# 2. Sustainomics Framework*

## Overview

In this chapter, the elements of the sustainomics framework are set out in greater detail. Section 2.1 describes the fundamental principles and methods. Sustainable development, traditional development and growth are defined. A practical approach based on *making development more sustainable*, or MDMS, is described as an alternative to pursuing abstract definitions of sustainable development. The sustainable development triangle (comprising social, economic, and environmental dimensions) is introduced, and the driving forces and concepts of sustainability underlying each viewpoint are explained. Sustainomics also promotes methods which transcend conventional boundaries of thinking, and full cycle analysis from data gathering to practical policy implementation. In Section 2.2, the dimensions of the sustainable development triangle, their interactions, and different concepts of sustainability are explained. Methods for integrating these three dimensions are described in Section 2.3, including the complementary concepts of optimality and durability. The poverty-equity-population-natural resources nexus, and linkages between economic efficiency and social equity are discussed. Next, Section 2.4 describes a variety of practical methods and tools for applying sustainomics principles to the real world, including the Action Impact Matrix, sustainable development assessment, cost-benefit analysis, multi-criteria analysis, and so on. It is important to select relevant, time and location specific indicators of sustainable development. Section 2.5 outlines approaches for restructuring long term growth and development to make them more sustainable, by harmonizing development with nature, while pursuing poverty reduction in developing countries that require continued growth of incomes and consumption.

## 2.1 BASIC CONCEPTS AND PRINCIPLES

World decision makers are facing traditional development issues (such as economic stagnation, persistent poverty, hunger, and illness), as well as new challenges (like environmental damage and globalisation). One key approach that has emerged is the concept of sustainable development or 'development which lasts'. Following the 1992 Earth Summit in Rio de Janeiro and the adoption of the United Nations' Agenda 21, this idea has become well accepted worldwide (UN, 1992; WCED, 1987). Subsequently, international events like the 2000 Millennium Development Goals (MDG), and the 2002 World Summit on Sustainable Development (WSSD)

* Some parts of the chapter are based on material adapted from Munasinghe (1992a, 1994a, 2002a, 2004a).

(UN, 2002) in Johannesburg, have helped to maintain the impetus.

The Bruntland Commission's original definition of sustainable development was succinctly paraphrased as "meeting the needs of the present generation without jeopardizing the ability of future generations to meet their needs" (WCED, 1987). Perman et al. (2003) give a good discussion of concepts and definitions of sustainability.

As a contribution to better define, analyse, and implement sustainable development, Munasinghe (1992a, 1994a) proposed the term *sustainomics* to describe "a transdisciplinary, integrative, comprehensive, balanced, heuristic and practical framework for making development more sustainable." Many other definitions have been proposed, but it is not the purpose of this book to review them.

Sustainomics broadly describes sustainable development as "a process for improving the range of opportunities that will enable individual human beings and communities to achieve their aspirations and full potential over a sustained period of time, while maintaining the resilience of economic, social and environmental systems." This definition recognizes that *development* of economic, social and ecological systems depends on expanding the set of opportunities for their improvement. Meanwhile, the *sustainability* of systems will be enhanced by improving their resilience and adaptive capacity. Based on this approach, a more focused and practical approach towards making development more sustainable also emerged, which sought "continuing improvements in the present quality of life at a lower intensity of resource use, thereby leaving behind for future generations an undiminished stock of productive assets (i.e. manufactured, natural and social capital) that will enhance opportunities for improving their quality of life" (Munasinghe, 1992a). This evolution of ideas takes us beyond traditional "development" (which relates to broadly improving the well-being of individuals and communities), and growth (which refers to increases in economic output or value added in goods and services, conventionally measured by gross national product, etc.)

The heuristic element in sustainomics underlines the need for continuous adaptation and rethinking of the framework based on new research, empirical findings and current best practice, because reality is more complex than our incomplete models. Sustainomics provides a dynamically evolving learning framework, to address rapidly changing sustainable development issues.

The basic ideas about sustainomics sketched out below have benefited greatly from the post-Bruntland discussions and work of other researchers. They also provide a fresh start. The intent is to stimulate discussion and further research that will help to further flesh out the basic framework. Many authors (cited throughout the text) have already contributed significantly to this effort, with work that is related to the sustainomics approach, including the sustainable development triangle and various analytical tools and methods (see below).

The core framework rests on several basic principles and methods:

(a) making development more sustainable (MDMS);
(b) sustainable development triangle and balanced treatment;
(c) transcending conventional boundaries for better integration; and
(d) full cycle application of practical analytical tools and methods, from data gathering to policy implementation and operational feedback.

### 2.1.1 Making development more sustainable (MDMS)

Since the precise definition of sustainable development remains an elusive goal, a less ambitious strategy might offer greater promise. Thus, the step-by-step approach of "making development more sustainable" (MDMS) becomes the prime objective, while sustainable development is defined as a process rather than an end point (see Section 2.2). Such an incremental (or gradient-based) method is more practical and permits us to address urgent priorities without delay, while avoiding lengthy philosophical debates about the precise definition of sustainable development. However, this approach does not eliminate the need to have a practical metric to measure progress towards sustainable development.

MDMS suggests a pragmatic, systematic process, which empowers people to take immediate action. We start with the many unsustainable activities that are easiest to recognize and eliminate – for example, reducing land degradation through improved farming practices, or conserving energy by switching off unnecessary lights. Section 2.1.2 argues that an appropriate measurement framework should cover the economic, social and environmental dimensions of sustainable development. Especially critical is the choice of appropriate indicators to suit the application (see Section 2.4.2). Conventional economic evaluation attempts to measure all such indicators (economic, social and environmental) in monetary units and then use economic cost-benefit analysis criteria to test for viability (see Section 3.2). However, problems arise because cost-benefit analysis is based on the concept of optimality which differs from sustainability (see Section 2.3), and such economic valuation is often difficult to do. In that case, our MDMS metric will need to rely on indicators that have different units of measurement (monetary, biophysical, social, etc.) and corresponding sustainability criteria. Multi-criteria analysis is more suitable to assess indicators that cannot be directly compared (see Section 3.6). If an activity results in an improvement of all sustainability indicators, it clearly satisfies the MDMS requirement – also called a "win-win" outcome. For other actions, some sustainability indicators may improve while others worsen. In such cases, judgement is required to trade-off one indicator against another, and practical ways of addressing such issues are discussed in the case studies (see Chapters 5 to 16). This process needs to continuously adapt and improve itself, as scientific knowledge about sustainable development improves.

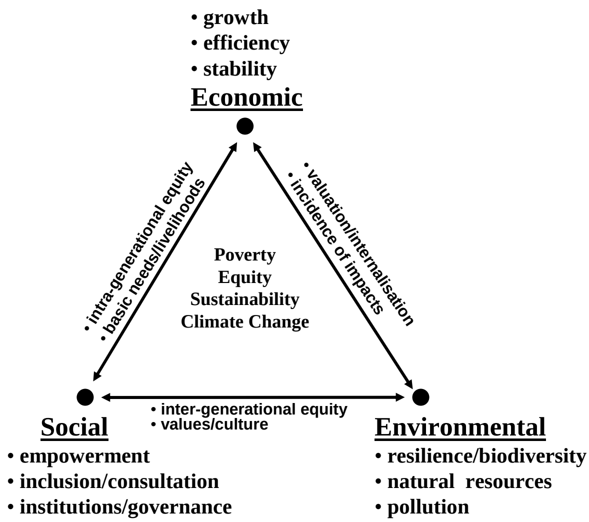
Instead of criticising the shortcomings of other disciplines, sustainomics takes a positive and practical viewpoint by borrowing appropriate methods and tools. Reliance on an eclectic set of concepts and methods does not imply lack of rigour, but rather, underlines the value of diversity in cross-disciplinary thinking. However, concepts drawn from different disciplines may not be mutually consistent, and thus require more efforts to ensure trans-disciplinary integration (see Sections 2.1 to 2.2).

Although MDMS is incremental, it does not imply any limitation in scope (e.g. restricted time horizon or geographic area; see Section 2.1.3). Thus, the effects of specific near term actions on long run sustainable development prospects need to be analysed, within the sustainomics framework. While pursuing the MDMS approach to deal with current problems, we also follow a parallel track by seeking to better define the ultimate goal of sustainable development (see Section 1.3). In particular, it is important to avoid sudden catastrophic ('cliff edge') outcomes, in case our MDMS analysis is too restricted and "myopic". Similarly, incremental analysis may fail to detect serious consequences of large scale changes (see Section 2.5.1). Finally, MDMS encourages us to keep future options open and seek robust strategies which could meet multiple contingencies, thereby increasing resilience and durability (see Section 2.3).

### 2.1.2 Sustainable development triangle and balanced treatment

Current thinking on the concept has evolved to encompass three major points of view: economic, social and environmental, as represented by the sustainable development triangle in Figure 2.1 (Munasinghe, 1992a). It encourages a more integrated and balanced approach. Each viewpoint corresponds to a domain (and system) that has its own distinct driving forces and objectives. The economy is geared mainly towards improving human welfare, primarily through increases in the consumption of goods and services. The environmental domain focuses on protection of the integrity and resilience of ecological systems. The social domain emphasizes the enrichment of human relationships and achievement of individual and group aspirations.

During the preparations for the 1992 Earth Summit in Rio de Janeiro, there was a lively debate on how the "three pillars" (environment, economy and society) might be integrated within development policy. The sustainable development triangle was presented at Rio to emphasize that the sides and interior of the triangle (representing interaction among the three pillars) are as important as the three vertices – e.g. placing an issue like poverty or climate change in the centre reminds us that it should be analysed in all three dimensions (Munasinghe, 1992a). There was considerable resistance to the idea, mainly due to disciplinary rivalries. However, by the time of the 2002 World Summit on Sustainable Development (WSSD) in Johannesburg, the approach had become widely accepted (e.g. GOSL, 2002). Several versions of the triangle are in operational use today (e.g. Hinterberger and Luks, 2001; Odeh, 2005; World Bank, 1996a). For some specialized applications, a fourth vertex such as "institutions" or "technology" has been proposed, converting the triangle into a pyramid. While these additions are useful in specific cases, the original triangle retains its advantages of simplicity and versatility.




Source: adapted from Munasinghe (1992a, 1994a)

*Figure 2.1 Sustainable development triangle – key elements and interconnections (corners, sides, centre).*

Key features of the three vertices of the sustainable development triangle (economic, social, and environmental), are elaborated in Section 2.2. The linkages represented by the sides of the triangle are explained in Section 2.3.5 and Box 2.4 (mainly social-economic, dealing with poverty and equity), Chapter 3 (economic-environmental) and Chapter 4, (environmental-social). Methods of integrating all three dimensions are introduced in Section 2.3. The case studies in Chapters 5 to 16 explore the three dimensions and their interactions – not always comprehensively or symmetrically, because the relative emphasis varies according to the circumstances and policy-relevance. These applications chapters are structured on a spatial scale, from global to local.

The substantive trans-disiplinary framework underlying sustainomics should lead to the balanced and consistent treatment of the economic, social and environmental dimensions of sustainable development (as well as other relevant disciplines and paradigms). Balance is also needed in the relative emphasis placed on traditional development versus sustainability. For example, Southern Hemisphere priorities include continuing development, consumption and growth, poverty alleviation and equity, whereas much of the mainstream literature on sustainable development which originates in the Northern Hemisphere tends to focus on pollution, the unsustainability of growth and population increase.

### 2.1.3 Transcending conventional boundaries for better integration

Sustainable development encompasses all human activities, including complex interactions among socioeconomic, ecological and physical systems. Accordingly, sustainomics encourages practitioners to synthesize novel solutions by transcending conventional boundaries imposed by discipline, values, space, time, stakeholder viewpoint, and operational focus.

**Discipline**

The neologism “sustainomics” underlines the fact that the emphasis is explicitly on sustainable development, and encourages a neutral approach free of any disciplinary bias or hegemony. Several authors suggest that sustainomics represents a new discipline, paradigm or science (e.g. Markandya et al., 2002; Vanderstraeten 2001). We stress that sustainomics is a practical, transdisciplinary framework (or “transdiscipline”), that seeks to establish an overarching, ‘holistic’ design for analysis and policy guidance, while the constituent components (principles, methods and tools drawn from many other disciplines) provide the rigorous ‘reductionist’ building blocks and foundation. It complements rather than replaces other approaches to addressing sustainable development issues.

The multiplicity and complexity of issues involved cannot be covered fully by a single discipline. Hitherto, *multidisciplinary* teams involving specialists from different disciplines, have been applied to sustainable development issues. *Interdisciplinary* work goes a step further by seeking to break down the barriers among various disciplines. However, what is now required is a truly *transdisciplinary* framework, which would bridge and weave the scientific knowledge from diverse disciplines into new concepts and methods, while facilitating a full information exchange among all stakeholders that could address the many facets of sustainable development – from concept to policy and actual practice (Box 2.1). Thus, sustainomics would provide a more comprehensive framework and eclectic knowledge base to make development more sustainable.

The sustainomics approach seeks to integrate knowledge from both the sustainability and development domains (see Chapter 1). Thus, it draws on information from other recent initiatives like ‘sustainability transition’ (McMichael et. Al. 2000; Adams and Jeanrenaud 2008) and ‘sustainability science' (Parris and Kates, 2001; Tellus Institute, 2001). Such a synthesis needs to make use of core disciplines like ecology, economics, and sociology, as well as anthropology, botany, chemistry, demography, ethics, geography, law, philosophy, physics, psychology, zoology etc. Technological skills such as engineering, biotechnology, and information technology also play a key role.

*Box 2.1 Trans-disciplinary methods*

Sustainomics is a neutral expression – the neologism focuses attention on sustainable development without any disciplinary bias. It seeks to integrate insights from other disciplines, and has much in common with other trans-disciplinary methods that attempt to bridge the economy-society-environment interfaces. The approach uses the most recent, practical and appropriate methods to inform and improve policy. Sustainomics is responsive to the context in which it is used, and may be combined flexibly with user judgment.

One closely related field is ecological economics, which combines ecological and economic methods to address a range of problems, and emphasizes the importance of key concepts like the scale of economic activities (Costanza et al., 1997). Environmental and resource economics attempts to incorporate environmental concerns into traditional neoclassical economic analysis (Freeman, 1993; Tietenberg, 1992). Newer areas related to ecological science such as conservation ecology, ecosystem management, industrial ecology and political ecology have birthed alternative approaches to the problems of sustainability, including crucial concepts like system resilience, and integrated analysis of ecosystems and human actors (Holling and Walker, 2003). Key papers in sociology have explored ideas about the integrative glue that binds societies together, while drawing attention to the concept of social capital and the importance of social inclusion (Grootaert, 1998; Putnam, 1993).

The literature on systems, energetics and energy economics has focused on the relevance of physical laws like the first and second laws of thermodynamics (covering mass/energy balance and entropy, respectively). This research has yielded valuable insights into how stocks and flows of energy, matter and information link physical, ecological and socioeconomic systems together, and analysed the limits placed on ecological and socioeconomic processes by laws governing the transformation of 'more available' (low entropy) to 'less available' (high entropy) energy (Boulding, 1966; Georgescu-Roegen, 1971; Hall 1995; Munasinghe, 1990a). Recent work on cultural economics, environmental psychology, economics of sociology, environmental sociology, social psychology, sociological economics, and sociology of the environment, are also relevant. The literature on environmental ethics has explored many issues including the weights to be attached to values and human motivations, decision making processes, consequences of decisions, intra- and inter-generational equity, the 'rights' of animals and the rest of nature, and human responsibility for the stewardship of the environment (Andersen, 1993; Sen, 1987; Westra, 1994; see also various issues of the Elsevier journal *Environmental Ethics*).

Understanding human behaviour is a challenge to all disciplines. For example, both biology and sociology can provide important insights into,this problem, which challenge the 'rational actor' assumptions of neoclassical economics (Box 2.3). Thus, recent studies seek to explain phenomena such as hyperbolic discounting (versus the more conventional exponential discounting), reciprocity, and altruistic responses (as opposed to selfish, individualistic behaviour) (Gintis, 2000; Robson, 2001). Siebhuner (2000) defines '*homo sustinens*' as a moral, cooperative individual with social, emotional and nature-related skills, as opposed to the conventional '*homo economicus*' motivated primarily by economic self interest and competitive instincts. Neoclassical economics has been criticized both for ignoring fundamental physical limitations (Georgescu-Roegen, 1971), and for being mechanistically (and mistakenly) modeled on classical thermodynamics (Sousa and Domingos, 2006).

### Values

Recent and ongoing global crises, as well as emerging problems (see Section 1.2.3), underline the need to transcend unsustainable values that prevail today, especially among the young. This is a key part of building social capital (see Section 2.2.3). For example, greed and over-reliance on uncontrolled market forces (which caused the asset crisis and ensuing economic collapse), ought to be replaced with more ethical and moral principles, including altruism, enlightened self-interest and respect for nature.

### Spatial and temporal scales

The scope of analysis needs to extend geographically from the global to the local scale, cover time spans extending to centuries (for example, in the case of climate change), and deal with problems of uncertainty, irreversibility, and non-linearity. Multi-scale analysis (see Box 2.2), and multi-stakeholder involvement are especially important with growing globalization of economic, social and environmental issues. The case studies in Chapters 5 to 16 are ordered on a spatial scale (global to local).

*Box 2.2 Multi-scale spatial and temporal aspects of sustainable systems*

An operationally useful concept of sustainability must refer to the persistence, viability and resilience of organic, biological and social systems, over their 'normal' life span (see Section 2.2.2). Sustainability is linked to both spatial and temporal scales, as shown in Figure B2.1. The *x*-axis indicates lifetime in years and the *y*-axis shows linear size (both in logarithmic scale). The central circle represents an individual human being – having a longevity and size of the order of 100 years and 1.5 metres, respectively. The diagonal band shows the expected or 'normal' range of life spans for a nested hierarchy of living systems (both ecological and social), starting with single cells and culminating in the planetary ecosystem. The bandwidth accommodates the variability in organisms and systems, as well as longevity.

We may argue that sustainability requires living systems to be able to enjoy a normal life span and function normally, within the range indicated in the figure. Environmental changes that reduce the life span below the normal range imply that external conditions have made the system unsustainable. For example, the horizontal arrow might represent an infant death – indicating an unacceptable deterioration in human health and living conditions. Thus, the regime above and to the left of the normal range denotes premature death or collapse. At the same time, no system is expected to last forever. Indeed, each sub-system of a larger system (such as single cells within a multi-cellular organism) generally has a shorter life span than the larger system itself. If subsystem life spans increase too much, the system above it is likely to lose its plasticity and become 'brittle' – as indicated by the region below and to the right of the normal range (Holling, 1973). Gunderson and Holling (2001) use the term 'panarchy' to denote such a nested hierarchy of systems and their adaptive cycles across scales (see Section 4.1.3).

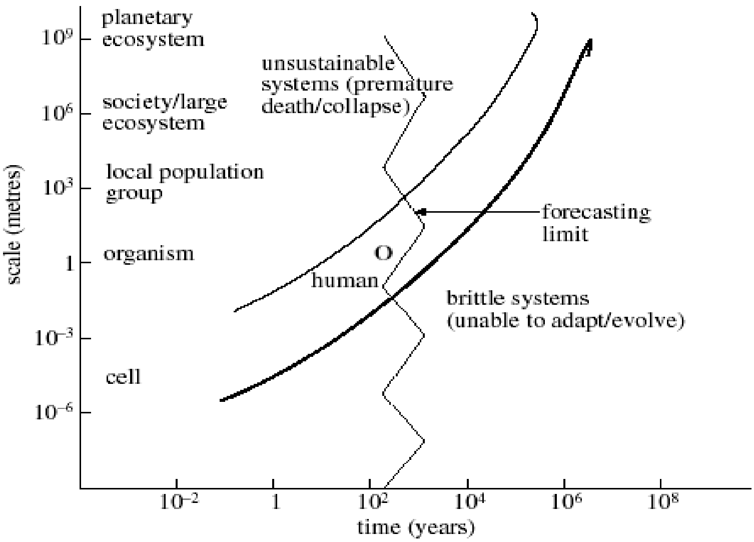



Figure B2.1 Transcending spatial and temporal scales

Forecasting over a time scale of several hundred years is rather imprecise. Thus, it is important to improve the accuracy of scientific analysis, to make very long-term predictions about sustainability more convincing – especially in the context of persuading decision makers to spend large sums of money to reduce unsustainability. The precautionary approach is one way of addressing uncertainty (especially if risks are large), by avoiding unsustainable outcomes using low cost measures, while studying the issue further (see Section 5.2.1).

## Stakeholder viewpoints and operational focus

Sustainomics encourages multi-stakeholder participation through inclusion, empowerment and consultation in analysis and decisionmaking (see Chapter 6). Such processes not only help to build the consensus, but also promote ownership of outcomes and facilitate implementation of agreed policies. Three basic groups – government, civil society, and the business community -- need to collaborate to make development more sustainable at the local, national and global levels. This multi-stakeholder, multi-level breakdown may be further tailored to suit location-specific circumstances (see Chapter 6). The principle of subsidiarity is especially important for good governance, whereby decentralized decisions are taken and implemented at the lowest practical and effective level.

The analytical process is operationally focused. The full cycle includes purposeful data gathering and observations, concepts and ideas, issues, models and analysis, results, remedies, policies and plans, implementation, monitoring, review and feedback. Modern life cycle analysis of products and processes, including supply/value chain analysis, also plays a key role (Gereffi and Kaplinsky 2001).

### 2.1.4 Full cycle application of practical analytical tools

Sustainomics includes a set of analytical tools which facilitate practical solutions to real world problems over the full operational cycle, from data gathering to policy implementation and review. These elements are described in Sections 2.3 and 2.4, including optimality and durability, issues-policy mapping, policy tunneling, Action Impact Matrix, sustainable development assessment, environmental valuation, extended cost-benefit analysis, multi-criteria analysis, life cycle analysis, etc. Practical applications and case studies are provided in Chapters 5-16.

## 2.2 KEY ELEMENTS OF THE SUSTAINABLE DEVELOPMENT TRIANGLE

Chapter 1 described the past evolution of economic, social and environmental thinking within the development paradigm. We elaborate on current ideas in this area and the need for an integrated approach.

### 2.2.1 Economic aspects

Economic progress is evaluated in terms of welfare (or utility) – measured as willingness to pay for goods and services consumed. Thus, economic policies typically seek to increase conventional gross national product (GNP), and induce more efficient production and consumption of (mainly marketed) goods and services. The stability of prices and employment are among other important objectives. At the macrolevel, some researchers have highlighted the role of economic forces like world trade to explain differences in affluence and growth rates of nations (Frankel and Romer, 1999; World Bank, 1993d). Mainstream (neoclassical) economics provides the concepts underlying this framework (Box 2.3).

However, human well being also depends on bodily and mental health status. Often, economic, physical and psychological aspects of well being support each other. For example, good physical health enhances income earning capacity and psychological satisfaction. Most religions emphasize non-material aspects. Typically, Buddhist philosophy (over 2500 years old) classified a comprehensive list of human desires and stressed that contentment is not synonymous with material consumption (Narada, 1988). More recently, Maslow (1970) and others have identified hierarchies of needs that provide psychic satisfaction, beyond mere goods and services. Alkire (2002) reviews the widely varying dimensions of human development (see Section 2.4.2 on indicators).

### Economic sustainability

The modern concept underlying economic sustainability seeks to maximize the flow of income that could be generated while at least maintaining the stock of assets (or capital) which yield this income (Maler, 1990; Solow, 1986). Fisher (1906) had defined *capital* as "a stock of instruments existing at an instant of time", and *income* as "a stream of services flowing from this stock of wealth". Hicks (1946) argued that people's maximum sustainable consumption is "the amount that they can consume without impoverishing themselves". Economic efficiency plays a key role in ensuring optimal consumption and production (Box 2.3).

Many argue that unrestrained economic growth is unsustainable, and point out practical limitations in applying the economic sustainability rule without additional environmental and social safeguards (see weak and strong sustainability in Section 2.3.2). Problems arise in defining the kinds of capital to be maintained (for example, manufactured, natural, human and social capital have been identified) and their substitutability (see section 2.2.2). Often, it is difficult to value these assets and the services they provide, particularly in the case of ecological and social resources (Munasinghe, 1992a). Even key economic assets may be overlooked, e.g. where non-market transactions dominate. Uncertainty, irreversibility and catastrophic collapse also pose difficulties (Pearce and Turner, 1990).

Many commonly used microeconomic approaches rely heavily on marginal analysis based on small perturbations (e.g. comparing incremental costs and benefits of economic activities). From the viewpoint of resilience theory (see Section 2.2.2), such a mildly perturbed system soon returns to its dominant stable equilibrium and thus there is little risk of instability. Thus, marginal analysis assumes smoothly changing variables and is not appropriate for analysing large changes, discontinuous phenomena, and rapid transitions among multiple equilibria. Economic system resilience is better judged by the ability to deliver key economic services and allocate resources efficiently in the face of major shocks (e.g. 1973 oil price shock or severe drought). More recent work is exploring the behaviour of large, non-linear, dynamic and chaotic systems, in relation to system vulnerability and resilience.

*Box 2.3 Key concepts in mainstream economics*

Mainstream economics today is basically Neoclassical economics, although less known alternatives exist, including Austrian, Classical, Evolutionary, Institutional, Marxist and Socialist economics. Neoclassical economics is based on several fundamental assumptions:

1. Individual consumers maximize their utility (or welfare), by making rational choices among goods and services available in the market – this is known as consumer theory.
2. Individual producers maximize their profits, by making rational choices about what outputs to produce, what inputs to use, and what technologies to adopt – this is the producer theory.
3. Individuals act independently, using full and accurate information – known as market

behaviour.

These ideas underlie the concept of “general equilibrium” (associated with Walras), where supply and demand for goods and services balance in all markets. Another key concept involves Pareto (economic) efficiency or optimality, which is a (Walrasian) equilibrium state where no further actions are possible that could make any single person better off (i.e. welfare improvement) without making someone else worse off. Economic efficiency in the real world is measured in relation to the ideal of Pareto optimality (Bator, 1957).

Within the neoclassical economics framework, one intellectual foundation of “capitalism” is the assumption of “perfect competition”. Here, large numbers of consumers compete for homogeneous goods and services, which are produced by many small firms. Neither consumers nor producers have market control – i.e. they must accept the market price. Under certain restrictive conditions, perfect competition could lead to a Pareto efficient outcome, which has become a major argument in favour of “free markets”. In this economist's ideal world, (efficient) prices reflect the true marginal social costs and ensure both efficient allocation of productive resources to maximize output, and efficient consumption choices that maximize consumer utility.

Neoclassical assumptions underlie standard microeconomics – e.g. consumer theory, producer theory, and cost-benefit analysis (see Chapter 3). Mainstream macroeconomic models (e.g. the simple IS-LM analysis described in Section 7.3), are also based on the neoclassical synthesis. The latter combines classical models (based on long term Walrasian market equilibrium, characterized by full employment and price stability) with Keynesian theory (which focuses on short-run disequilibrium phenomena such as unemployment and inflation).

A serious issue arises because the existing income distribution is ignored when strict efficiency criteria are used to determine economic welfare. The result may be unethical, socially inequitable and politically unacceptable, especially if there are large income disparities. For example, the cost-benefit criterion (see Section 3.2) accepts all projects whose net benefits are positive (i.e. aggregate benefits exceed costs). It is based on the weaker ‘quasi’ Pareto condition, which assumes that net benefits could be redistributed from the potential gainers (based on their willingness-to-pay or WTP) to the losers (based on their willingness-to-accept or WTA), so that no one is worse off than before. Such transfers are rarely practical. More generally, interpersonal comparisons of (monetized) welfare are difficult to make – both within and across nations, and over time. Cost-benefit analysis assumes that the marginal utility of each unit consumed is the same for a given individual, and across individuals (irrespective of the levels of consumption).

Perfectly competitive conditions rarely exist in the real world. Distortions due to monopoly practices, externalities (e.g. environmental impacts which are not internalized – see Chapter 3), interventions in the market process through taxes, duties and subsidies, all result in market prices for goods and services which diverge from efficient values. Thus, neither consumption nor production decisions may be efficient. Moreover, the rational actor assumption is also questionable (Box 2.2).

Neoclassical economists have responded to such criticisms – e.g. with “second best” changes, when ideal (first best) conditions do not apply. One example relevant to sustainomics is the use of shadow prices (instead of market prices), to determine optimal investment decisions (via cost benefit analysis) and pricing policies (see Chapter 3). Chapters 7 to 9 also describe examples which seek to incorporate environmental and social concerns into macroeconomic models.

### 2.2.2 Environmental aspects

Unlike traditional societies, modern economies have only recently acknowledged the need to manage scarce natural resources in a prudent manner – because human welfare ultimately depends on ecological services (MA-CF 2003). Ignoring safe ecological limits will increase the risk of undermining long-run prospects for development. Munasinghe (2002b) reviews how economic development and the environment have been linked in the literature since Malthus. Dasgupta and Maler (1997) point out that until the 1990s, the mainstream development literature rarely mentioned the topic of environment (Stern 1989; Chenery and Srinivasan 1988, 1989; and Dreze and Sen 1990). More recent examples of the growing literature on the theme of environment and sustainable development include books by Faucheux et al. (1996) describing models of sustainable development, and Munasinghe et al. (2001) addressing the links between growth and environment. Several researchers argue that environmental and geographic factors have been key drivers of past growth and development (Diamond 1997, Sachs 2001).

#### Environmental sustainability

The environmental interpretation of sustainability focuses on the overall viability and health of living systems – defined in terms of a comprehensive, multiscale, dynamic, hierarchical measure of resilience, vigour and organization (Costanza 2000). These ideas apply to both natural (or wild) and managed (or agricultural) systems, and cover wilderness, rural and urban areas. Resilience is the potential of a system state to maintain its structure/function in the face of disturbance (Pimm 1991; Ludwig et al. 1997; Holling and Walker 2003). An ecosystem state is defined by its internal structure and set of mutually re-enforcing processes. Holling (1973) originally defined resilience as the amount of change that will cause an ecosystem to switch from one system state to another. Resilience is also related to the ability of a system to return to equilibrium after a disruptive shock (Pimm 1984). Petersen et al (1998) argue that the resilience of a given ecosystem depends on the continuity of related ecological processes at both larger and smaller spatial scales (Box 2.2). Adaptive capacity is an aspect of resilience that reflects a learning element of system behavior in response to disturbance. Natural systems tend to be more vulnerable to rapid external changes than social systems – the latter may be able to plan their own adaptation. Vigour is associated with the primary productivity of an ecosystem. It is analogous to output and growth as an indicator of dynamism in an economic system. Organization depends on both complexity and structure of an ecological or biological system. For example, a multicellular organism like a human being is more highly organized (having more diverse subcomponents and interconnections among them), than a single celled amoeba. Higher states of organization imply lower levels of entropy. Thus, the second law of thermodynamics requires that the survival of more complex organisms depends on the use of low entropy energy derived from their environment, which is returned as (less useful) high entropy energy. The ultimate source of this energy is solar radiation.

In this context, natural resource degradation, pollution and loss of biodiversity are detrimental because they increase vulnerability, undermine system health, and reduce resilience (Perrings and Opschoor 1994; Munasinghe and Shearer 1995). Ciriacy-Wantrup (1952) introduced the idea of safe thresholds (also related to carrying capacity), which is important – often to avoid catastrophic ecosystem collapse (Holling 1986, Ekins et al. 2003). Sustainability may understood also in terms of the normal functioning and longevity of a nested hierarchy of ecological and socioeconomic systems, ordered according to scale (Box 2.2).

Sustainable development goes beyond the static maintenance of the ecological *status quo*. A coupled ecological-socioeconomic system may evolve so as to maintain a level of biodiversity that will ensure long term system resilience. Such an ecological perspective supercedes the narrower economic objective of protecting only the ecosystems on which human activities directly depend. Sustainable development demands compensation for opportunities foregone by future generations, because today's economic activity changes biodiversity in ways that will affect the flow of vital future ecological services.

The linkage between and co-evolution of socioeconomic and ecological systems also underlines the need to consider their joint sustainability – Section 2.3.1. In brief, what ecological (and linked socioeconomic) systems need is improved system health and the dynamic ability to adapt to change across a range of spatial and temporal scales, rather than the conservation of some 'ideal' static state (Box 2.2).

### 2.2.3 Social aspects

Society is empowered and encouraged to act now by the MDMS principle of sustainomics. Social development occurs when improvements in both individual well-being and the overall social welfare result from increases in social capital – typically, the accumulation of capacity for individuals and groups of people to work together to achieve shared objectives (Coleman 1990, Putnam 1993). Social capital is the resource which people draw upon in pursuit of their aspirations and is developed through networks and connectedness, membership of more formalized groups and relationships of trust, reciprocity, and exchanges. The institutional component of social capital refers mainly to the formal laws as well as traditional or informal understandings that govern behaviour, while the organizational component is embodied in the entities (both individuals and social groups) which operate within these institutional arrangements. For our purposes we assume that human capital (e.g. education, skills, etc.), and cultural capital (e.g. social relationships and customs) are also included within social capital -- although fine distinctions do exist.

The quantity and quality of social interactions that underlie human existence, including the level of mutual trust and extent of shared social norms, help to determine the stock of social capital. Thus social capital tends to grow with greater use and erodes through disuse, unlike economic and environmental capital which are depreciated or depleted by use. Furthermore, some forms of social capital may be harmful (e.g. cooperation within criminal gangs may benefit them, but impose far greater costs on the larger community).

Equity and poverty alleviation are important – Section 2.3.5. Thus, social goals include protective strategies that reduce vulnerability, improve equity and ensure that basic needs are met. Future social development will require socio-political institutions that can adapt to meet the challenges of modernization -- which often destroy traditional coping mechanisms that disadvantaged groups have evolved in the past.

From the poverty perspective, social capital may be classified into three basic types that overlap in practice: bonds, bridges, and links -- Box 16.1. Bonding social capital is centered on relations of trust and common activities among family, friends and groups within the same community. It helps to create broad-based social solidarity, meet the daily needs of the poor, and reduce their risk vulnerability. Bridging social capital relies on individuals and local groups building connections with nearby communities, as well as regional and national organizations, which share similar values or interests (e.g. credit organizations and livelihood networks that provide social protection and job opportunities). Such bridging has facilitated the emergence of many Non-governmental and Civil Society Organizations. Linking social capital is built on influential associations -- e.g. having access to powerful people or organizations like government ministries and international agencies. Such links are useful to facilitate access to benefits (e.g. loans, jobs, help with small enterprise development, etc.) and lift people out of poverty.

Trust, power and security are also important elements of cognitive social capital. Levels of trust in individuals, groups or institutions provide an indication of the extent of cooperation. Where networks are weak, people generally have lower levels of trust. Power is usually equated with influence and connections. If leaders are distant and do not deliver beneficial changes, people do not recognize them as powerful. Leaders often fail to link with the poorest groups, thereby disempowering them further. Secure relationships play a key role in good governance. Analysis of the dynamics of community relations provides a social map that allows practitioners to tailor specific programmes to targeted groups, thereby creating better opportunities for the poor to participate in decision making.

Recent research has emphasized the role of institutions in explaining differences among nations in terms of economic growth or stagnation – i.e. how behavioral norms govern social conduct, which ultimately determines economic behavior (North 1990, Acemoglu et al. 2001).

**Social sustainability**

Social sustainability parallels the ideas discussed earlier regarding environmental sustainability (*UNEP, IUCN, and WWF 1991*). Reducing vulnerability and maintaining the health (i.e. resilience, vigour and organization) of social and cultural systems, and their ability to withstand shocks, is important (Chambers (1989; Bohle et al. 1994; Ribot et al. 1996). Enhancing human capital (through education) and strengthening social values, institutions and equity will improve the resilience of social systems and governance. Many such harmful changes occur slowly, and their long term effects are overlooked in socio-economic analysis. Preserving cultural capital and diversity across the globe is important – there are about 6000 cultural groups with different languages worldwide, while indigenous cultures (as opposed to state cultures) may represent over 90% of global cultural diversity (Gray 1991). Munasinghe (1992a) drew the parallels between the respective roles of biodiversity and cultural diversity in protecting the resilience of ecological and social systems, and the interlinkages between them. Several subsequent reports from international organizations have highlighted cultural diversity (UNDP 2004, UNESCO 2001). Strengthening social cohesion and networks of relationships, and reducing destructive conflicts, are also integral elements of this approach. An important aspect of empowerment and broader participation is subsidiarity – i.e. decentralization of decision making to the lowest (or most local) level at which it is still effective.

Understanding the links that radiate out from poor communities, and their interface with agencies and government is critical for building connections and channeling resources more directly to make social development more sustainable. Emphasis has sometimes been placed on the formation of new community level organizations, which occasionally undermine existing networks and local groups -- ultimately causing the locals to feel that they have no stake or ownership in the project. Thus, the focus is shifting towards improving governance by giving poor people the right to participate in decisions that affect them. Working with existing community-based social capital generates pathways to lever people upward from poverty. It also results in a more sustainable link with communities, and creates opportunities for more meaningful participation.

## 2.3 INTEGRATION OF ECONOMIC, SOCIAL AND ENVIRONMENTAL ELEMENTS

### 2.3.1 Need for integration

It is important to integrate and reconcile the economic, social and environmental aspects within a holistic and balanced sustainable development framework. Economic analysis has a special role in contemporary national policy making, since many important decisions fall within the economic domain. Unfortunately, mainstream economics which is used for practical policy making has often ignored the environmental and social dimensions of sustainable development. However, there is a small but growing body of literature which seeks to address such shortcomings – e.g. see journals *Ecological Economics* and *Conservation Ecology*.

As a prelude to integration, it is useful to compare the concepts of ecological, social and economic sustainability. One useful idea is that of the maintenance of the set of opportunities, as opposed to the preservation of the value of the asset base (Githinji and Perrings 1992). In fact, if preferences and technology vary through successive generations, merely preserving a constant value of the asset base becomes less meaningful. By concentrating on the size of the opportunity set, the importance of biodiversity conservation becomes more evident, for the sustainability of an ecosystem. The preservation of biodiversity allows the system to retain resilience by protecting it from external shocks, while the maintenance of stocks of manufactured capital protects future consumption. Differences emerge because economics indicates that a society which consumes its fixed capital without replacement is not sustainable, whereas using an ecological approach, unsustainable loss of biodiversity and resilience implies a reduction in the self-organization of the system, but not necessarily a loss in productivity. In the case of social systems, resilience depends to a certain extent on the capacity of human societies to adapt and continue functioning in the face of stress and shocks. Thus, linkages between socio-cultural and ecological sustainability emerge through their interactions, organizational similarities between human societies and ecological systems, and the parallels between biodiversity and cultural diversity. From a longer term perspective, the concept of co-evolution of social, economic and ecological systems within a larger, more complex adaptive system, provides useful insights regarding the harmonious integration of the various elements of sustainable development; see Figure 2.1 and Chapter 4 (Costanza et al., 1997; Munasinghe, 1994; Norgaard, 1994).

*Optimality* and *durability* are two broad approaches that help to integrate the economic, environmental and social dimensions of sustainable development. While there are overlaps between the two methods, the main thrust is somewhat different in each case. Uncertainty often plays a key role in determining which approach would be preferred. For example, a system modeler expecting relatively steady and well-ordered conditions may pursue an optimal solution that attempts to control and even fine-tune theoretical outcomes. Meanwhile, a subsistence farmer facing chaotic and unpredictable circumstances might opt for a more durable and practical response that simply enhances survival prospects.

### 2.3.2 Optimality

The optimality-based approach has been widely used in economic analysis to generally maximize welfare (or utility), subject to the requirement that the stock of productive assets (or welfare itself) is non-decreasing in the long term This assumption is common to most sustainable economic growth models, as reviewed by Pezzey (1992) and Islam (2001). The essence of the approach is illustrated by the simple example of maximization of the flow of aggregate welfare (W), cumulatively discounted over infinite time (t), as represented by the expression:

$$\mathrm{Max}\int_0^{\infty} W(C, Z).e^{-rt}\ dt.$$

where, *W* is a function of *C* (the consumption rate), *Z* (a set of other relevant variables), and *r* is the discount rate. Further side constraints may be imposed to satisfy sustainability needs, e.g. non-decreasing stocks of productive assets (including natural resources). The welfare maximizing, optimality-based approach underlies commonly used economic techniques like shadow pricing and cost-benefit analysis (see Section 3.2).

Some ecological models also optimize variables like energy use, nutrient flow, or biomass production – giving more weight to system vigour as a measure of sustainability. In economic models, utility is measured mainly in terms of the net benefits of economic activities, i.e. the benefits minus the costs (see Chapter 3 and Freeman, 1993 and Munasinghe, 1992a). More advanced economic optimization methods seek to include environmental and social variables (e.g. by valuing environmental externalities, system resilience, etc). However, given the difficulties of valuing such 'non-economic' assets, the costs and benefits associated with market-based activities dominate in most economic optimization models.

Within this framework, the optimal growth path maximizes economic output, while sustainability rules are met by ensuring non-decreasing stocks of assets (or capital). Some analysts support a 'strong sustainability', which requires separate preservation of each type of critical asset (e.g. manufactured, natural, socio-cultural and human capital), assuming that they are complements rather than substitutes (Pearce and Turner, 1990). Others have argued for 'weak sustainability,' which seeks to maintain the aggregate monetary value of total stocks of all assets, assuming that various asset types may be valued and that there is some degree of substitutability among them (Nordhaus and Tobin, 1972).

Side constraints are often necessary, because the underlying basis of economic valuation, optimization and efficient use of resources may not be easily applied to ecological objectives like protecting biodiversity and improving resilience, or to social goals such as promoting equity, public participation and empowerment. Thus, such environmental and social variables cannot be easily combined into a single valued objective function with other measures of economic costs and benefits (see Section 2.4.2 and Chapter 3). Moreover, the price system (which has time lags) might fail to anticipate reliably irreversible environmental and social harm, and non-linear system responses that could lead to catastrophic collapse. In such cases, non-economic measures of environmental and social status would be helpful – e.g. area under forest cover, and incidence of conflict (Hanna and Munasinghe, 1995a,1995b; Munasinghe and Shearer, 1995; UNDP, 1998; World Bank, 1998). The constraints on critical environmental and social indicators are proxies representing safe thresholds, which help to maintain the viability of those systems. Multicriteria analysis facilitates trade-offs among a variety of non-commensurable variables and objectives (see Chapter 3). Risk and uncertainty will also necessitate the use of decision analysis tools. Recent work has underlined the social dimension of decision science, by pointing out that risk perceptions are subjective and depend on the risk measures used, as well as other factors such as ethno-cultural background, socio-economic status, and gender (Bennet, 2000).

### 2.3.3 Durability

The second broad integrative approach focuses primarily on sustaining the quality of life, e.g. by satisfying environmental, social and economic sustainability requirements. Such a framework favours 'durable' development paths that permit growth, but are not necessarily economically optimal. There is more willingness to trade off some economic optimality for the sake of greater safety, in order to stay within critical environmental and social limits – e.g. among increasingly risk-averse and vulnerable societies or individuals who face chaotic and unpredictable conditions (see the precautionary principle in Chapter 5). The economic constraint might be framed in terms of maintaining consumption levels (defined broadly to include environmental services, leisure and other 'non-economic' benefits) – i.e. per capita consumption that never falls below some minimum level, or is non-declining. The environmental and social sustainability requirements may be measured by indicators of 'state' relating to the durability or health (resilience, vigour and organization) of ecological and socio-economic systems. For example, consider a simple durability index ($D$) for an ecosystem measured in terms of its expected lifespan (in a healthy state), as a fraction of the normal lifespan (see Box 2.2). We might specify: $D = D(R,V,O,S)$ to indicate the dependence of durability on resilience ($R$), vigour ($V$), organization ($O$), and the state of the external environment ($S$) – especially in relation to potentially damaging shocks. Further interaction between the sustainability of social and ecological systems may be relevant – e.g. social conflict could exacerbate damage to ecosystems, and vice versa. For example, long-standing social norms in many traditional societies have helped to protect the environment (Colding and Folke, 1997).

Durability encourages a holistic systemic viewpoint, which is important in sustainomics analysis. The self-organizing and internal structure of ecological and socioeconomic systems makes 'the whole more durable (and valuable) than the sum of the parts' (see Chapter 4). A narrow measure of merit based on marginal analysis of individual components may be misleading (Schutz, 1999). For example, it is more difficult to value the integrated functional diversity in a forest ecosystem than the individual species of trees and animals. Therefore, the former is more likely to fall victim to market failure (as an externality). Furthermore, use of simple environmental shadow prices could lead to homogenization and reductions in system diversity (Perrings, Maler and Folke, 1995). Systems analysis helps to identify the benefits of cooperative structures and behaviour, which a more partial analysis may neglect. Durability is also linked to the well-known concept of "satisficing" behaviour, where individuals seek to reach a *minimum* level of satisfaction, without striving to achieve the *maximum* possible value (Simon, 1959).

The possibility of many durable paths favours simulation-based methods, including consideration of alternative world views and futures (rather than one optimal result). This approach is consonant with recent research on integrating human actors into ecological models (Ecological Economics, 2000). Key elements include, multiple-agent modeling to account for heterogeneous behaviour, recognition of bounded rationality leading to different perceptions and biases, and emphasis on social links which give rise to responses like imitation, reciprocity and comparison.

In the durability approach, sustainability constraints could be met by maintaining stocks of assets (as for optimality). Here, the various forms of capital are viewed as a bulwark that decreases vulnerability to external shocks and reduces irreversible harm, rather than mere accumulations of assets that produce economic outputs. System resilience, vigour, organization and ability to adapt will depend dynamically on the capital endowment as well as the magnitude and rate of change of a shock.

### 2.3.4 Complementarity and convergence of optimality and durability

National economic management provides good examples of how the two approaches complement one another. For example, economywide policies involving both fiscal and monetary measures (e.g. taxes, subsidies, interest rates and foreign exchange rates) might be optimized on the basis of quantitative macroeconomic models. Nevertheless, decision makers inevitably modify these economically 'optimal' policies before implementing them, to take into account other sociopolitical considerations based more on durability (e.g. protection of the poor, regional factors), which facilitate governance and stability. Setting an appropriate target for future global GHG emissions (and corresponding GHG concentration) provides another useful illustration of the interplay of the durability and optimality approaches (see Chapter 5, Munasinghe 1998a).

The complementarity and convergence of the two approaches may be practically realised in several ways. First, waste generation should be limited tot rates less than or equal to the assimilative capacity of the environment. Second, the utilization of scarce renewable resources should be limited to rates less than or equal to their natural rate of regeneration. Third, non-renewable resources need to be managed in relation to the substitutability between these resources and technological progress. Both wastes and natural resource input use might be reduced, by moving from the linear throughput to the closed loop mode. Thus, factory complexes could be designed in clusters – based on the industrial ecology concept – to maximize the circular flow of materials and recycling of wastes among plants. Finally, additional aspects should be considered (at least in the form of safe limits or constraints), including inter- and intra-generational equity (poverty alleviation), pluralistic and consultative decision making, and enhanced social values and institutions.

Greenhouse gas mitigation provides one example of how such an integrative framework could help to incorporate climate change policies within a national sustainable development strategy. The rate of total GHG emissions (G) may be decomposed by means of the following identity:

$$G = [Q/P] \times [Y/Q] \times [G/Y] \times P \qquad (2.1)$$

where [Q/P] is quality of life *per capita*; [Y/Q] is the material consumption required per unit of quality of life; [G/Y] is the GHG emission per unit of consumption; and P is the population. A high quality of life [Q/P] can be consistent with low total GHG emissions [G], provided that each of the other three terms on the right hand side of the identity could be minimized (see 'tunnelling' in Section 2.5.2). Reducing [Y/Q] implies 'social decoupling' (or 'dematerialization') whereby satisfaction becomes less dependent on material consumption, through changes in tastes, behaviour and values -- more sustainable consumption. Similarly [G/Y] may be reduced by 'technological decoupling' (or 'decarbonization') that reduces the intensity of GHG emissions in both consumption and production. Finally, population growth needs to be reduced, especially where emissions per capita are already high. The links between social and technological decoupling need to be explored (*IPCC 1999*) -- changes in public perceptions and tastes could affect the directions of technological progress, and influence the effectiveness of mitigation and adaptation capacity and policies. A range of economic and social policy instruments may be used to make both consumption and production patterns more sustainable. Policy tools include market incentives and pricing, legislation and controls, improved technological alternatives, and consumer education (see Chapters 5 and 14).

Climate change researchers are currently exploring the application of large and complex integrated assessment models or IAMs, which contain coupled submodels that represent a variety of ecological, geophysical and socioeconomic systems (IPCC, 1997). Both optimality and durability might be appropriately applied to the various submodels within an IAM.

### 2.3.5 Poverty, equity, population and sustainable natural resource use

This section examines key issues in the nexus of poverty-equity-population-natural resources, from a holistic sustainomics perspective.

#### Dimensions of equity and poverty

Equity and poverty are two important issues, which have mainly social and economic dimensions, and also some environmental aspects (see Figure 2.1). Compelling worldwide statistics were given in Section 1.2. Meanwhile, income disparities are worsening – the per capita ratio between the richest and the poorest

20 percentile groups was 30 to 1 in 1960 and over 60 to 1 by 2000.

Equity is an ethical and people-oriented concept with primarily social, and some economic and environmental dimensions. It focuses on the fairness of both the processes and outcomes of decision making – e.g. ensuring equal opportunities and avoiding extreme deprivation. The equity of an action may be assessed in terms of several approaches, including parity, proportionality, priority, utilitarianism, and Rawlsian distributive justice. Rawls (1971) stated that "Justice is the first virtue of social institutions, as truth is of systems of thought". Societies seek to achieve equity by balancing and combining several of these criteria.

Economic policies aiming to increase overall human welfare have been used for poverty alleviation, improved income distribution and intra-generational (or spatial) equity (Sen 1981, 1984; Durayappah 1998). Brown (1998) points out shortcomings in the utilitarian approach, which underlies the economic approach to equity. Broadly speaking, economic rules provide guidance on producing and consuming goods and services more efficiently, but are unable to choose the most equitable outcome among alternative patterns of efficient consumption. Equity principles provide better tools for making judgments about such choices.

Social equity is also linked to sustainability, because highly skewed or unfair distributions of income and social benefits are less likely to be acceptable or lasting in the long run. Equity will be strengthened by enhancing pluralism and grass-roots participation in decision making, as well as by empowering disadvantaged groups -- defined by income, gender, ethnicity, religion, caste, etc. (Rayner and Malone 1998). In the long term, considerations involving inter-generational equity and safeguarding the rights of future generations, are key factors. In particular, the economic discount rate plays a key role with respect to both equity and efficiency aspects (Arrow et al. 1995b). Box 2.4 reviews links between social equity and economic efficiency within the sustainomics framework.

Equity in the environmental sense has received more attention recently, because of the disproportionately greater environmental damages suffered by disadvantaged groups. Thus, poverty alleviation efforts (that traditionally focused on raising monetary incomes) are being broadened to address the degraded environmental and social conditions facing the poor. Martinez-Allier (2004) argues that the poor who rely more directly on natural resources are often good environmental managers, whereas the rich impose a more harmful environmental footprint through the indirect effects of their consumption. Munasinghe (1997) challenges the common belief that poverty and population growth *per se* are harmful to nature, which conceals a crucial equity issue -- the poor although more numerous consume far less than the rich (see below). Ethics and equity in relation to climate change, are discussed in Section 5.2.3.

*Box 2.4 Interactions between social equity and economic efficiency*

Conflicts between economic efficiency and equity may arise during the definition, comparison and aggregation of the welfare of different individuals or nations. For example, efficiency implies maximization of output subject to resource constraints, assuming that increases in average income *per capita* will make most or all individuals better off. However, if the income distribution becomes less equitable, overall welfare might drop depending on how welfare is defined in relation to income distribution. Conversely, total welfare may increase if policies and institutions ensure appropriate resource transfers – typically from rich to poor.

Aggregating and comparing welfare across and within different countries is also a disputable issue. Gross National Product (GNP) is a measure of the total economic output of a country, and does not represent welfare directly. Aggregating GNP within a nation may not be a valid measure of total welfare. However national economic policies frequently focus more on GNP growth rather than its distribution, implying that additional wealth is equally valuable to rich and poor alike, or that there are mechanisms to redistribute wealth in an equitable way. Attempts have been made to incorporate equity considerations within an economic framework, by weighting costs and benefits so as to favour the poor. Although systematic procedures exist for determining such weights, often the arbitrariness in assigning weights has caused practical problems.

At the same time, it should be recognized that all decision making procedures do assign weights (arbitrarily or otherwise). For example, progressive personal income taxes are designed to take proportionately more from the rich. On the other hand, traditional cost-benefit analysis (CBA) based on economic efficiency assigns the same weight to all monetary costs and benefits – irrespective of income levels. More pragmatically, in most countries the tension between economic efficiency and equity is resolved by keeping the two approaches separate, e.g. by maintaining a balance between maximizing GNP, and establishing institutions and processes charged with redistribution, social protection, and provision of basic needs. The interplay of equity and efficiency at the international level is shown later, in the climate change case study.

In summary, both equity and poverty have not only economic, but also social and environmental dimensions, and therefore, they need to be assessed using a comprehensive set of indicators (rather than income distribution alone). From an economic policy perspective, emphasis needs to be placed on expanding employment and gainful opportunities for poor people through growth, improving access to markets, and increasing both assets and education. Social policies would focus on empowerment and inclusion, by making institutions more responsive to the poor, and removing barriers that exclude disadvantaged groups. Environmentally related measures to help poor people might seek to reduce their vulnerability to disasters and extreme weather events, crop failures, loss of employment, sickness, economic shocks, etc. Thus, an important objective of poverty alleviation is to provide poor people with assets (e.g. enhanced physical, human and financial resources) that will reduce their vulnerability. Such assets increase the capacity for both coping (i.e. making short-run changes) and adapting (i.e. making permanent adjustments) to external shocks (Moser 1998).

The foregoing ideas merge quite naturally with the sustainable livelihoods approach to poverty alleviation. We identify three key aspects of livelihoods that are important for the sustainability of poverty programs (Munasinghe 2003). First, there are gainful activities that people engage in, ranging from formal, full-time employment to seasonal, informal and ad-hoc jobs, which provide only a bare subsistence income in both urban and rural settings. Second, access to productive assets and the services they provide are important. Economic assets consist of the familiar manufactured capital like machines and buildings. Key environmental assets, which draw on the base of natural capital are often overlooked. Social capital is equally important and includes social, political and other processes and institutions, which facilitate human interactions, and are linked to values, culture and behavioural norms. Third, there are rights and entitlements, which are especially important for poor and destitute groups to meet basic needs for survival (Sen, 1981). Other authors have identified five types of assets that are important for sustainable livelihoods: human, social, natural, physical and financial (Carney, 1998).

An even broader non-anthropocentric approach to equity involves the concept of fairness in the treatment of non-human forms of life or even inanimate nature. One view asserts that humans have the responsibility of prudent ‘stewardship’ (or ‘trusteeship’) over nature, which goes beyond mere rights of usage (Brown, 1998).

### Population and natural resource use

The linkage between population and natural resource use is also complex, and needs to be studied in the context of poverty and equity (Munasinghe, 1995a). Sustainomics encourages us to take a balanced view, where people are seen as a resource, and not necessarily an unsustainable burden. One general belief is that the growth of poor population is harmful to natural resources, starting with Malthus (1798); see Section 7.1.1. For example, a widely cited article on conservation of wild living resources (Mangel et al., 1996) asserts provocatively that “the only practicable way to reduce human per capita resource demand is to stabilize and then decrease the human population” (our emphasis). This proposition is misleading and detracts from the overall content of an otherwise authoritative and comprehensive paper. No convincing evidence exists to link per capita natural resource demand with population size. Even the link between *total* resource use and population is complex and cannot be captured adequately by a simple statement.

Consider the earlier equation (2.1), rewritten to show total natural resource use as: $N = [N/P] \times P$. Here $P$ is the population, and $[N/P]$ is per capita natural resource use. An exclusive focus on population control is one-sided, because high levels of per capita consumption are as much to blame for resource depletion as is simple population growth. Currently, a mere 15 per cent of the world’s rich population consume over sixteen times as much as the almost 60 per cent of the poor population (and will do so for the foreseeable future). A more equitable and balanced viewpoint would recognize the implications of both population and per capita consumption for sustainability. Furthermore, the growth rates of per capita consumption and population among the rich should be matters of greater concern, than the same indices among the poor.

Environmental degradation, population and poverty are known to form a nexus with complex interactions (see Section 4.2.6). The poor are the most frequent victims of both pollution and resource degradation usually caused by the rich -- which is inequitable. At the same time, there are macro-circumstances in which the landless poor are forced to encroach on fragile lands, eventually degrading their own environment (Munasinghe and Cruz, 1994). A comprehensive multi-agency report argued recently that poverty alleviation requires environmental protection, and that both objectives should be pursued simultaneously (DFID et al., 2002). Grima, Horton and Kant, (2003) discuss reconciliation of the opposing viewpoints of ecologists favouring natural resource sustainability, and economists promoting development and poverty alleviation, under four different themes – institutions, ecotourism, measurement indicators, and fragile lands. Meanwhile, population growth itself depends on many factors, including not only the highly visible elements like family planning programmes, but also deeper underlying factors such as education level (especially of women), the status of women, family income, access to basic needs and financial security (Dasgupta, 1993).

A simple mathematical exposition suggests that the common wisdom linking population growth with natural resource depletion is not necessarily as straightforward as it seems (Munasinghe, 1997b). Consider a society which has a population $P$ and a stock of natural resources $N$. One useful indicator of the sustainability of natural resource stocks would be the ratio $R = N/P$. More specifically, one might seek a development path in which this ratio was non-decreasing. Thus, sustainability would require that $dR/dt \geq 0$. A more convenient sustainability rule may be defined as:

$$S = (dR/dt) / R = [(d/dt)\,(W/P)] \,/\, [W/P] \;\geq\; 0$$

It is possible to decompose the measure $S$ to show the distinct effects of growth in natural resource stocks and growth in population. Assuming that $N = N(P,t)$ and $P = P(t)$, we obtain:

$$S = [(\partial W/\partial t)/N\,] - \{[(dP/dt)/P]\,[1 - e]\};\quad \text{where } e = (\partial N/\partial P)/(W/P)$$

Clearly, the first term […] is positive if $(\partial W/\partial t) > 0$; that is, $S$ rises as natural resource stocks increase over time, holding population constant. However, the sign of the second term {…} depends on the sign of both $(dP/dt)$ and $(1 - e)$. Thus, reducing the population $(dP/dt < 0)$ will increase sustainability $S$, only if $e < 1$. The opposite condition $e > 1$ is more likely to prevail if $N/P$ is low to begin with and $\partial N/\partial P$ is relatively high: for example, if mild population growth stimulates greater efforts towards protecting and increasing resource stocks. One example might be a community living in an arid area. If the human population dwindles, the natural progress of desertification could well proceed unimpeded. By contrast, a growing and thriving population (with increasing income levels) is likely to devote more efforts towards environmental protection, ensuring that the condition $e>1$ is maintained.

Rapid declines in population growth rates have serious demographic implications -- as many countries are discovering today. The base of the population pyramid shrinks as birth rates drop and the population ages, leaving a smaller group of productive young people to support an increasing fraction of elderly and dependent persons. Some countries have responded by encouraging immigration to increase the labour force. The policy implications of an aging population include a radical rethinking of many serious issues including the retirement age, encouraging more productive activity among the elderly, rebalancing social insurance contributions and pension payments, etc.

The foregoing argument may be summarized as follows. While it is ‘fashionable’ to automatically assume that people are a threat to natural resources and sustainability, a good case may be made for considering human beings as a valuable resource for sustainable development (see Section 4.3.2). Human and natural resources are complementary. Furthermore, human attitudes towards the environment and their patterns of economic activity are at least as important as the number of people. From a sustainomics perspective, if scarce environmental resource stocks are at risk, building human and social capital through enhanced education, training, health, and other social services could be the key to unlocking the potential of poor people and converting a perceived liability into an asset. The third element of the sustainable development triangle (economic resources) could also play a role through improved technology to reduce the pressure on mineral and living wild resources.

To conclude, if both per capita resource demand and population are examined more even-handedly, some promising options for conservation of natural resources will emerge. A background factor that cannot be ignored is that economic growth is a prime imperative for developing countries, especially ones with large numbers of poor and destitute people. Section 2.5 shows how growth could be re-structured to make development more sustainable, and how policies might be tailored to find a more sustainable path or “tunnel” (see Figure 2.4).

## 2.4 TOOLS AND METHODS FOR INTEGRATED ANALYSIS AND ASSESSMENT

Some important tools and methods that may be used for integrated analysis and assessment are summarized below. Given the vast scope of sustainable development, the “tool kit” is eclectic and by no means exhaustive. The idea is to provide the sustainomics practitioner with a selection of key methods. Later chapters provide practical applications, indicating tools that are appropriate under various circumstances.

### 2.4.1 Action impact matrix (AIM)

The Action Impact Matrix (AIM) is a multi-stakeholder consultative approach that facilitates the integration of the social, economic and environmental dimensions of development, identifies and prioritises key interactions among them, and determines policies and projects that make development more sustainable. The method has been widely used since the early 1990s, and was originally presented as part of the sustainomics framework, at the 1992 Rio Earth Summit (Munasinghe 1992a). Initially, it was used to integrate a range of environmental and social concerns into development planning (Munasinghe 1994a, 1997, 2002a, 2006), and later, adapted to address specific issues like climate change, energy and water (Munasinghe 2002b, Munasinghe and Swart 2005, MIND 2004).

#### Basic procedure

Typically, the AIM is used as a strategic tool to better understand inter-linkages among critical elements, at the country-specific level:
(a) major national development policies and goals; and (b) key sustainable development vulnerabilities and issues– e.g. relating to economic sectors, ecological systems, and social factors.

The AIM process begins with an ex-ante analysis of the two-way linkages between the fundamental elements (a) and (b) – i.e. the effects of (a) on (b), and vice versa. By explicitly linking development goals with key economic-environmental-social issues, the AIM identifies potential barriers to sustainable development, and helps to determine the priority strategies that will overcome them.

The approach uses a fully participative multi-stakeholder exercise to generate the AIM itself. Up to 50 analysts and experts are drawn from government, academia, civil society and the private sector, who represent various disciplines and sectors relevant to both sustainable development and other issues relevant to the exercise. Initially, the stakeholders interact intensively over a period of about two days, to build a preliminary AIM. This participative process is as important as the product (i.e. the AIM), since important synergies and cooperative team-building activities emerge. The collaboration helps participants to better understand opposing viewpoints, resolves conflicts, builds ownership, and facilitates implementation of agreed policy remedies. On subsequent occasions, the updating or fine-tuning of the initial AIM can be done quickly by the same group, since they are already conversant with the methodology.

For maximum effectiveness, the AIM workshop needs to be carefully prepared by trained instructors who conduct the exercise, documentation (e.g. AIM Guide), screening and pre-selection of a balanced group of participants, and advance gathering of relevant background data.

The AIM methodology draws on the basic principles and methods of the sustainomics framework described earlier in this chapter, including a focus on making development more sustainable (MDMS), balanced consideration of the sustainable development triangle, emphasis on transcending boundaries, and full cycle application of integrative tools – where the AIM plays a key role. Thus, the AIM is the key link from initial data gathering to practical policy application and feedback.

The AIM process consists of the following key steps:

<u>*Screening and Problem Identification*</u>

a) Determine the most important development goals and policies (DG) – matrix rows.
b) Determine key sustainable development vulnerabilities and issues (VI) – matrix columns.
c) Determine the current status of VI – matrix cells.
d) Identify how DG might affect VI (Matrix DEV) – matrix cells.
e) Identify how VI might affect DG (Matrix VED) – matrix cells.

<u>*Analysis, Prioritisation and Remediation*</u>

f) Analyse and prioritize most important interactions and determine appropriate remedial policies and measures.
g) Perform more detailed studies and analysis of key interactions and policy options identified in step f above.
h) Update and refine steps (c) to (f) above.

Two matrices are derived, representing the two-way links:.

1. Matrix DEV – effects of development goals and policies on vulnerabilities and issues (DG → VI).
2. Matrix VED – effects of vulnerabilities and issues on development goals and policies (VI → DG).

To summarize, AIM rows show national development goals and policies (DG) and columns indicate sustainable development vulnerabilities and issues (VI). The cells of the two preliminary matrices identify broad relationships between DG and VI, provide a quantitative and qualitative idea of the magnitudes of the key interactions, help to prioritize the most important links, and facilitate formulation of appropriate policy responses. Meanwhile, the organization of the overall matrices facilitates the tracing of impacts, as well as the coherent articulation of the links among development activities (policies and projects).

The AIM process is flexible and may be adapted in various ways to address different problems. Typical examples include:

1. Once the preliminary AIM is prepared, priority linkages may be pursued in two complementary ways:

(a) Upward link: where SD vulnerability concerns are embedded in the macroeconomic and sectoral development strategy of a country via the mediumto long-term sustainable development path.

(b) Downward link: where SD vulnerability concerns are integrated into the subnational-level development strategy in the short- to medium-term, by carrying out sustainable development assessments aimed at making specific projects and policies more sustainable.

2. After completing a national level AIM exercise, it is possible to apply the process at a subnational or community level, to fine-tune the analysis.

3. In a subsequent step, the impacts of other major external factors (such as climate change, natural disasters, rising oil prices, etc.) may be overlaid on the primary interaction between national development goals and policies (DG) and sustainable development vulnerabilities and issues (VI).

A practical application of the AIM procedure is provided in Section 6.3

### 2.4.2 Other methods and indicators

#### Sustainable development assessment (SDA)

Sustainable development assessment (SDA) is an overarching methodology (with many components), which is used in evaluating investment projects (as well as programmes and policies), to ensure balanced analysis of both development and sustainability concerns. The 'economic' component of SDA is based on conventional economic and financial analysis (including cost benefit analysis, as described below and in Chapter 3). The other two key components are environmental and social assessment (EA and SA) – see Chapter 4 (World Bank 1998). However, many other more specialized types of assessments may be included within an integrated SDA.

Economic, environmental and social analyses need to be integrated and harmonised within SDA. Historically, Environmental Assessments (EA) and Social Assessments (SA) had developed as separate processes. However, a full appreciation of all impacts requires a thorough understanding of all biophysical and social changes invoked as a result of planned interventions. Biophysical impacts have social impacts, and social changes also affect the biophysical environment. Recent work attempts to integrate biophysical and social impacts using a conceptual framework which is consistent with sustainomics, and this has led to a better understanding of the full extent of human impacts as well as the impact pathways that result from such interventions (e.g. Lee and Kirkpatrick 2000). Green (2001) shows a practical application to mining.

There is increasing interest in exploring various integrated approaches for sustainable development assessment (SDA), to facilitate research, policy planning and decision making (Boulanger and Brechet 2002). Among the growing list of more specialised forms of appraisal are social assessment, health assessment, risk assessment, climate assessment, development impact assessment, poverty assessment and environmental assessment, and gender impact assessment.

This increase in number of different components within the SDA framework has brought about an increasing number of difficulties. At the procedural level it has become more difficult to coordinate the timings of separate appraisals and to synchronise this with decisions made about the project. At the methodological level, there is an increasing likelihood of inconsistencies between the appraisal methods used, of interdependencies between certain types of impacts, and of increasing difficulties in constructing an overall appraisal for use in decision making. At the organizational level, the workload has increased considerably, due to the burdens of managing and coordinating separate appraisals and multi-disciplinary teams as part of the project planning and management process. The weaknesses in this aspect by aspect approach include the risk of misjudgment of impacts and overlooking of better alternative solutions based on taking cross-cutting issues into account (Brown 1998). Projects appraised in this manner risk failure as their formulation is biased or incomplete. In an ideally integrated SDA approach, different assessments are no longer required and the project officer would be presented with an integrated overall picture, covering all choices that can be made.

Various degrees of integration could be done. For example, procedural tuning of the various sectoral assessments may create sufficient overlap in the timing of assessments so that different assessment teams have the opportunity to communicate and exchange findings. Assefa (2005) argues that SDA may be combined with traditional technology assessment (TA) and systems analysis to provide an integrated, holistic approach.

Development cooperation has resulted, so far, in less than optimal project quality. Initially development cooperation targeted only economic and technical goals. As awareness grew, policy themes relating to culture, equity, gender, environment, and institutional capacity emerged. An integrated approach would overcome the weaknesses of an aspect-by-aspect approach, leading to a more optimal project formulation and that would simplify project decision making.

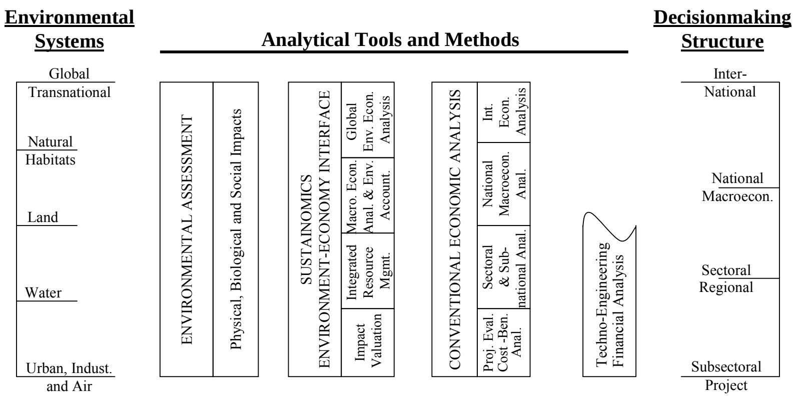
Since the sustainable development goal has independent economic, social and environmental components, it is argued that appraisal procedures and methodologies should use interconnected economic, social and environmental appraisal criteria which are consistent with achieving this goal. There is a clear need to strengthen SDA methods to use at a more strategic level of decision making relating to development policies, plans and programmes (see Section 3.4).

Traditional decision making relies heavily on economics. Thus, an initial practical step towards integration would be the systematic incorporation of environmental and social issues into the economic policy framework of human society – e.g. using the Issues-Policy Transformation Mapping (ITM) method.

### Issues-policy transformation mapping (ITM)

Issues-policy transformation mapping (ITM) is a method of integrating and applying various components of SDA (like environmental and social assessments) within the policy process. Figure 2.2 provides an example of how environmental issues are transformed and mapped into implementable actions and policies in the decision making domain. The right-hand side of the diagram indicates the hierarchical nature of conventional decision making and implementation in a modern society.

The global and transnational level consists of sovereign nation states. In the next level are individual countries, each having a multisector macroeconomy. Various economic sectors (like industry and agriculture) exist in each country. Finally, each sector consists of different subsectors and projects. The usual decision making process on the right side of the figure relies on techno-engineering, financial and economic analyses of projects and policies. In particular, conventional economic analysis has been well developed in the past, and uses techniques such as project evaluation/cost-benefit analysis (CBA), sectoral/regional studies, multisectoral macroeconomic analysis, and international economic analysis (finance, trade, etc.) at the various hierarchic levels.




Source: Munasinghe (1992).

*Figure 2.2 Issues-policy transformation mapping (ITM) to incorporate sustainable development issues into conventional decisions.*

Unfortunately, environmental and social analysis cannot be carried out readily using the above decision making structure. We examine how environmental issues might be incorporated into this framework (with the understanding that similar arguments may be made with regard to social issues). The left side of the figure shows one convenient environmental breakdown in which the issues are:

- global and transnational (e.g. climate change, ozone layer depletion);
- natural habitat (e.g. forests and other ecosystems);
- land (e.g. agricultural zone);
- water resource (e.g. river basin, aquifer, watershed); and

- urban-industrial (e.g. metropolitan area, airshed).

In each case, a holistic environmental analysis would seek to study an integrated biogeophysical system in its entirety. Complications arise when such natural systems cut across the structure of human society. For example, a large and complex forest ecosystem (like the Amazon) could span several countries, and also interact with many economic sectors within each country.

The causes of environmental degradation arise from human activity (ignoring natural disasters and other events of non-human origin), and therefore, we begin on the right side of the figure. The ecological effects of economic decisions must then be traced through to the left side. The techniques of environmental assessment (EA) have been developed to facilitate this difficult analysis (World Bank 1998). For example, destruction of a primary moist tropical forest may be caused by hydroelectric dams (energy sector policy), roads (transport sector policy), slash and burn farming (agriculture sector policy), mining of minerals (industrial sector policy), land clearing encouraged by land-tax incentives (fiscal policy), and so on. Disentangling and prioritizing these multiple causes (right side) and their impacts (left side) needs a complex analysis.

Figure 2.2 also shows how sustainomics could play its bridging role at the ecology-economy interface, by transforming and mapping the EA results (measured in physical or ecological units) onto the framework of conventional economic analysis. A variety of environmental and ecological economic techniques including valuation of environmental impacts (at the local/project level), integrated resource management (at the sector/regional level), environmental macroeconomic analysis and environmental accounting (at the economywide level), and global/transnational environmental economic analysis (at the international level), facilitate this process of incorporating environmental issues into traditional policy making. Since there is considerable overlap among the analytical techniques described above, this conceptual categorization should not be interpreted too rigidly. Furthermore, when economic valuation of environmental impacts is difficult, techniques such as multi-criteria analysis (MCA) would be useful (see below).

Once the foregoing steps are completed, projects and policies must be redesigned to reduce their environmental impacts and shift the development process towards a more sustainable path. Clearly, the formulation and implementation of such policies is itself a difficult task. In the deforestation example described earlier, protecting this ecosystem is likely to raise problems of coordinating policies in a large number of disparate and (usually) non-cooperating ministries and line institutions (i.e. energy, transport, agriculture, industry, finance, forestry, etc.).

Analogous reasoning may be readily applied to social assessment (SA) at the society-economy interface, in order to incorporate social considerations more effectively into the conventional economic decision making framework. In this case, the left side of the figure would include key elements of SA, such as asset distribution, inclusion, cultural considerations, values and institutions. Impacts on human society (i.e. beliefs, values, knowledge and activities), and on the biogeophysical environment (i.e. both living and non-living resources), are often interlinked via second and higher order paths, requiring integrated application of SA and EA. This insight also reflects current thinking on the co-evolution of socio-economic and ecological systems (see Chapter 4).

In the framework of the figure, the right side represents a variety of institutional mechanisms (ranging from local to global) which would help to implement policies, measures and management practices to achieve a more sustainable outcome. Implementation of sustainable development strategies and good governance would benefit from the trans-disciplinary approach advocated in sustainomics. For example, economic theory emphasizes the importance of pricing policy to provide incentives that will influence rational consumer behaviour. However, cases of seemingly irrational or perverse behaviour abound, which might be better understood through findings in areas like behavioural and social psychology, and market research. Such work has identified basic principles that help to influence society and modify human actions, including reciprocity (or repaying favours), behaving consistently, following the lead of others, responding to those we like, obeying legitimate authorities, and valuing scarce resources (Cialdini 2001).

### Cost-benefit analysis (CBA) and multi-criteria analysis (MCA)

Cost-benefit analysis (CBA) is the main tool for economic and financial assessment. It is a single valued approach based on neoclassical economics (Box 2.3), which seeks to assign monetary values to the consequences of an economic activity. The resulting costs and benefits are combined into a single decision making criterion like the net present value (NPV), internal rate of return (IRR), or benefit-cost ratio (BCR). Useful variants include cost effectiveness, and least cost based methods. Both benefits and costs are defined as the difference between what would occur *with and without* the project being implemented. The economic efficiency viewpoint usually requires that shadow prices (or opportunity costs) be used to measure costs and benefits. All significant impacts and externalities need to be valued as economic benefits and costs. However, since many environmental and social effects may not be easy to value in monetary terms, CBA is useful mainly as a tool to assess economic and financial outcomes. Chapter 3 provides further details.

Multi-criteria analysis (MCA) or multi-objective decision making is particularly useful in situations when a single criterion approach like CBA falls short – especially where significant environmental and social impacts cannot be assigned monetary values (see Chapter 3). In MCA, desirable objectives are specified and corresponding attributes or indicators are identified. Unlike in CBA, the actual measurement of indicators does not have to be in monetary terms – i.e. different environmental and social measures may be developed, side by side with economic costs and benefits. Thus, more explicit recognition is given to the fact that a variety of both monetary and non-monetary objectives and indicators may influence policy decisions. MCA provides techniques for comparing and ranking different outcomes, even though a variety of indicators are used.

### Life cycle analysis and supply/value chains

Full life cycle analysis can facilitate more sustainable consumption and production by using supply and value chains to capture the complete range of inputs and activities that firms and workers use to deliver products and services. The approach describes all stages of production and consumption from conception to end use and beyond, typically including raw material production, design-manufacture-processing, logistics-distribution, marketing-retail, consumer use, recycling and disposal. Supply/value chains can be contained within a single firm or spread over many different firms. They can be local or global.

Table 2.1 illustrates how this approach can make development more sustainable by pinpointing key points of intervention (Munasinghe et al. 2009). In the case of light-bulbs, 95% of carbon emissions occur in the home, and therefore, the best method of reducing emissions is to encourage energy conservation by changing the light switching behaviour of consumers. For imported orange juice, the highest fraction of emissions occurs during distribution (i.e., transport), which offers the best potential for emissions mitigation, while for milk, emissions reduction efforts should be focused on the raw material production (i.e., farm).

*Table 2.1 Life cycle analysis across product categories showing very different percentage carbon emission patterns along the supply/value chain*

| Raw material production | Manufacture processing | Logistics distribution | Retail | Use by consumer | Recycling & disposal |
|---|---|---|---|---|---|
| Light bulb (UK 11W) | | | | | |
| 2% | | 1% | 1% | **95%** | 1% |
| Orange Juice (Brazil freshly squeezed 1L) | | | | | |
| 28% | 19% | **47%** | 5% | 1% | 0% |
| Milk (UK, National Tesco) | | | | | |
| **76%** | 5% | 4% | 10% | 3% | 1% |

Source: Adapted from Munasinghe et al. (2009)

### Other specific models and methods

The subsequent chapters contain other methods and models which are specific to particular applications and adapted to the sustainomics approach, including:

- Integrated assessment models (IAM)

- Macroeconomic models (simulation, growth, computable general equilibrium - CGE, etc.)
- Green Accounting (integrated national economic-environmental accounting or SEEA),
- Sectoral approaches (sustainable energy development - SED, sustainable transport development - STD, sustainable water resources management - SWARM, sustainable hazard reduction and management - SHARM, etc.)
- Shadow pricing and costing methods (economic efficiency, social equity, environmental externalities, separable costs remaining benefits allocation - SCRB, etc.)
- Integrated resource pricing (energy – LRMC based, water, etc.)

### Indicators and measures

The practical implementation of sustainomics principles and application of integration tools will require the identification of specific economic, social and environmental indicators, that are relevant at different levels of aggregation ranging from the global/macro to local/micro. It is important that these measures of sustainable development be comprehensive in scope, multi-dimensional in nature (where appropriate), and account for spatial differences. If we wished to apply the full cycle analysis approach of sustainomics (see Sections 2.1.3 and 2.1.4) to trace causal linkages, one useful classification of indicators would be by pressure, driver, state, impact, and response. For example, consider the following chain (see Chapter 5): underlying *pressure* – societal values and tastes; immediate *driver* – greater use of sport utility vehicles (SUV); *state* – increased GHG concentrations; *impact* – global warming; *policy response* – tax on SUVs and consumer education to encourage more sustainable behaviour.

A wide variety of indicators are described already in the literature (Adriaanse, 1993; Alfsen and Saebo, 1993; Azar, Homberg and Lindgren, 1996; Bergstrom, 1993; Eurostat, 2006; Gilbert and Feenstra, 1994; Holmberg and Karlsson, 1992; Kuik and Verbruggen, 1991; Liverman et al., 1988; Moffat, 1994; Munasinghe and Shearer, 1995; OECD, 1994; Opschoor and Reijnders, 1991; UN, 1996; UNCSD, 2007; UNDP, 1998; World Bank, 1998). We discuss briefly below, how measuring economic, environmental (natural), human and social capital raises various problems. In the economic dimension, the word "capital" or "asset" implies stock of wealth to produce economic goods and services. Social and environmental assets have a broader meaning, as discussed below.

Manufactured capital may be estimated using conventional neoclassical economic analysis. As described later in the section on cost-benefit analysis, market prices are useful when economic distortions are relatively low, and shadow prices could be applied in cases where market prices are unreliable (see, e.g. Squire and van der Tak, 1975).

Natural assets need to be quantified in terms of key biophysical attributes. Typically, damage to natural capital may be assessed by the level of air pollution (e.g. suspended particulates, sulphur dioxide or GHGs), water pollution (e.g. biological-oxygen demand (BOD) or chemical-oxygen demand (COD)) and land degradation (e.g. soil erosion or deforestation). Then the physical damage could be valued using a variety of techniques based on environmental economics (see Chapter 3, Freeman, 1993; Munasinghe, 1992a; Tietenberg, 1992).

Social capital is the one that is most difficult to assess (Grootaert, 1998). Putnam (1993) described it as 'horizontal associations' among people, or social networks and associated behavioural norms and values, which affect the productivity of communities. A somewhat broader view was offered by Coleman (1990), who viewed social capital in terms of social structures, which facilitate the activities of agents in society – this permitted both horizontal and vertical associations (like firms). An even wider definition is implied by the institutional approach espoused by North (1990) and Olson (1982), that includes not only the mainly informal relationships implied by the earlier two views, but also the more formal frameworks provided by governments, political systems, legal and constitutional provisions etc. Recent work has sought to distinguish between social and political capital (i.e. the networks of power and influence that link individuals and communities to the higher levels of decisionmaking). Human resource stocks may be measured in terms of the value of educational levels, productivity and earning potential of individuals. Chopra (2001) argues that one key measure of social capital especially relevant to development of poor communities is the cooperation between individuals across the traditional divides separating state, market and non-market institutions.

Currently, there is no universally accepted aggregate measure of sustainable development to rival economic indicators of welfare like GDP (whose shortcomings are discussed in Chapters 3 and 7). While many alternative indicators have been suggested by individual researchers, measures proposed by UN organizations are more widely known, including the human development index (UNDP, 2005b), wealth stocks (World Ban,k 2006), and environmentally adjusted national accounts (UN, 2003); see Section 3.7.5. The UN Commission on Sustainable Development proposes a set of social, economic, environmental and institutional indicators. Data for most nations are available through the "Dashboard of Sustainability" -- a versatile and effective tool which allows users to select various sustainable development indicators, aggregate them appropriately, and apply them at different geographic scales and for specific years (CGSDI, 2006). This tool also contains the MDG indicators, currently the most important framework for development policy. IISD (2006) provides further information on indicators.

## 2.5 RESTRUCTURING DEVELOPMENT AND GROWTH FOR GREATER SUSTAINABILITY

A wide range of recent ideas on long term growth and sustainable development was introduced earlier in Section 1.4. The same theme is pursued further in this section, with a focus on restructuring to make development more sustainable. Growth is a major objective of almost all developing countries – especially the poorest ones. This promise cannot be fulfilled unless economic growth is sustained into the long term. The developing countries need to ensure that their endowments of natural resources are not taken for granted and squandered. If valuable resources such as air, forests, soil, and water are not protected, development is unlikely to be sustainable – not just for a few years, but for many decades. Furthermore, on the social side, it is imperative to reduce poverty, create employment, improve human skills and strengthen institutions.

### 2.5.1 Harmonizing development with nature

Next, let us examine the alternative growth paths available, and the role of sustainomics principles in choosing options. Lovelock (1975) made a pioneering contribution with his Gaia hypothesis. He proposed that the totality of life on earth might be considered an integrated web which works together to create a favourable environment for survival. As a corollary, unregulated expansion of human activity might threaten the natural balance. In this spirit, Figure 2.3(a) shows how the socioeconomic subsystem or "anthroposphere" (solid rectangle) has always been embedded within a broader biogeophysical system or "biogeosphere" (large oval). National economies are inextricably linked to, and dependent on natural resources – since everyday goods and services are in fact derived from animate and inanimate resources that originate from the larger biogeosphere. We extract oil from the ground and timber from trees, and we freely use water and air. At the same time, such activities continue to expel polluting waste into the environment, quite liberally.

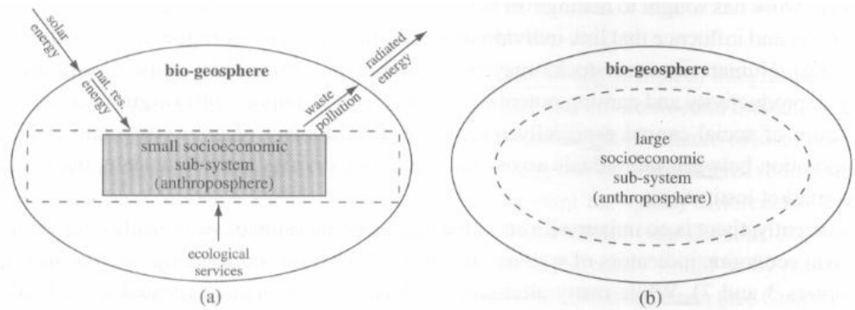



*Figure 2.3 Restructuring development to make the embedded socioeconomic sub-system (anthroposphere) more sustainable within the broader bio-geosphere. (a) Unsustainable; (b) Sustainable.*
Source: Munasinghe (1992)

The broken line in Figure 2.3(a) symbolically shows that in many cases, the scale of human activity in the anthroposphere has increased to the point where it is now impinging on the underlying biogeophysical system (see Chapter 3). This is evident today, if we consider that forests are disappearing, water resources are being polluted, soils are being degraded, and even the global atmosphere is under threat. Consequently, the critical question involves how human society might contain or manage this problem of scale?

One traditional view causing confusion among world leaders is the assumption that concern for the environment is not necessarily good for economic activity. Thus, until recently the conventional wisdom held that it was not possible to have economic growth and a good environment at the same time, because they were mutually incompatible goals. However, the more modern sustainomics viewpoint indicates that growth and environment are complementary. One key underlying assumption is that it is often possible to devise so-called ‘win-win’ policies, which lead to economic as well as environmental gains (Munasinghe et al., 2001). As shown in Figure 2.3(a), the traditional approach to development has led to a situation where the economic system impinges harmfully on the boundaries of the ecosystem. On the other hand, Figure 2.3(b) summarizes the modern approach that would allow us to have the same level of prosperity without severely damaging the environment. In this case, the oval outer curve is matched by an oval inner curve, where economic activities have been restructured more harmoniously with the ecosystem.

### 2.5.2 Changing the structure of growth

The importance of changing the structure of development and growth is illustrated in Figure 2.4, which shows how environmental risk in a country (e.g. GHG emissions per capita) might vary with the level development (e.g. GNP per capita).

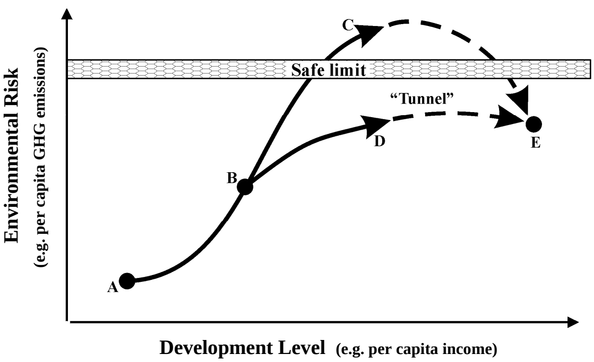


*Figure 2.4 Environmental risk versus development level*
Source: Adapted from Munasinghe (1995a)

One would expect carbon emissions to rise more rapidly during the early stages of development (along *AB*), and begin to level off only when per capita incomes are higher (along *BC*). A typical developing country may be at a point such as *B* on the curve, and an industrialized nation at *C*. Ideally, industrial countries (exceeding safe limits) should increase environmental protection efforts and follow the future growth path *CE*. Munasinghe (1995a, 1999a) proposed the idea of developing countries adopting policies to "tunnel" through (along *BDE*), by learning from past experiences of the industrialized world – the tunnel would lie below the safe limit where environmental damage (like climate change or biodiversity loss) could become irreversible.

Such a tunnel also corresponds to a more economically optimal path, and resembles "turnpike" growth paths which appeared in past literature (Burmeister and Dobell, 1971). The highly peaked path *ABCE* could result from economic imperfections that make private decisions deviate from socially optimal ones. Corrective policies would help to reduce such divergences and permit movement through the tunnel *BDE*. Developing countries could thereby avoid severe environmental degradation along conventional development paths of industrial economies (*ABCE*). This approach is not concerned with the related issue of the existence of the so-called environmental Kuznets curve for any single country or group of nations. Instead, "tunneling" focuses on identifying policies to delink environmental degradation and economic growth (Munasinghe, 1995a, 1999a; Opschoor, 1998b).

Chapter 7 describes several ways to find such a policy "tunnel":

1. Actively seek 'win-win' policies that simultaneously yield both economically and environmentally (and socially) sustainable paths.
2. Use complementary policies. Growth inducing economywide policies could combine with imperfections in the economy to cause environmental and social harm. Rather than halting economic growth, complementary measures may be used to remove such imperfections and thereby prevent excessive environmental and social harm. Such measures include, ex-ante environmental (and social) assessment of projects and policies, introducing remedies that eliminate imperfections (like policy distortions, market failures and institutional constraints), and strengthening capacity for environmental and social protection.
3. Consider the fine-tuning of growth inducing economywide policies (e.g. altering their timing and sequencing), especially where severe environmental and social damage could occur.

It would be fruitful to encourage a more proactive approach whereby the developing countries could learn from the past experiences of the industrialized world – by adopting sustainable development strategies and climate change measures which would enable them to follow development paths such as BDE, as shown in the figure (Munasinghe, 1998b). Thus, the emphasis is on identifying policies that will help delink carbon emissions and growth, with the curve in Figure 2.4 serving mainly as a useful metaphor or organizing framework for policy analysis.

This representation also illustrates the complementarity of the optimal and durable approaches discussed earlier. It has been shown that the higher path ABC in the figure, could be caused by economic imperfections which make private decisions deviate from socially optimal ones (Munasinghe, 1998c). Thus the adoption of corrective policies that reduce such divergences from optimality and thereby reduce GHG emissions per unit of output, would facilitate movement along the lower path *ABD*. Concurrently, the durability viewpoint also suggests that flattening the peak of environmental damage (at *C*) would be especially desirable to avoid exceeding the safe limit or threshold representing dangerous accumulations of GHGs (shaded area in the figure).

Several authors have econometrically estimated the relationship between GHG emissions and per capita income using cross-country data and found curves with varying shapes and turning points (Cole, Rayner and Bates, 1997; Holtz-Eakin and Selden, 1995; Sengupta, 1996; Unruh and Moomaw, 1998). One reported outcome is an inverted U-shape (called the environmental Kuznet's curve or EKC) – like the curve *ABCE* in Figure 2.4. In this case, the path *BDE* (both more socially optimal and durable) could be viewed as a sustainable development 'tunnel' through the EKC (Munasinghe, 1995a; 1999a).

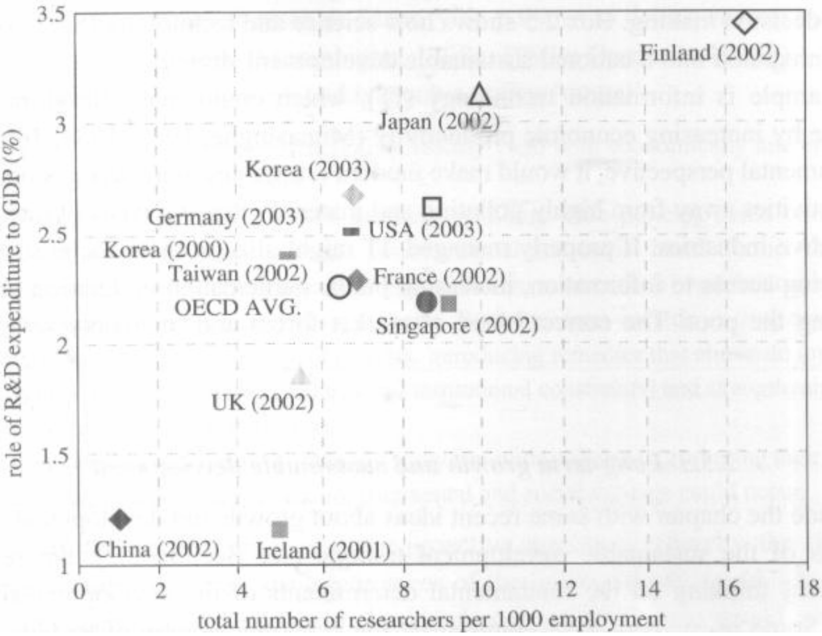
In the above context, it would be fruitful to seek specific interventions that might help to make the crucial change in mindset, where the emphasis would be on the structure of development, rather than the magnitude of growth (conventionally measured). Sustainomics promotes environmentally- and socially-friendly technologies, which use natural resource inputs more frugally and efficiently, reduce polluting emissions, and facilitate public participation in decision making. Box 2.5 shows how science and technology (S&T) policy may be better integrated into national sustainable development strategy.

One example is information technology (IT), which could make development more sustainable by increasing economic productivity (Munasinghe, 1987, 1989, 1994a). From an environmental perspective, it would make modern economies more services oriented -- by shifting activities away from highly polluting and material intensive types of manufacturing and extractive industries If properly managed, IT might also promote social sustainability, by improving access to information, increasing public participation in decision making, and empowering the poor. The correct blend of market forces and regulatory safeguards are required.

*Box 2.5 Science and technology for making development more sustainable*

Making development more sustainable (MDMS), will require science and technology (S&T) and research methods that are in harmony with the new sustainable development paradigm, human values and social institutions (see Section 1.2). Sustainomics encourages a more holistic, transdisciplinary analysis and solutions. This view is confirmed by findings in basic areas like quantum physics and complexity theory, as well as applied disciplines like economics, sociology and ecology, which show that everything is interdependent. Many of our current problems have arisen because we have ignored increasingly important interconnections -- given the rapidly growing scale of human activity and consequent impacts on both natural and socioeconomic systems. A new synthesis is needed that combines the dominant Cartesian analytical, reductionist methods of modern science (which have made great advances in knowledge possible), with the more holistic philosophies of the past (which stress interdependence at all levels). Sustainomics seeks to use S&T to address current major world issues and make development more sustainable (see Section 1.2), rather than to reverse progress and go back to some pre-technological state. Ultimately, we wish to make a fundamental long term transition to a global sustainable society (see Figure 1.1).

Worldwide investments in R&D (both public and private) are large and growing. For example, the largest R&D spenders USA and China allocated US $ 330 and 136 billion for this purpose in 2006 (FT 2006a, b). Meanwhile, Ford and Samsung spent about US $ 8 and 5.5 billion, respectively, on R&D during 2005 and 2006. Figure B2.2 shows R&D expenditures and the number of researchers in scientifically advanced countries. In some cases, the north-south S&T divide is narrowing, with the growing capabilities and accomplishments of scientists, and more effective policies in scientifically advanced developing nations (Hassan, 2005). Typically, China and India invest 1 to 1.5% of GDP on S&T and are emerging as world leaders in key areas. However, there is a disturbing south-south gap emerging between the scientifically proficient countries (e.g. Brazil, China, India) and lagging ones (e.g. sub-Saharan Africa).




Source: Ministry of Science and Technology Database, Korea.

Figure B2.2. R&D expenditures and number of researchers in selected countries.

It is widely agreed that building S&T capacity is critical to harnessing knowledge for development. S&T innovation may be promoted by strengthening S&T capacity that focuses on (1) solving priority problems; (2) supporting key sectors; and (3) improving decision making (Watkins et al., 2007). Sustainomics provides the framework for such actions.

Sustainomics promotes an S&T policy that is better integrated into national sustainable development strategy and objectives. Such a mainstreaming approach enable scientists to make clear to decision makers and senior officials, what the key linkages and priorities might be, and how to identify practical options and implement solutions. Ultimately, national policies should not only guide public investments in research and development (especially education and capacity building), but also provide incentives to encourage corresponding activity in the private sector and make effective use of market forces. It would require developing strategic policy tools (like Action Impact Matrix – AIM), and applying them through multi-disciplinary, multi-stakeholder teamwork and consultations.

The AIM methodology (see Section 2.4) has been used to identify and prioritise impacts of investments in key S&T areas (like agro-, bio-, energy, information, medical, micro- and nano-, technologies, and indigeneous sciences and knowledge) on major national sustainable development goals and policies (like growth, poverty alleviation, food security, employment, health, etc.). A more sophisticated two stage AIM process is also possible, where the first matrix identifies impacts of S&T on key economic sectors, and the second determines effects of sectoral developments on national SD goals and policies (MIND, 2004). The convolution of the two AIMs yields the desired links between S&T areas and SD goals and policies.

While sensible public policy interventions could be very beneficial, prudence suggests that such policy should be flexible, encourage innovation, and avoid locking-in specific technologies for long periods -- because future scientific discoveries and their outcomes are unpredictable. Every innovation that solves one set of problems is likely to create new ones. One example is nuclear technology, which has both peaceful and military uses. Another key example is the race between S&T progress (which improves resource productivity and reduces costs), and problems caused by the greater consumption it stimulates. Almost 150 years ago, Jevons (1865) set out his famous paradox concerning energy use: “It is wholly a confusion of ideas to suppose that the economical use of fuel is equivalent to diminished consumption. The very contrary is the truth … every improvement of the engine … accelerates anew the consumption of coal”. In this same vein, at the turn of the 19$^{th}$ century transport experts warned that the streets of London would soon be knee-deep in horse droppings because of the growth of traffic. This issue was resolved with the advent of the “horseless carriage” (motor car) in the early 20$^{th}$ century. However, rising oil use, traffic jams and urban air pollution from cars again caused pessimism in the post-World War 2 period. In recent decades, mobility management and more energy efficient and less polluting vehicles, have eased the problem, and new technologies (like hydrogen fueled cars) offer further hope. This type of cycle will undoubtedly continue, unless we focus more on the MDMS approach.

### 2.5.3 Long term growth and sustainable development

We conclude the chapter with some recent ideas about growth and development. The three dimensions of the sustainable development triangle (see Section 2.2), are reflected in contemporary thinking on the fundamental determinants of the developmental status of countries. Some researchers have emphasized the economic engine of trade as the main driver of growth and development (World Bank, 1993, Frankel and Romer, 1999). Others feel that natural environment, climate and location represented broadly by geography and resource endowments are the dominant influences that explain the difference between development and stagnation (Diamond, 1997; Sachs, 2001). Finally, a third argument has been advanced that social forces are important in explaining wide income variations between rich and poor countries. They emphasize the role of institutions – i.e. how explicit and implicit behavioral norms govern social conduct, and ultimately determine economic behavior (Acemoglu et al., 2001; North, 1990). A more integrated viewpoint is provided by the concept of long term co-evolution of socioeconomic and ecological systems within a more complex adaptive system (see Section 2.3.1). Munasinghe et al. (2001) provide a wide range of current ideas on the complex links between long term growth and sustainable development, by leading researchers in the world.

### Growth and sustainability

Opschoor (2001) explores the negative relationships between economic growth and environmental sustainability, while proposing institutional and moral reforms to promote sustainable development. Norgaard (2001) illustrates some basic problems with rapid growth, discusses some myths concerning economic growth, and finally outlines an agenda based on ecological economics to go beyond growth and globalization. Hinterberger and Luks (2001) deal with competitiveness (economic development), employment (social development), and dematerialization (environmental sustainability) in a rapidly globalizing world. A fourth 'corner' is added to the sustainable development triangle (institutions – which was embedded within the social dimension in Figure 2.1) -- forming a pyramid. Ocampo (2001, 2007) advocates consolidation of strong institutions for sustainable development in Latin America and the Caribbean, and argues that price reforms are less effective than technical change.

### General analytical frameworks

Daly (2001) shows how traditional marginal analysis in microeconomics, which fails to internalize environmental and social externalities, will lead to overestimation of macroeconomic GNP. Globalization is pushed by powerful transnational corporations to weaken the nation state, leading to uneconomic growth, increased population, greater inequality, increased unemployment and environmental harm. Sachs (2001) seeks to integrate development (economic), human rights (social) and environment. He disputes the usefulness of valuing ecosystems, since it may promote unbalanced agreements on intellectual property rights, and the unsustainable privatization of all natural capital and ecosystem services. Because ecological economics addresses social issues inadequately, a new discipline is proposed, along the lines of sustainomics. Naredo (2001) argues that even recent valuation methods such as the pollution analysis, life-cycle analysis and the new System of National Accounts (SNA) are inadequate for sustainable development, because they mainly incorporate the monetary values but not the underlying physical information. He proposes a complementary approach that would allow more accurate calculations of the physical cost of recovering mineral resources from the earth's crust. Gasco et. al. (2005) apply a physical input-output table (PIOT) to evaluate total water resources and gross annual availabilities at each stage of the natural-artificial water cycle in order to assess the importance of above-/below-ground hydrological links in the decision making in order to provide a satisfactory supply of water in Spain

### Modeling applications

Kadekodi and Agarwal (2001) show that the shape of the Environmental Kuznets Curve (EKC) depends upon the capital intensity of the energy-based natural resource-using sectors, during the process of economic development (see Section 2.5.2). Factor price changes that favour labour-intensive goods will affect the shape of the curve. Tsigas et al. (2001) use a modified global, applied general equilibrium model to suggest that trade liberalization in the Western Hemisphere coupled with harmonization of environmental policy will benefit all countries, although environmental quality may decline in Mexico and Brazil. Batabyal, Beladi and Lee (2001) explain how developing countries (DCs) have attempted to improve their balance of payment positions and develop manufacturing industries, by actively following a policy of encouraging import-substituting industrialization. Brazil, Mexico, Pakistan and the Philippines have used the infant industry argument to apply trade policies that systematically protect the manufacturing sectors. Baer and Templet (2001) use the Greenhouse Limitation Equity Assessment Model (GLEAM) to analyse global climate mitigation policies (see Chapter 5). They conclude that per capita allocations of greenhouse gas emissions permits produce the greatest average welfare levels – with feasible emission scenarios that stabilize $CO_2$ at less than twice pre-industrial levels. Hansen (2001) compares the merits of five different methods for estimating the capital consumption of non-renewable resource rents, and shows how the discount rate, depletion period, and depletion path influence the outcome. Neumayer (2001) criticizes the World Bank "genuine savings" method, which appears to show that many Sub-Saharan, North African, Middle Eastern and other countries have failed to pass the test of weak sustainability (see Section 2.3.2). These results are reversed if the alternative El Serafy method is used, with a relatively low discount rate of 4%. The genuine savings concept is unreliable because it depends on a dynamic optimization framework, whereas most economies develop along non-optimal paths.