to update land degradation data from time to time. Also possibility of using GIS technology for this purpose may have to be explored.

(iii) It would be useful to have the share of land degradation on account of natural causes and on account of economic activities.

Forest Survey of India

(i) As monitoring of forest fire is done by FSI and State Forest Departments are appraised of the same, this information could be useful.

(ii) As regards production and consumption of forest products, data are available through the production and consumption study done by FSI..

(iii) Assessment and valuation of trees outside forests is an important factor. In fact, trees out of forest area and minor products were included in the national accounts in 2004-05 and since then there has been substantial contribution on account of these items to GDP.

(iv) FSI uses three different definitions and it may be decided which definition to follow so that the classification like agriculture land in forest, private forest area, etc. can be settled.

(v) With respect to valuation, pricing of forest trees might vary vastly due to policies of some State Governments..

Central Pollution Control Board

(i) Presently, 12 parameters of air quality and 35 parameters of water quality which have direct impact on health are monitored by CPCB. Further, data on health aspects are available with Indian Council of Medical Research, New Delhi and data on occupational diseases are available with M/o Labour and Employment . Possibilities of using these data could be explored.

(ii) CPCB regularly monitors air/water pollution both manually and through monitoring stations in addition to the manual monitoring of noise pollution. Further, CPCB monitors major rivers every month and ground water quarterly. There is a need to explore how the data generated through these monitoring systems along with information on physical characteristics of water could be used for environmental accounting purposes.

(iii) Major industries have the system of monitoring source-wise pollution and emissions. Possibilities of compilation and dissemination of these data available with Industries/State Pollution Control Boards need to be explored.

(iv) There is a need for integration of industry–wise pollution data with ambient data. If the purpose is to have a separate environment/sustainability index, ambience data can be used , but in case integration of environment with national accounts is required, then relation between source and ambient quality matters. Also linking ambient quality with activities is important which perhaps can be taken care of by the comprehensive monitoring system of CPCB .

(v) Though contribution to global pollution may be easier to capture, at national level localized source-wise pollution with more details will be relevant. For preparation of extended input-output tables too, rather than ambient data, more specific data would be required. Therefore, instead of studies based on broad geographic areas, localized studies in general on pollution and relating pollution to health aspects, would be more useful. There is also a need to identify the availability of data to assess the exact contribution of local and external sources to pollution in an area/place/region.

(vi) Some mathematical models developed by CPCB can be used to work out the impact of pollution.

(vii) Information on abatement costs and regulation of emission would be useful.

(viii) There are also data sets on pollution generated available with academic/research institutes and individual researchers. Is it possible to tap such potential through some mechanism?

(ix) Mostly pollution control monitoring stations are in cities whereas many rural areas are also polluted. Hence, there is a need to have such stations in rural areas too.

(x) Presently, available data on pollution provide for highlighting the impact on health due to pollution. However, this information would not be useful to assess the damage to forests, capital, etc.

Prof. Janakarajan

(i) Data on use of water are available with State Irrigation Departments. One can collect the data from States. Also water quality monitoring stations set up by States generate data on water pollution which need to be collected and consolidated.

(ii) The data available with CWC pertain to major rivers only. Data on small rivers, sub-stream flow, etc. which are also important are not available.

Botanical Survey of India

(i) There is a need to measure change in bio-diversity between two points of time (at least decennially) for various purposes (eg.conversion of forest areas for non-forest activities). It is difficult to re-visit the areas/places for such a purpose, at least information must be generated to measure changes on sample basis. Whether under any project, time series data on change are available?

(ii) There exists potential bio-diversity in non-forests. How to capture this information? Specifically, given correlation between different types of bio-diversity, a possible approach could be for FSI to come out with some Tree diversity index, which can be used for estimating information on bio-diversity. There is a need to bring linkage between bio-diversity data and FSI data (like canopy cover).

(iii) Valuation is complicated with respect to bio-diversity. In particular, hot spots (bio-diversity rich areas) are more important and will thus need to be treated differently for valuation purposes than other areas. Value of bio-diversity may need to be estimated through surveys.

(iv) Can potential of bio-diversity be treated as future value?

(v) Several ecological studies have been done by many Universities. There is a need for networking so that one can have access to all available data on bio-diversity. .

Zoological Survey of India

(i) There are rich data available even at district level on flora and fauna with BSI and ZSI in monographs, research papers, etc. which need to be properly consolidated and disseminated . At least for environmental accounting, these can be collected from them and used.

Ministry of Earth Sciences

(i) Vast and potential data with regard to climate change and environmental aspects relating to coastal areas, ocean, etc. are available with the M/o Earth Sciences.

Geological Survey of India

(i) Data on proved–category, possible category, etc. of mineral deposits and changes from one category to another are available with GSI. Can information on parameters which are considered for explorations/findings of mineral deposits be used in some manner?

(ii) Information available on land use with different agencies like M/o Agriculture, GSI, Remote Sensing Agency, etc. need to be integrated properly to make land use data more robust and consistent.

(iii) Information on land use by industries is required . One can go for type surveys in order to compile such information.

(iv) As regards expenditure data for land rehabilitation, there will be problem with information pertaining to private sector.

Indian Bureau of Mines

(i) Indian Bureau of Mines has lot of data on production of minerals, etc. In the case of pollution, data are available only for the periods pertaining to getting clearances by the mining companies. There is a need to explore mechanism of gathering data on pollution and water use during the period of operation of mining concessions.

Central Water Commission

(i) There is lot of data available in the area of water. CWC brings out three publications, viz, Water Year Book, Sediment Year Book and Water Quality Year Book which provide lot of data on water. Further, data relating to water are available with Central Ground Water Board (CGWB) and M/o Water Resources. Also ground water level monitoring through 15000 observation wells generate certain data. With regard to cause of sediment, whether any information is available and if not how to get the same?

(ii) Water Quality monitoring stations of CWC and Water Quality monitoring stations of CPCB seem to be different. There is a need for further details in this area and to find out whether both can be combined so that more coverage is achieved.

(iii) Surface water and ground water are to be combined for the purpose of information on water availability and use. What should be the unit in this case? Further, what should be the level of disaggregation for water use?

(iv) CGWB has projects at selected places with regard to water re-charge measures. Can such information be used in some way?

(v) Water Balance Studies are done by many states.

(vi) Can ASI data be used for water information?

(vii) In ASI 1997-98, three types of information relating to environment were collected viz. (i) whether pollution caused by industry (air, water, etc.)?, (ii) whether abatement measures were taken? and (iii) value of assets on pollution control. These details were collected only during that year and were subsequently dropped. Presently, only information on value of pollution control equipment is collected which is also not compiled.

(viii) With regard to collecting data through ASI on environment related information, one needs to keep in mind the length of ASI schedule so as to ensure that the quality of information is not compromised.

(ix) Under water quality, there is a need to have information separately on industries polluting surface/ground water.

Prof. Haripriya

This presentation covered a suggested framework for forest accounting, structure of the core set of land cover/land use accounts, physical accounts for minerals and bio-diversity. The framework for forest accounting comprised opening stocks, changes due to economic activities, other changes, closing stocks, area accounts for forest land, physical accounts for timber and carbon and monetary accounts. Data requirements, data availability and data gaps pertaining to the items covered in the presentation were discussed . The important points are:

(i) FSI provides lot of requisite data for physical accounting of forests, etc. Information on changes due to consumption of natural resources is relevant and hence required. Other than the published data, FSI maintains lot of other data required for the purpose of accounting which could be made available.

(ii) Whether to include economically proven reserves or proven and probable reserves or the entire resource base? In case the entire resource base is to be included, then an extended framework will be required.

(iii) There is inconsistency in data pertaining to mines between the periods pre-2003 and post-2003 because of change in the definition of classification. Can IBM do something on this?

(iv) How to get data on increase in mines reserves?

(v) Bio-diversity needs to be defined and indicators identified (should it be genetic, species or eco-system level?) for accounting purposes.

National Natural Resources Management Systems

(i) NNRMS programme covers several projects like forest type mapping, coastal studies, mapping of wild life sanctuaries, national parks, snow & glaciers, etc.

bringing various environmental aspects together. Data are generated through these projects which may be used.

Social Statistics Division

This presentation identified the do-ables, medium-term plan and long-term plan. The plans were identified based on (i) two parts of the Reports of CESS (Centre for Economic and Social Studies, Hyderabad) prepared on the basis of the 8 studies on Natural Resource Accounting (NRA) commissioned by CSO, (ii) outcome of the discussions of first meeting of Expert Group held in August, 2011, (iii) outcome of the meeting of the Technical Advisory Committee on NRA headed by Dr. Kirit Parikh held in March,2012 and (iv) availability of data for various sectors of environment for preparation of physical and monetary accounts. The following are the highlights of the discussions:

(i) Satellite accounts, sector-wise, would be useful as these will enable to infer on wealth related parameters.

(ii) There is problem of additivity in the case of physical assets for aggregation. In order to overcome this, monetary valuation is required.

(iii) Valuation is difficult in areas like eco-tourism, non-timber forest products, etc. In such cases, is it possible to develop some coefficients which can be used to derive estimates?

Detailed discussions and exchange of different views of the Group members and special invitees have culminated into the following decisions:

1. The Report of the Group would cover all aspects of Green National Accounting consisting of theoretical framework, existing system of national accounts, doables under environmental accounting and medium and long term plans.

2. SNA is based on a set of accounts with consistency checks across different types of accounts. Thus in order to incorporate environmental concerns one has to work with each of the major activity of national accounts. The environmental accounting framework will need to be consistent with the SNA. In a sense, this is the essence of the work plan recommended under SEEA.

3. The immediate do-able would be preparation of physical supply use tables for selected sub-sectors specifically focusing on land, forests, minerals and water.

4. The Interim Report would essentially be a draft version of the final report comprising the following:

(i) The first chapter will be on a conceptual framework on green national accounting for India. This may include items like how to handle fugitive resources, new discoveries, etc.

(Action: Chairman of the Group)

(ii) A separate brief chapter on valuation covering the principles of valuation, strategies in valuation (market-based) and identification of areas and priorities may be prepared which may be separately circulated among Central Departmetns/Organizatons dealing with environment subjects by May, 2010 for their quick comments before incorporating it into the interim Report.

(Action: Ms.Kanchan Chopra and Ms. Priya Shyamsunder)

(iii) The third chapter will have a summary of concepts and methods followed under national accounts of India and coverage of environment in the national accounts. This chapter will also include salient features of SEEA (based on Central Framework) and in what manner environment can be incorporated into national accounts. Also some illustrative tables may be included in this chapter.

(Action: NAD/SSD, CSO)

(iv) The last Chapter will be on do-ables, medium and long –term plans based on the paper circulated by CSO. This Chapter would also discuss on data requirements for implanting green accounts, data availability and gaps and suggest areas where studies/surveys would be required.

(Action: SSD & Prof.Haripriya, IIT, Bombay)

6. The Interim Report should be ready by early June, 2012 which would then be circulated to concerned Central Ministries/Departments/Organizations for their views/comments/suggestions by July, 2012.

7. The third meeting of the Group may be convened during September-October, 2012 for considering the views/comments/suggestions received and the Report could be finalized by October, 2012.

The meeting ended with a vote of thanks to the Chair.

Annexure

List of Participants

Second Meeting of Expert Group on Green National Accounting for India
at National Institute of Public Finance and Policy, New Delhi during 16-17 April, 2012

Sl.No	Name	Designation	
1.	Dr. Partha Dasgupta	Professor-Emeritus, Cambridge University, UK	Chairman
2.	Dr. Pronab Sen	Principal Economic Advisor, Planning Commission	Member
3.	Dr. Kaushik Basu	Chief Economic Advisor, MOF	Member
4.	Dr. Nitin Desai	D-63, Defence Colony, New Delhi	Member
5.	Dr. Kanchan Chopra	Former Director, IEG, Delhi	Member
6.	Prof. K. Sundaram	Professor (Retd.), DSE, Delhi	Member
7.	Dr. Haripriya Gundimeda	Associate Professor, IIT, Mumbai	Member
8.	Dr. Priya Shyamsunder	Program Director, SANDEE, Bangkok	Member
9.	Dr. E. Somanathan	Professor, ISI, Delhi	Member
10.	Dr. T.C.A. Anant	CSI & Secretary, MOSPI, New Delhi	Member-Convener
11.	Shri. S. K. Das	Director General, CSO, MOSPI, New Delhi	Special Invitee
12.	Smt. Nandita Chatterjee	Additional Secretary, MOE&F, New Delhi	Special Invitee
13.	Smt. S. Jeyalakshmi	Additional Director General, Social Statistics Division, CSO, MOSPI, New Delhi	Special Invitee
14.	Shri. Ashish Kumar	Additional Director General, National Accounts Division, CSO, MOSPI, New Delhi	Special Invitee
15.	Dr. Janakarajan	Professor, Madras Institute of Development Studies, Chennai	Special Invitee
16.	Dr. Manoj Panda	Director, CESS, Hyderabad	Special Invitee
17.	Shri. G. C. Manna	Deputy Director General, Economic Statistics Division, CSO, MOSPI, New Delhi	Special Invitee
18.	Shri. V. Parameswaran	Deputy Director General, Social Statistics Division, CSO, MOSPI, New Delhi	Special Invitee
19.	Shri. N. K. Ghosh	Statistical Advisor, MOE&F, New Delhi	Special Invitee
20.	Shri. D. P. Mondal	Advisor, Central Water Commission, New Delhi	Special Invitee
21.	Shri. S. K. Wadhavan	Deputy Director General, Geological Survey of India, Jaipur	Special Invitee
22.	Shri. B. P. Sinha	Controller of Mines, Indian Bureau of Mines, Nagpur	Special Invitee
23.	Dr. Harendu Prakash	Scientist, Min. of Earth Sciences, New Delhi	Special Invitee
24.	Shri. A. Sudhakaran	Scientist, Central Pollution Control Board, New Delhi	Special Invitee

25.	Dr. Paramjeet Singh	Director, Botanical Survey of India, Kolkata	Special Invitee
26.	Dr. K. A. Subramanian	Scientist, Zoological Survey of India, Kolkata	Special Invitee
27.	Shri. Rajesh Kumar	Director, Forest Survey of India, Dehradun	Special Invitee
28.	Shri. J. C. Dagar	Asstt. Director General, Indian Council of Agricultural Research, New Delhi	Special Invitee
29.	Shri. James Mathew	Director, SSD, CSO, MOSPI, New Delhi	Special Invitee
30.	Dr.H.Kharkwal	Deputy Director, MOEF, New Delhi	Special Invitee
31.	Shri. S. Suresh Kumar	Deputy Director, SSD, CSO, MOSPI, New Delhi	
32.	Shri. Ram Lautan	Asstt. Director, SSD, CSO, MOSPI, New Delhi	
33.	Shri. R. K. Panwar	SSO, SSD, CSO, MOSPI, New Delhi	
34.	Shri. Nurul Amin	SSO, SSD, CSO, MOSPI, New Delhi	

Summary Record of the Third Meeting of the Expert Group on Green National Accounting for India held during 6-7 December, 2012

The third meeting of the Expert Group on Green National Accounting for India was held on 6th and 7th of December, 2012 at National Institute of Public Finance and Policy, New Delhi under the chairmanship of Prof. Sir Partha Dasgupta, Professor Emeritus, Cambridge University, UK. The list of participants in the meeting is enclosed.

Dr. T.C.A. Anant, Chief Statistician of India and Secretary, Ministry of Statistics and Programme Implementation, and Member Convener of the Group, after welcoming all, said that this would be purely a business meeting to discuss the draft chapters circulated and obtain inputs for finalizing the draft report which should spell out a roadmap for green national accounting for India which, interalia, include incorporating the elements of natural resources into the system of national accounts. He mentioned that in the second meeting held in April 2012, the Group did a detailed review of the availability of data relating to sectors associated with the environment. In this meeting, the draft report would need to be finalized so that after incorporating the comments/suggestions, the final draft could be circulated to the concerned Government Departments and other stakeholders by February 2013. This process would enable the Group to submit the Report to the Government by June 2013.

Prof. Partha Dagupta, Chairman of the Group gave a brief account of the draft chapters circulated and more details about the first chapter on the conceptual framework. He indicated the need for wealth accounting and moving from GDP to NDP, as the latter would be a better indicator for measuring the wealth of a country. He mentioned about the importance of having strong foundations for wealth accounting which includes human capital also. He was of the view that there would be a great deal of attention to health besides environment in the coming years. He also said that not only net savings but also growth rate of savings would have to be monitored.

Thereafter, Chapter 1 of the draft report on Conceptual Framework of Green Accounting was taken up for discussion. The following are the salient features of the points emerged out of the discussions:

Conceptual Framework

1. There is a need to translate the conceptual framework into empirical situation. For this both production and asset boundaries of SNA would need to be changed for bringing the non-productive assets into the system. Even in SNA 1993 there were changes in the asset boundaries.
2. The case of non-linearity is taken care of by the valuation.
3. How to take into account the general consumption patterns as well as that of natural resources of various countries for wealth accounting? Can shadow prices reflect the consumption patterns?
4. The draft chapter indicates the local valuation. As there have been variations in shadow prices at different levels, would it be feasible to have bottom-up approach so that national level green accounting can be based on sub-national level figures?, otherwise, it may have to be decided which shadow prices are to be taken.
5. With regard to bottom-up approach, the other view expressed was whether it could be feasible to have this approach to achieve results in short run. It would be preferable to aim at national level figures and for this wherever required, estimates based on sampling (representative sample) could be used. It was also opined that at least for degradation, one should have state level data.
6. For the development of a nation, particularly developing countries, exploitation of natural resources is a must. In the context of global level comparison, the developing countries may require some level of additional exploitation of natural resources. Therefore, can there be a limit beyond the optimal value of exploitation which will be an additional cushion for faster rate of development of developing countries?
7. Reclassification within resources would be required for merging environmental accounting with SNA. What type of reclassification would be required, how it can

be done, and the valuation exercises for the resources are to be looked into and decided.

8. There would be a need to identify and come out with reasonable shadow prices.
9. The conceptual framework is holistic and some of the items only can be taken for implementation based on feasibility from the point of view of statistical measurements and availability/collection of data.
10. There are interfaces between asset and production boundaries, and one needs to decide what extensions are required. It is also important to delineate two way interactions.
11. Some exercises are in progress to include environmental factors relating to production activities existing under SNA. One has to proceed step-by-step towards environmental accounting and hence, to begin with, one may not tamper with the production boundary and only expand the asset boundary within the existing production boundary of SNA. It may also have to be decided which assets have to be included when the asset boundary is expanded for the purpose of environmental accounting. Thus, in the beginning, one may see what can be done without violating SNA and then to proceed to what would be further required and how it could be done. One could also think of extending the production boundary little bit and work on do-ability.
12. It is important to note that everything which is taken under environmental accounting cannot come under SNA framework. It is also to be noted that the equations under environmental accounting can affect the identities under SNA. Therefore, the accounting framework of environmental accounting would have to be clearly specified.
13. Air and health may be included for green accounting. Health and education expenditures are already included under SNA. If these are to be included under asset boundary, then their measurements have to be different. As these expenditures are treated as consumption under SNA, under environmental accounting a reclassification to treat them as investment would be required. Another view expressed was to confine to only natural resources.

14. Pollution control expenditure is consumption expenditure and the related measures do not add to stock. This is the problem with other defensive expenditures also.
15. The present draft report is different from the report of the project commissioned to Centre for Economic and Social Studies (CESS) for synthesizing the 8 studies undertaken by CSO through various research/academic institutes, and various studies done in India and internationally in the field of Natural Resource Accounting, in the sense that the report of the Expert Group is more of a macro-level report as it includes a broad conceptual framework of Green National Accounting.
16. The report may broadly have three parts relating to (i) what modifications of SNA are required to include environmental factors i.e. a conceptual framework along with translation into implementable parts? (ii) areas for further research, discussions etc. and (iii) how to capture sustainability and inter-generational wealth.
17. There is a need to have another chapter in the report, i.e. chapter 2 which would spell out the transition from conceptual framework to actual implementation.

Thereafter, a presentation on chapter 2 viz. "SNA in India and SEEA" was made by Shri. V. Parameswaran, which covered in brief the broad System of National Accounts which is in practice in India, highlights of activities included in the compilation of National Accounts Statistics relevant to environment, limitations of National Accounts with respect to environment, the concept of SEEA, the features of SEEA Central Framework, classification of environmental assets in the SEEA Central Framework, comparison between SNA and SEEA in terms of production and asset boundaries etc., and environmental factors not included in SNA. This presentation was followed by detailed discussions, the highlights of which are as under:

1. It was noted that there were differences in asset boundary of SNA and asset boundary of SEEA in physical terms, whereas in monetary terms the asset boundaries of SNA and SEEA Central Framework were the same.

2. From the PSUTs and asset accounts it was observed that for implementation of SEEA in India it would be necessary to have the type of classification indicated in the tables of SEEA Central Framework from the type of classification possible as per availability of data.
3. Based on tables of environmental accounting, would it be possible to forecast?
4. For the present, the ideal situation could be to keep the SNA intact and expand the tables to produce PSUTs, etc. for environmental factors.
5. The environmental accounting does not bring any change in GDP but it changes only NDP. At some point of time, production boundary would need to be re-visited, in which case GDP would also be affected.

After this, a presentation on Chapter 3 with regard to implementing the Green Accounting Framework was made by Dr. Haripriya, which covered the framework for physical asset accounts for the selected assets; actual asset accounts for land resources, forest land, timber and carbon, agricultural and pasture lands, and minerals based on available data; accounting prices and wealth of forests, agricultural land and minerals; integration with the supply use accounts depicting what extensions over SNA are required for environmental accounting; greening of national accounts with an illustration; and data required for developing the accounts. The following points emerged out of the discussions on this presentation:

1. It was observed from the tables developed that many of the cells were vacant implying non-availability of data.
2. The classification shown in the tables does not match with the classification as per SEEA tables implying that merging of some categories would be required to bring the tables on line with SEEA.
3. For developing accumulation account, information about degradation would be required. In this context, it may be mentioned that with regard to computation of CFC, valuation is not an issue. However, one needs to give attention to valuation of non-produced assets as it is not same as valuation of produced assets.

4. As regards land, inclusion of expenditure on fertilizer in SNA amounts to incorporation of the level of degradation of soil/land. Drawing an analogy with "machines", expenditure on repair/maintenance is included as well as depreciation on account of wear and tear is accounted for, but the land is not treated in the same manner. Whether land and machines are to be treated in the same manner or not?
5. As no regular data are available on land degradation, time dimension is to be handled carefully.
6. In case of land, tables may be prepared by having 9 fold classification both in rows and columns as such tables explain how the movement from one category to other categories takes place.
7. In the context of bio-diversity, a reference was made to the minutes of the second meeting of the Expert Group held in April, 2012 with regard to consolidation of rich data available at district level on flora & fauna, measuring changes of bio-diversity on sample basis, and estimation based on developing some tree diversity index, etc.
8. The asset boundaries of SEEA Central Framework and the SNA are the same in monetary terms which implies that GDP would not change but only NDP would change. As NDP is not used as widely as GDP, it would be preferable to link "investment" to natural assets accounting.

There was also a presentation on "Way Forward" by Shri. V. Parameswaran, and there were discussions on the same.

The following are the decisions that emerged out of the discussions in the two day meeting:

1. The immediate do-able would be preparation of PSUTs and Asset accounts. For this purpose, the classification of environmental assets as per SEEA may not be followed, and these tables would be prepared for the sectors (i) Land and Soil (ii) Forest and Timber (iii) Minerals. The components like landfill and solid waste would be linked to relevant environmental assets as classified here.

2. The medium term plan extending to a period of 5-year would be (i) planning and preparation of monetary supply and use tables for land and soil, forest and timber, and minerals, (ii) consolidation of data (based on information available but scattered) and type studies/surveys are to be planned and organized for preparation of PSUTs for the sectors – water, carbon, and energy, and (iii) planning for valuation of the sectors water, carbon, and energy, and collection of data.
3. The long term plan extending to a period of 10 years would be (i) preparation of monetary supply and use tables for water, carbon, and energy, (ii) collection and compilation of data for valuation and preparation of physical and monetary supply use tables for the sectors – aquatic resources, other biological resources, air, and biodiversity, and (ii) institutionalisation of collection of regular/periodical data and organizing periodical studies/surveys for environmental accounts.
4. There will be 5 chapters of the Report viz. Chapter 1 on Conceptual Framework, Chapter 2 (newly added) on transition from conceptual framework to feasible way of moving it forward within SNA, Chapter 3 on SNA in India and SEEA, Chapter 4 on Feasibility of Implementing the Framework, and Chapter 5 on Way Forward.
5. The chapters 1, 3, 4 and 5 will be modified in the light of the discussions in the meeting. In finalizing Chapter 4, Dr. N. Egambaram, Deputy Director General (Retd.), NAD, CSO would also be associated.
6. The draft chapters 1, 2 and 3 shall be completed by end of December, 2012. The chapter 2 (the transition chapter) will be drafted by Dr. Pronab Sen.

   (Action: Prof. Partha Dasgupta/ Dr. Pronab Sen/ Shri. V. Parameswaran)
7. The chapters 4 and 5 will be completed by Dr. Haripriya and Shri. V. Parameswaran respectively by end of January 2013.

   (Action: Dr. Haripriya/ Shri. V. Parameswaran)
8. The Executive Summary will be drafted by Prof. Partha Dasgupta within 7 days of receipt of Dr. Haripriya's chapter and also track changes on all submissions will be drafted as his contribution to the revised chapters.

   (Action: Prof. Partha Dasgupta)

9. CSO cleans up the track changes and circulates the Draft Report among the members of the Expert Group by 2nd week of February with notice that the comments are to be received within a week.

(Action: CSO/SSD)

10. The Draft Report shall be circulated to the concerned Government Departments and other stakeholders giving them 2 weeks time to send us their comments.

(Action: CSO/SSD)

11. The comments received shall be collated to prepare the final report by 1st week of March 2013. The Executive Summary shall be produced in a visually attractive document.

(Action: Prof. Partha Dasgupta/ Dr. T. C. A. Anant/ Shri. V. Parameswaran)

12. The Report shall be submitted by the Expert Group to the Government by March-April 2013, and an International Workshop of reputed academicians and statisticians will be held during the same period to deliberate on the Report.

The meeting ended with a vote of thanks to the chair.

List of Participants

3rd Meeting of Expert Group on Green National Accounting for India at National Institute of Public Finance and Policy, New Delhi during 6-7 December, 2012.

Sl. No.	Name	Designation	
1.	Dr. Partha Dasgupta	Professor-Emeritus, Cambridge University, UK	Chairman
2.	Dr. Pronab Sen	Principal Economic Advisor, Planning Commission	Member
3.	Dr. Nitin Desai	D-63, Defence Colony, New Delhi	Member
4.	Dr. Kirit Parikh	Former Member, Planning Commission	Member
5.	Dr. Kanchan Chopra	Former Director, IEG, Delhi	Member
6.	Prof. K. Sundaram	Professor (Retd), DSE, Delhi	Member
7.	Dr. Haripriya Gundimeda	Associate Professor, IIT, Bombay	Member
8.	Dr. Priya Shyamsundar	Program Director, SANDEE, Bangkok	Member
9.	Dr. E. Somnathan	Professor, ISI, Delhi	Member
10.	Dr. T. C. A. Anant	CSI & Secretary, MOSPI	Member – Convener
11.	Dr. Manoj Panda	Director, IEG, Delhi	Special Invitee
12.	Shri. V. K. Arora	ADG, ESD, CSO	Special Invitee
13.	Shri. Vijay Kumar	ADG, NASA, CSO	Special Invitee
14.	Smt. S.Jeyalakshmi	ADG, SSD, CSO	Special Invitee
15.	Shri. Ashish Kumar	ADG, NAD, CSO	Special Invitee
16.	Dr. N. Egambaram	DDG (Retd.), NAD, CSO	Special Invitee
17.	Shri. V. Parameswaran	DDG, SSD, CSO	Special Invitee
18.	Smt. Vandana Agarawal	EA, MoE&F	Special Invitee
19.	Dr. S. Durai Raju	DDG, NAD, CSO	Special Invitee
20.	Smt. Shailaja Sharma	DDG, NAD, CSO	Special Invitee
21.	Smt. T. Rajeswari	DDG, NAD, CSO	Special Invitee
22.	Shri. James Mathew	Director, SSD, CSO	Special Invitee
23.	Shri. S. Suresh Kumar	Deputy Director, SSD, CSO	
24.	Shri. R. K. Panwar	SSO, SSD, CSO	
25.	Shri. P. Sai Manohar	Consultant, SSD, CSO	