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THE ENVIRONMENTAL CRITIQUE OF THE ECONOMIC PROCESS AND SOME IMPLICATIONS FOR ECONOMIC ANALYSIS*

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1 INTRODUCTION

In an earlier paper[1] I reviewed the history of economic thought for contributions influencing and shaping the new sub-discipline of what is now Environmental Economics. As theory this subject area developed slowly during the 1960s and 1970s, but it became a true growth industry in the development of economics since the late 1980s, through increased public interest in improving environment policy at the national and global scales.

In brief, it was shown that the classical economists of the late 18th and 19th century paid much attention to the long term dynamic interaction of population growth and diminishing returns to land. Technological change became looked upon as a hoped for palliative, to postpone the inevitable coming of the stationary state. The mode of analysis tended to be somewhat abstract, and the conclusions appeared pessimistic. Economic theory was not a separate university level subject matter (Kastelein, et.al. 1990, Chapter 2). David Ricardo nor John Stuart Mill worked in a university environment. Economics became primarily an academic discipline only in the last decades of the 19th century. It acquired a reputation as a 'dismal science'.

Neo-classical economics emerged around the turn of the 20th century. It predominantly concerned itself with issues of short-term allocative efficiency achievable through market-based processes under the impact of the price mechanism. The approach and content followed the early codification and synthesis of Marshall's *Principles of Economics* (1890). A 'body of economic theory' became progressively formalised in 'modern' standard economics textbooks from the 1950s. In turn, these texts were increasingly used around the world, across countries and continents, as if this type of analysis had universal relevance and applicability, and regardless of social, cultural and political differences.

Throughout the 19th and much of the 20th century a methodological conflict existed among economists between those inclined to abstract reasoning and calling upon logic, and on the other hand critics of this approach and its scientific aspirations, such as historians and institutionalists. The sentiments of Alfred Marshall, a key figure at the cross-roads of these various strands of thinking, and in the transition from the 19th to the 20th century, may be illuminating. For these sentiments shed light on the manner in which they helped define and shape a new 'professionalism in economics'. In turn, economic theorizing thereby tended to distance itself not only from those economists working on the 'real economy', such as historicists and institutionalists, but also vis-à-vis other social sciences.

Marshall dominated academic economics in Cambridge at that period, and he judged his academic colleagues and students primarily on their ability to think analytically. In this sense, he did not highly value philosophers with interest in economics or historians: 'I want, however, to keep my hold on the historical men: they are Kittle-kattle, and yet important'. Regarding more developed economic theory and statistics, he was of the view 'that it is not suitable for men of the Historical type - intelligent, more or less earnest, but not very profound...'. He therefore made a sharp distinction between the 'literary' and the 'scientific' economists. Mathematics enabled clarity in thought and analysis, in contradistinction to the confusion which, among 'literary' economics, and according to Marshall, was rampant and widespread. Analytic ability was the criterion to distinguish the *insiders* (professionals) and the *outsiders*. This distinction also determined in no mean measure his preference for his successor Arthur Cecil Pigou (Kastelein, et. al., 1990. 52).

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[1] Aart van de Laar (1996), *Economic Theory and the Natural Environment: A Historical Overview*, Working Paper Series No 209, Institute of Social Studies. January.

As was shown in my earlier paper, it took a long time for neo-classical economics to acknowledge the existence of 'externalities' in economic theory, the unintended outcomes of market processes. Moreover, it was shown that such externalities, seen as 'market failures', are not minor exceptions to the general case of viewing the economic process as the sum total of market-based transactions, but are universal when placed in the context of the natural environment. All economic processes influence air, water and land quality.

The review of the history of economic thought has also shown that there is little of relevance to a theory of the nature, scale and scope of the state in a market economy. In economic theory the state is treated as the provider of 'pure public goods', but that is a vague and expandable concept (Musgrave, 1959). Key events shaping actual economic development trends in the first half of the 20th century were: two world wars, a devastating economic depression in the 1930s and the impact of the socialist experiment in the Soviet Union after 1917.

The relative growth of the state in the OECD countries in the first half of the 20th century, as indicated by rising shares of government taxation, the build-up of a welfare state with features of (1) government-assumed tasks of stabilization of the economic process, (2) provision of social safety nets and (3) realising redistributive political policy objectives through extensive transfer payments systems, did not emerge by planning or a *grand design*. These developments simply happened.

The long term consequences of this much expanded role of the state in an increasingly globally integrated world system only gradually became apparent. It became a serious problem in the third quarter of the 20th century, after the Golden Age of rapid generalised growth of the world economy during the 1950s and 1960s began to falter.

While the role of the state in a market economy is thus unclear, there is a clear and urgent need to focus analytic economic theory attention on the role of the state in matters of the natural environment, and in environmental policy, where 'market failure' is widespread. Especially for future environmental policy, and in the absence of markets, a balance needs to be struck between state and market. In view of the global level of a growing range of environmental problems, the concept of the state and governance is also to be considered at different levels and scales: from the regional to the national and the international level.

The conflict between economic theory as an aspiring science, and the historicists/institutionalists as sketched above and in my earlier paper, is only one unsettled and unsettling issue. A second potential conflict, especially important for the development of environmental economics, is whether the conceptualisation of the economic process by economic theory is at all relevant to the 'real world', seen as a geobiophysical entity. If there is a basic 'mismatch' at this level of primary definition and conceptualisation, it will be very difficult indeed to establish meaningful interaction between economists and natural scientists in respect of linking future environmental management with development policy, in a context of the Brundtland's report on *Our Common Future* (WCED, 1987). Moreover, if the economists' perception of the economic process is basically wrong or at least seriously flawed, all economic theorizing on the basis of this poor foundation will be suspect, especially when economic theory, as environmental economics, aspires to a role in environmental policy analysis and design. Thus, a confrontation between economists' and natural scientists' perceptions of the economic process is a necessary first step towards communication and dialogue.

In light of the above considerations the objectives of the present paper, as a complement to my earlier paper (see Van de Laar, 1996, Introduction), are the following:

1 to contrast economic and environmental conceptualisations of the economic process, which leads to different conceptions of what should be the aims of economic policy. This is done step by step in Sections 2 through 5.

2 to show how economists and natural scientists have different conceptions of the meaning of scarcity of natural resources. This often leads, as shown in Section 6, to dismissal of each other's viewpoint.

3 to show how the environmental conceptualization of the economic process leads to a range of issues which economic analysis should usefully address, but which it has largely ignored. Several such issues are discussed in Sections 7 and 8.

In addition, where the earlier paper argued (p 41-42) that natural scientists have to develop environmental standards and indicators of environmental health and stress, to assist them facing up to the growing necessity of having to consider trade-offs (Munasinghe and Shearer, 1995; Kuik and Verbruggen, 1991), it has to be stated that standard economic performance indicators, though further advanced and internationally standardised, are basically misleading.
Therefore, this paper also aims:

4 to critically look at conventional indicators of economic performance from an environmental perspective, and at attempts by both economists and natural scientists to improve upon indicators measuring the state of the economy and of the natural environment. This is done in Section 9.

The paper thus aims to illustrate and possibly clarify differences between economists and natural scientists. The future is clearly to forge better cooperation and interaction between economists and natural scientists in tackling the important issues of coming to grips with the implications of linking development and environmental perspectives. Historical empirical research is by definition backward looking, and thus can be no firm guide to the future, particularly not under conditions of unprecedented and unparalleled large rates of change in key parameters on a global scale. Nevertheless, careful historical empirical research could provide some insights in the nature of changes that have actually occurred in response to different forms and intensities of environmental stress on populations. Messy statistics on environmental trends are sought and have become available over the last 20 years. And a guide to some basic findings may be of more use for further study that attempting to work towards abstract mathematical elegance which already is threatening the development of environmental economics as a discipline.

2 CIRCULAR VERSUS LINEAR VIEWS OF THE ECONOMIC PROCESS

The environmental critique of the economic system centres on the distinction between the economic system as a *circular system*, as against a *linear system*.

Kenneth Boulding has been among the first prominent economists to forcefully draw to the attention of the economics profession the relevance of the fundamental laws of thermodynamics for the manner in which the economics profession had come to conceptualize the economic system, especially after the Keynesian revolution of the 1940s and 1950s (Boulding, 1966). Boulding is a former (1968) president of the *American Economic Association*, and recipient of the John Bates Clark medal of the AEA, given every other year to 'that American economist under the age of forty who is adjudged to have made a significant contribution to economic thought and knowledge' (Blaug, 1985, 22-23).

While Mishan had stated in 1965 that welfare economics and positive economics cannot reach conclusions applicable to the real world without some knowledge of the real world (cited in Ayres and Kneese, 1969: 282), Boulding argued that the economists' perceptions of the 'real world' were quite wrong, because economists do not understand the natural sciences and the natural characteristics of earth itself.

Interpretation of the relationships between the human enterprise and Earth's life support systems seem, in fact, to be rather wide apart between ecologists and economists. Holdren, Daily and Ehrlich (1995, 12) argue that members of both groups tend to be highly self-selected and to differ in fundamental world views. Most ecologists have a passion for the natural world, where the existence of limits to growth and the consequences of exceeding those limits are apparent. Ecologists recognize that human ingenuity has vastly increased the capacity of the planet to support *Homo Sapiens*; nonetheless, they perceive humans as being ultimately subject to the same sorts of biophysical constraints that apply to other organisms.

Economists, in contrast, tend to receive little or no training in the physical and natural sciences. Few explore the natural world on their own, and few appreciate the extreme sensitivity of organisms - including those upon which humanity depends for food, materials, pharmaceuticals, and free ecosystem services - to seemingly small changes in environmental conditions. The narrow education and inclinations of economists in these respects are thus a major source of disagreements with environmentalists about sustainability.

Ayres and Kneese (1990: 90) state:

> However elegant the standard neoclassical (Walrasian) model of the economic system may be, it does not represent the real world at all well. It has properly been criticized as a system devoid of human beings and a spuriously deterministic one at that. Milton Friedman once described it as a form of analysis without much substance.

Boulding (1966) evocatively distinguished between the *cowboy economy* and the *spaceman economy*. Primitive men imagined themselves to be living on a virtually illimitable plane. There was always a frontier as some place else to go, when life got too difficult either by reason of the deterioration of the natural environment or a deterioration of the social structure. But gradually men has to accustom himself to the notion of a spherical earth and a closed sphere of human activity.

Economists, he argued, have failed to come to grips with the ultimate consequences of the transition from the earth as an open plain or prairie to the closed earth: *Spaceship Earth*. In a *closed system*, the outputs of all parts of the system are linked to the inputs of other parts. There are no inputs from outside and no outputs to the outside, for there is no outside. The environment may be defined as a system comprising the earth's living things and the thin global skin of air water and soil, which is their habitat. Within this ecosphere, the basic functional element is the ecological cycle, in which each separate element influences the behaviour of the rest of the cycle, and is in turn influenced by it.

This view of a *closed economy* should be clearly distinguished from the *circular economy* as in modern text books in economics. The standard textbook representation of the economic process is of a circular diagram, a pendulum movement between production and consumption within a circular system, with all flows being completely reversible. The Walrasian model is essentially circular and closed. It posits abstract resources being converted endlessly into abstract goods and services, to be 'consumed' by abstract labour and finally back into resources. This is a kind of perpetual motion machine (Georgescu-Roesen, 1993a, 75). Also in Marx's famous diagram of reproduction, the economic process is represented as a completely circular and self-sustaining affair.

The primary limiting factors of production are perceived, in both neoclassical and marxist economic analysis, to be human labour and man-made capital.

This *circular economy* is *disembodied from the natural world*. Since both nature's capacity and human ingenuity are seen as boundless, there is little conceptual possibility for the combination of the accumulation of damage and the depletion of resources to eventually limit production and human opportunity (Colby, 1990: 9; Pearce and Turner, 1990, Chapter 2).

From a natural science perspective the economic process is nothing but the transformation of matter and energy, where the *Laws of Thermodynamics* apply. Linking the laws of thermodynamics from the natural sciences to economics is mostly due to the work of Nicholas Georgescu-Roesen: *The Entropy Law and the Economic Process* (1971). Georgescu-Roesen defines entropy as 'an index of the amount of unavailable energy in a given thermodynamic system at a given moment of its evolution' (Georgescu-Roesen, 1993). For the critique of Roesen on the canonical neoclassical economic theory of natural resource scarcity, see the papers by Georgescu-Roesen and Stiglitz in Smith and Krutilla, 1979)[2].

The First Law of Thermodynamics says that 'matter' can neither be created nor destroyed. And the Second Law says that entropy increase in each conversion in a linear and non-reversible manner. Low-entropy matter is recycled into useful products for mankind and as high-entropy states in 'waste materials'. For a given total earthly stock, the proportion between low entropy and high entropy matter continuously shifts towards the latter. Consequently, the capacity of the natural environment to 'recycle matter' is thereby progressively being impaired. From a natural science perspective of the world as a geobiophysical entity, the exploitation of nature by man should thus be seen as a linear process and not as a circular process as in textbook economics.

The ultimate usable stuff of the universe is low-entropy matter-energy. Low-entropy matter exists in two forms: a terrestrial stock, and a solar flow. The terrestrial stock consists of two kinds of resources: those renewable on a human time scale and those renewable only over geological time, which, for human purposes must be considered non-renewable. Terrestrial low-entropy stocks may be classified into energy and matter. Although we can turn matter into energy, we have no means to turn energy into matter on a significant scale. Thus, material low entropy is not reducible to energy terms for earthly purposes (Georgescu-Roesen, 1971, cited in Daly: 1992: 25, Georgescu-Roesen, 1993a,b).

The solar source of low entropy is more abundant than the terrestrial source: if all the world's fossil fuels were burned, they would provide only the equivalent of a few weeks of sunlight (Daly, 1992: 22). Because sunlight is a non-depletable, non-polluting source of energy, it would seem prudent to make technology run on solar low entropy to the greatest possible extent. The scarce non-renewable terrestrial resources should be invested in structures to increase our ability to capture solar low entropy energy to the greatest possible extent. But the opposite has happened: mankind has increasingly come to rely on limited earthly stocks.

Energy in History

Only two innovations have had a truly crucial influence on man's technical powers to exploit terrestrial resources (Georgescu-Roesen 1971, 71-2). First came the mastery of fire. This is a qualitative energy

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2 For a biographical sketch of Georgescu-Roesen see Blaug (1985).

conversion of chemical energy of combustible materials into caloric power. It opened up the *Wood Age*. For centuries wood served as the only source of caloric power. In many developing countries, and especially in rural areas fuel wood is still the primary source of caloric power at the present time. In principle, it is a renewable source of energy, though over-exploitation of woody biomass seems to be occurring on a large scale in many developing countries, even though published statistics are notoriously unreliable (Van de Laar, 1990, 1991).

With industrialisation, forests began disappearing with increasing speed. Wood served several purposes: it was the major source of fuel, a building material, an industrial material of unsurpassed versatility, and a critical source of chemical inputs as in the use of potash in the production of alkalis. Laws were passed already under the reign of Queen Elizabeth in England which limited forging and furnace operations in districts where timber had become sufficiently scarce. British industrial expansion by the early 17th century was confronted with nothing less than a 'national crisis' as a result of the severe depletion of her timber supplies.

Coal was already known as a source of caloric power, but difficulties prevented its substitution for wood on a large scale. First, coal burns dirty, a disadvantage not only for home heating but for industrial use as well. The chemical interchange between the mineral fuel and the final product frequently damaged or produced a highly inferior product - as in glass-making, baking, the drying of malt for the brewing industry, and, most importantly, for the production of iron. However, the greatest obstacle was the fact that any mine becomes quickly flooded, whereas the power required to drain it was not available from the energy sources used at that time: muscular power of humans and beasts of burden, wind and running water. It could be stated that the technology based on wood was running out of its fuel!

By the end of the 18th century these technical problems were successfully overcome in the metallurgical uses of coal and industrialisation could proceed. The *Industrial Revolution* in Britain essentially substituted cheap coal for wood as a source of fuel and power, and cheap and abundant iron for vanishing timber resources (Rosenberg, 1973, 112).

However, in the United States resource supplies were drastically different, and Americans continued to use wood long after the British had adopted coal. They developed new technology in woodworking machinery specifically geared to the intensive use of wood. In 1860 the lumber industry was the second-largest industry after cotton in terms of value added (Rosenberg, 1973, ibid), and per capita lumber consumption may have been as much as five times as high as in England and Wales. Wood was a *by-product*, or even *waste-product* of agricultural expansion west of the Mississippi. The abundance of forest resources led to adaptations which involved substituting natural resource inputs for other, scarcer sources of production. The American builder relied on wood, where his European counterpart would have employed stone, iron, or other materials.

The increase in the relative prices of forest products and the cheapening of coal and iron in mid-19th America signalled a shift away from the use of wood. In 1850 mineral fuels still supplied less than 10 percent, as against 90 percent for wood, of all fuel-based energy.

The second key energy invention was the discovery of the heat engine by Thomas Savery and Thomas Newcomen. It enabled the conversion of caloric power into motor power. Motor power then made it possible to tap a new source, that of mineral fuels. In contrast to the prolonged dominance of coal in other industrial countries, the supremacy of coal as an energy source in the United States was relatively short: coal accounted for over 50 percent of energy sources only for the period between 1885 and 1940 (Schurr and Netschert, 1960:

36, cited in Rosenberg, op.cit.), and coal was rapidly being replaced by oil and natural gas. The USA and other developed countries are still largely in that age.

The developing countries at present are in the midst of a transition from wood energy to fossil fuel energy sources. Except for India and China, which have largely coal-based energy strategies, most other developing countries move directly from wood to oil and gas as dominant sources of primary energy, and despite the oil-price shocks of the 1970s. This trend has occurred despite available estimates showing that coal reserves are larger than oil reserves. (Van de Laar, 1990).

Projections for the period 1990-2010 show that in all scenarios the primary energy demands of the developing countries will have outstripped energy demands in the developed countries, and fossil fuels continue to dominate the energy mix over the next three decades and are likely to do so well beyond this period (WEC, 1993: 28). But fossil fuels are a non-renewable source of energy, and this makes the development process risk-prone, and possibly not sustainable.

Whether there will be a successor to a third new key power source and another 'new' fuel depends on the assessment of whether nuclear power can be harnessed in controlled form. That technology has thus far been mostly the province of the most advanced countries. Especially France and Japan have made great strides in shifting to nuclear power. However, its spread has involved complex problems of a military strategic nature associated with the Cold War. Nuclear proliferation also faces numerous technical issues concerning the safety of nuclear reactors and of the disposition of residuals. Early optimism has given way to much more sober assessments, and increasingly problems come to the surface in respect of nuclear reactors of an older generation, which are to be scrapped or dismantled due to failures of various kinds. Especially troublesome is the current situation of the nuclear industry in the former Soviet Union, where inherent technical problems are compounded by institutional instability affecting maintenance and safety in a context of generalized 'transition from socialism' instability. Nearly everywhere, the initial rapid expansion has come to a halt in a climate of uncertainty (Van de Laar, 1990).

Commoner (1990: 162) goes much further and argues that nuclear power has already failed as an instrument of economic development because of its environmental faults. Nuclear power has failed so dramatically because the high cost generated by its environmental hazards have been internalized economically and are therefore directly reflected in its economic productivity. Delayed bills of environmental damage may still come due from technically failing generations of older nuclear power plants, especially those in the former Soviet Union, but also in the USA and in France, the early pioneers of applied nuclear energy power.

Internalization of external effects is the standard neoclassical recipe to deal with environmental externalities (Pearce and Turner, 1990; Baumol and Oats, 1988; Tietenberg 1988). The application of this principle has now blocked the nuclear power sector in its development. Nuclear energy provides a stark example of applying the *Polluter-Pays-Principle (PPP)* adopted by the OECD in the mid-1970s (OECD, 1975). By way of contrast, the fossil fuel sector has largely escaped being charged for its environmental effects. Fossil fuel sources continue to be underpriced by a large factor, due to the lack of any link between the market price paid and the subsequent cost of uncompensated environmental damage. Environmental costs of mineral fuels centre on CO^2 emissions, which play a dominant role in policy discussions on the *Climate Change Convention* (OECD, 1992; Hayes and Smith, 1993; GEC, 1994).

Ayres and Kneese (1990: 97) argue that the true dynamic equilibrium price of any exhaustible resource [such as fossil fuels] would have to correspond to a rate of use such that the discounted marginal environmental degradation (cost) resulting from the ultimate disposal of the material is balanced by a discounted stream of marginal benefits. Such a resource price would be a large factor higher than present prices. As an indication of magnitude it might be helpful to consider what the cost of energy would be if no increase in atmospheric carbon-dioxide, or environmental acidity were permitted. Incidentally, this formulation of the true resource cost involves a considerable extension of the standard conventional economic theory of exhaustible resource extraction, which follows the line of thinking developed by Hotelling (1931) (Devarayan and Fisher, 1981; Dorfman, 1985). That analysis is confined to the extractive phase of the cycle and does not cover the ultimate disposal of the waste materials, as would be required in a linear view of the material-balances economy as a closed system.

The historical development trend in the energy field generally has thus been one where man has increasingly sought to develop scarce terrestrial stocks, e.g. man began to live on geological capital. The seductive advantage of these terrestrial stocks is that they can be exploited at a rate of man's own choosing, while the rate of solar energy is externally given. With also the developing countries basing their own development paths increasingly on fossil fuels when shifting away from the *Wood Age*, the rate of exploitation and the threat of approaching exhaustion could become increasingly real (WEC, 1993; Van de Laar, 1990, 1991).

Whether the distinction of stocks versus flows (extractive or use rates) is empirically significant depends crucially on the *scale* at which the two are compared. Growth rates in the 20th century, and especially in the second half, should give rise to concern. Between 1950 and 1986 the scale of the world population doubled from 2.5 to 5 billion, while the scale of gross world product and world fossil fuel consumption each quadrupled. In this century, world population has tripled and the world economy has expanded to 20 times its size in 1900.

However, not these absolute rates of resource use are important, but rather the rates of resource use compared to relevant stocks of resources. Matter and energy flows - the physical presence of the economy within the ecosphere - were not negligible in 1900, but they now rival in magnitude the flow rates of many natural cycles and fluxes[3] (Colby, 1990: 4). Of considerable interest in this respect is the finding by Vitousek, Ehrlich, Ehrlich, and Matson (1986) that organic matter equivalent to about 40 percent of the net primary production of all terrestrial ecosystems was being diverted directly or indirectly for human use. This percentage is bound to rise sharply in the 21st century!

The difference between the *cowboy economy* and the *spaceman economy* can apparently, and in the perspective of environmentalists and some, as yet a small number of economists, be formulated in respect of the growth of the scale of the human presence and his activities in the earthly ecosystem. The question whether this intuitively appealing notion can be made to stick, and what its operational consequences are, is the object of the next sections of this paper.

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[3] A flux is a flow that cannot be accumulated (Daly, 1992, 30).

3 ECONOMIC PRINCIPLES FOR THE CLOSED ECONOMY

If the earth is to be seen as a *closed earth* of the future, it requires economic principles which are different from those of the *open (and boundless) earth* of the past. In the *cowboy* economy consumption is regarded as a good thing and production likewise; and the success of the economy is measured by the amount of the *throughput* from the 'factors of production', part of which is extracted from the reservoirs of raw materials and non-economic objects, and another part is output into the reservoirs of pollution 'sinks'. If there are infinite reservoirs from which materials can be obtained and into which emissions and residuals can be deposited, then 'throughput' is at least a plausible measure of the success of the economy, and the Gross Domestic Product (GDP) as a rough economic measure of this total throughput, is contributing to human welfare.

On the other hand, in the *spaceman* economy, throughput is by no means a desideratum, and is, indeed to be regarded as something to be *minimized* rather than *maximized*. The essential measure of the success of such an economy is not production and consumption, but the nature, extent, quality and complexity of the total capital stock, including the state of human bodies and minds included in the system. In this spaceman economy one is primarily concerned with *stock maintenance*, and any technological change which results in the maintenance of a given capital stock with a lesser throughput - lesser consumption and production - is clearly a gain.

The primary objective of an economic system is then to pursue not output, as throughput, but rather resource use efficiency. This may be expressed as follows:

$$\text{EFFICIENCY} = \frac{\text{SERVICE}}{\text{THROUGHPUT}} = \frac{\text{SERVICE}}{\text{STOCK}} \times \frac{\text{STOCK}}{\text{THROUGHPUT}}$$

Economic output is not throughput itself, as conventionally interpreted in economics, but the services as satisfactions or utilities derived from throughput (consumption). These services are to be derived from the stock of resources. The stock/throughput ratio can then be interpreted as a scale factor symbolising the human presence in the earth's natural environment.

The distinction between throughput and stocks is a useful way to conceptualize a potential link between the world of economics and the world of geobiophysical scientists, or environmentalists for short. The concerns of economists have been to study the determinants of a flow of goods and services available to mankind. Increases in this flow are generally judged to be desirable to enable an increase in options open to individuals and societies, and to offer a perspective that existing inequality in economic life might be lessened in an economic growth perspective. The idea behind this is that it may be socially and politically more palatable and feasible to divide a 'larger pie' than to redivide a constant pie, leave alone a shrinking pie relative to growing population size. The neoclassical tradition in economics is concerned with efficiency in input use in the components of what is taken as a proxy for economic performance, the GDP. This efficiency is achievable in a dynamic setting in a competitive market-guided context. But, this focus by economics on throughput as flows, impedes an explicit consideration of stocks, and of linking flows to stocks.

In contrast, environmentalists originally studied eco-systems *per se*, in a detached, 'hands-off' manner, where humans are considered not actors but observers. Their policy stance tends to be Conservationists. Confronted with the inevitable demands on ecosystem capacities to provide inputs to satisfy demands for human development, environmentalists are increasingly drawn to devote attention to environmental resources as stocks and flows to meet these human demands, and to issues and problems of ecosystem modification towards those ends.

Consequently, modern environmentalists are paying attention to four key questions regarding the behaviour of natural ecosystems over time. Implications of this change in focus are given below by way of illustration of the general approach taken.

Natural ecosystems can be analyzed for the following four properties, as related to human requirements:
* Productivity, expressed in yields. Systems with high productivity are to be preferred over those with low productivity.
* Stability. Stable yields are to be preferred over unstable yields.
* Sustainability or resilience. This relates to the capacity of ecosystems to cope with, and recuperate from external shocks. Of special concern is the identification of discontinuities, interpreted as thresholds, beyond which ecosystems cannot recover.
* Equitability. This asks the question of the proportion of the ecosystem-dependent population which can benefit from ecosystem resources. Systems which benefit large percentages of such populations are to be preferred over those which only can benefit a few.

These four properties can be considered as composite indicators. To enable judgements to be formed on each, one has to develop an underlying primary data base, which relates environmental functions to direct intervention effects, and to the identification of possibly existing mitigating or enhancing impacts and interventions in relation to ecosystem functions.

Such Tables have, for instance, been elaborated for a range of environmentally sensitive development interventions by Van Raay, Van de Laar, et.al. (1980), revised and expanded in Van Raay, Dolman, Kazi, eds (1989). Interventions analyzed cover: (new) land development and settlement; production intensification through irrigation, and seeds, fertilizer and pesticide packages; use of fertilizer/pesticides/weedicides; forestry development: forestation, afforestation and agro-forestry; water resources development, such as dams and reservoirs; water resources for rural redistribution of water; wells for drinking water; and for the impacts of human settlements. Such Tables can sensitize and assist planners and policy makers in identifying, structuring and shaping initial project identification and project-scoping efforts.

Figure 1. *Environmental Impact Tables for Development Interventions*

ECOSYSTEM FUNCTIONS	DIRECT EFFECTS	POSSIBLE NEGATIVE/ POSITIVE ENVIRONMENTAL IMPACTS	MEASURES TO PREVENT/ CORRECT/MITIGATE NEGATIVE ENVIRONMENTAL IMPACTS	MEASURES TO ARTICULATE POSITIVE ENVIRONMENTAL IMPACTS
PRODUCTION	+ , -	+ , -	+ , -	+ , -
CARRIER	+ , -	+ , -	+ , -	+ , -
REGULATION	+ , -	+ , -	+ , -	+ , -
PURIFICATION	+ , -	+ , -	+ , -	+ , -
INFORMATION	+ , -	+ , -	+ , -	+ , -

For economists and ecologists, in joint efforts, to think simultaneously of stocks and flows, is potentially useful in several ways.

First, it focuses attention to examine the nature, composition and adequacy of the 'throughput' measures favoured by economists, such as GDP.
Second, it focuses attention on the measuring and measurability of the environmental stock concept. Is it a concept useable beyond its intuitive appeal? If so, then it is useful to also think in terms such as *Environmental Space*, as a basis for developing reference values and denoting the dynamic relationship between current environmental resource use trends and environmental resource stocks, in relation to the remaining capacity of the natural environment to act as a 'sink', and to recycle waste products back into the natural environment (Opschoor and Van der Ploeg, 1990).
Third, it permits one to look at stock maintenance and implications of deferred maintenance of environmental resources through clean-up activities, in their consequences for and effects of current economic consumption and investment activities decisions.

Usually, a considerable time lag exists between economic activities and the emergence of subsequent environmental damage. This time difference has two types of consequences. On the one hand, it may be impossible to apply the Polluter-Pays-Principle, as the economic entities which caused these environmental diseconomies may have long since disappeared: either altogether, or only in a legal sense, as a body to which litigation can be initiated in courts of law. For instance, the Netherlands and other industrialised countries are full with chemical dumps, by-products of industrial activities of the 1950s and 1960s, or of the early 20th century, which ceased operating in the 1970s and 1980s. The accumulation of environmental claims against the producers and users of asbestos, which has been found harmful for human health, causes havoc on the world's largest (re)assurance market, Lloyds of London. Moreover, the removal of asbestos in existing constructions is costly and difficult, precisely because of the dangers of harmful fibres being 'freed', thus acting as a reactivated source of further environmental hazards to health. The legality of compensation claims dating back when the regulatory regime was absent or different, or when the environmental effects where not known or not judged harmful, is contested in the courts as inappropriate as it smacks of retro-active law-making. Compensation claims for environmental damage, such as clean-up costs for oil spills, may wipe out a large part of profits for one or several years for even large multinational oil corporations.

A second, and possibly positive effect of the time-lag between economic activities and harmful environmental effects later on, is that it gives some breathing space to mobilize resources and research efforts to develop new technologies to clean up this environmental damage, or, much better still, prevent environmental damage arising through the redesign of industrial technologies. But the development of such different technologies is a complex process, often requiring decades to develop and become generally accepted. In a number of countries legislation requiring clean-up has been imposed only when environmental risks became a public concern in the 1970s. This also happened in the Netherlands, where a spate of environmental regulations were quickly put on the books and under short-term political pressures. But the absence of abatement technologies has forced the government into tolerating dumping and disposal practices in violation of the very environmental laws which have been enacted. Government became a criminal actor in what was later seen as a conspiracy or at least as collusion between regulators and polluters. This legal nightmare was compounded by the diffusion of law enforcement regulations among: (i) levels of government (national, provincial, district city/village); (ii) functional organisations such as Water Boards with command areas which are overlapping government administrative boundaries; (iii) organisations with widely different capacities to enforce the new legislation; and (iv) under uncertainty regarding legal issues as relevant jurisprudence still had to be developed.

Against this background, it has become clear that the recognition of the geobiophysical world by economists could well provide a powerful perspective to pull modern economic theorizing out of its conventional theoretical abstractions. The economic process is not just converting abstract labour into abstract production and consumption in pendular fashion, but is rooted in a geobiophysical reality. Economic theory should reflect this.

If one believes that there is an absolute ecological constraint on economic activity, then one must accept that there are absolute limits to economic exploitation of the environment. Environmentalists, from early conservationists to the present, argue consistently for structural changes in the economic process in order to limit ecological damage, regardless of the costs in terms of production and foregone consumption. In essence, such changes involve minimizing the material and energy throughput requirements of the economic process, investing directly in the 'improvement' of the environment, and preserving environmental quality.

These basic resource-saving criteria for the economy of conservationists have been summarized by Page as follows (Page, 1977, 175):

* The regenerative capacity or potential of renewable resources (such as forests, grazing land, cropland and water) should not be physically damaged or destroyed.
* Renewable resources should be used in place of minerals, in so far as is physically possible.
* Plentiful mineral resources should be used before less plentiful ones, in so far as is physically possible.
* Non-renewable resources should be recycled as much as possible.

It should be emphasized that these 'guidelines' are not necessarily helpful for policy-making. For instance, are all natural resources not to be damaged or destroyed, or only a fraction? If so which fraction, and who is to determine that fraction? The issue of the decision-maker is crucial from the perspective of weighing conservation against whose production and consumption is to be foregone by such decisions. The forceful promotion of the use of renewable resources may lead, in turn, to stress and over-exploitation of in principle renewable resources, which in the end may make them non-renewable resources (wood and wood products, for instance). The advocacy use of plentiful over non-plentiful mineral resources is vague as the volume of such resources is a function of quality of these resources and of the price one is willing to pay to extract lower grade materials. Finally, the caveat 'as far as physically possible' allows for an expanding physical ecological barrier to economic activity due to technological change which then, perhaps regrettably, corresponds to a lesser felt need to conserve resources. At the same time, the *caveat* could be interpreted more positively as providing potential guidelines for setting a technological research agenda. This requires a conceptualization of technological change: is it something autonomous, an attribute of some societies, or some individuals, and occurring only in some times and only in some geographic locations? Or can there be a generalized theory of induced technological change, and if so, what are its determinants? It may be observed here that the notion of induced technological change, i.e. endogenous to the economic process, was not widely accepted in economics as recent as the early 1960s.

It should be realised that it is not at all difficult to identify influential contemporary economic theorists who continue to ridicule the usefulness of notions of scarcity implied in the concept of natural resource stocks. Smith and Krutilla (1979, 3) state:

> The current debate over the adequacy of materials resources offers the widest range of opinion of any recent policy issue. Judgements range from Houthakker's statement that "the ancient concern about the depletion of natural resources no longer rests on any firm theoretical basis", to the completely opposite conclusions of Georgescu-Roesen, which draw on principles from the natural sciences in support of his position.

Houthakker's[4] position seems to imply an attitude arguing that 'if I do not have a theory, reality cannot exist'. But why should reality depend on and be in conformity with somebody's limited theorizing?

Robert T. Solow, in his Richard T. Ely lecture as President of the AEA, observed what to environmentalists must look like mere drivel (1974, 12):

> If it is very easy to substitute other factors for natural resources, than there is in principle no problem. The world can, in effect, get along without natural resources, so exhaustion is just an event, not a catastrophe.

The background to Solow's statement, and perhaps also Houthakker's posturing, are shaped by the fact that nearly all economists who in the past were dealing with natural resources, such as Hotelling (1931), Stiglitz (1976), Schulze (1974) or Heal (1975), use models which are confined to what might be considered the neoclassical tradition, that *implicitly assigns a dominant role to a classically well-behaved production function* for their results (Smith and Krutilla, 1979, 10; emphasis in original). Functions used are either Cobb-Douglas (with partial elasticities adding up to 1) or CES (constant elasticity) functions for describing production processes and factor substitutions. Well-behaved production functions can be mathematically manipulated, have no kinks or discontinuities and are smooth over the full range of variables. Such models also feature in many current expositions of environmental economic theory.

The difference in functional form is not at issue. *Rather it is whether the micro-responses implied by aggregate substitution over the full range of labour, capital and natural resource combinations are feasible* (Smith and Krutilla, 1979, 12). What little empirical research on the matter appears to be existing, the findings are that factor substitutions apply only over part of the range, and this might be taken as limits to resource substitutions (Humphrey, et.al. 1975; Brown and Field, 1979, 241; Barnett, 1979). But this is precisely the point of the closed-earth adepts: to increase awareness that such boundary conditions may apply and to point at research needs to find out where such bounds are in the reality of time, space and technological levels actually available in such disaggregated contexts. Abstract models which postulate full substitutability among all resources in unspecified real world environments are unsuitable to explore the existence of boundaries existing in specific settings. At best one can say of neo-classical empirical research on resource scarcities that it is 'so far, so good, in some countries'. But that is a weak basis to defend such findings as the general case across the world and for the future (see further section 6, below).

Simplicity or simple-mindedness, however, are not the exclusive attribute of theoretical economists. Some advocates of the stock view of natural resources, whether economists of natural scientists, suffer from simplifications as well. Advocates of a closed Space Ship economy tend sometimes to argue that durability of production outputs is to be preferred over short-lived production's 'life expectancies' because it reduces the demand for new scarce inputs, and recycling is to be preferred over new production when this implies the use of new virgin source materials (Boulding, 1966; Daly, 1992: 36). This is too simplistic as will be shown in Section 8. Durability of production is not necessarily a friend of wise management of natural resources.

In sum, moving from abstract economic theorizing about environmental resources to the way environmentalists conceptualize the notion of resources and resource stocks on planet earth would seem to be a potentially fruitful

[4] A Dutch economist who moved to the USA to become i.a. professor at Harvard University, and a member of staff of the Council of Economic Advisors under Presidents Johnson and Nixon.

approach to try to sort out in more specific ways what type of problems it presents for economic analysis and for trying to untangle why and how economists and environmentalists continue to disagree on so many points, even to the present.

In the following sections a number of such differences will be taken up.

4 THE REALITY OF THE LINEAR WORLD.

If the economic system is to be seen as a linear conversion of matter, from extraction through various forms of processing to its ultimate disposal in degraded form in a closed system, it needs a different conceptualization from the process depicted in standard economic theory textbooks. Such an improved conceptualization is provided in a materials-balances model. It differs from conventional economic system flow diagrams expressed in values because of the pervasive impacts of environmental externalities and a much wider scope of the realm[5].

In the words of Ayres (1978, 36-37):

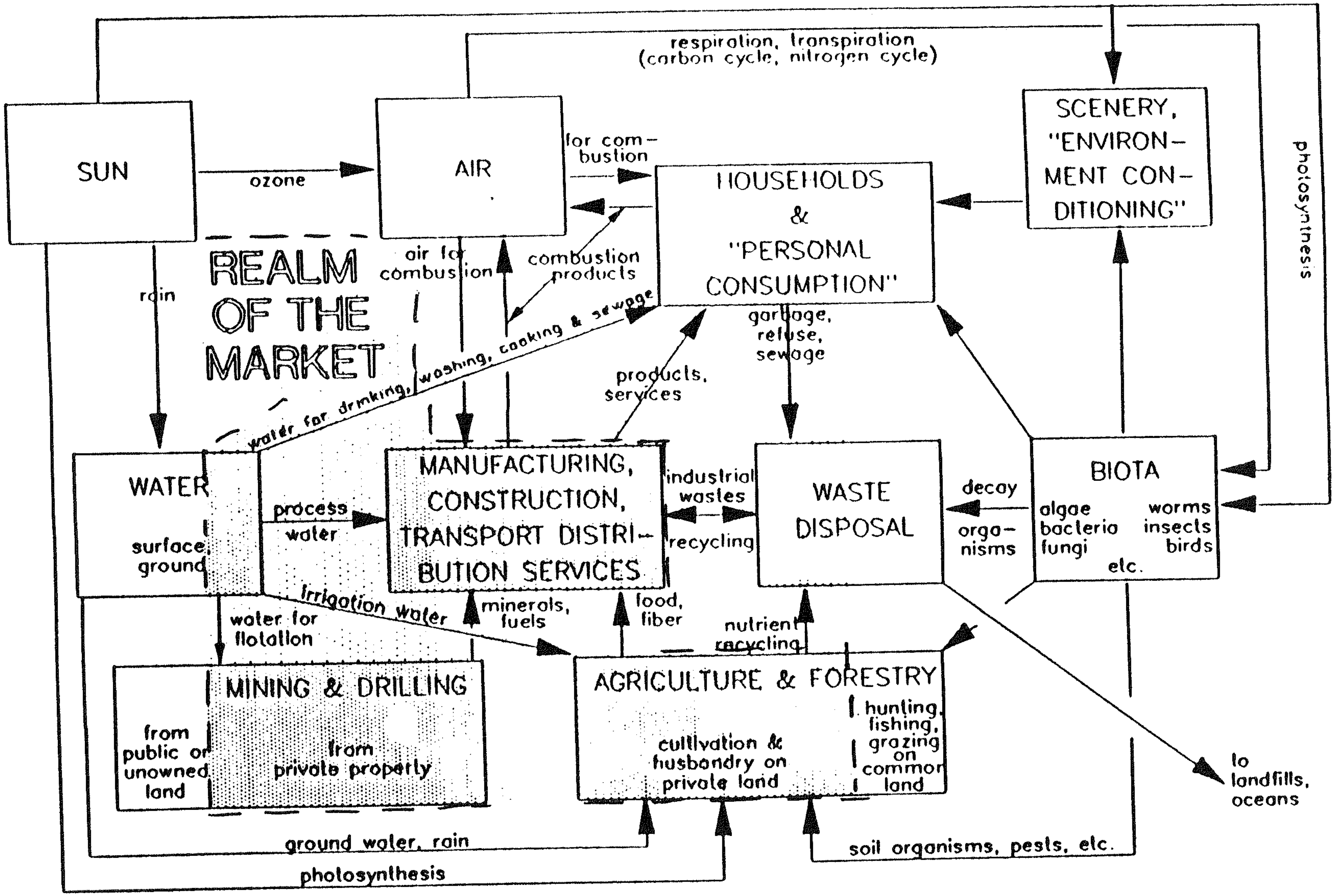
> Lacking the mechanism of the market to relate value to physical quantity, the economist must revert to dealing with quantity itself. Thus models are needed that describe the movements of physical materials through the economy to supplement models describing the movement of dollars (cited in Van der Straaten, 1990, 57).

An example of such an extended flow diagram, which include the realm of the 'market', can be visualised as in Figure 2. It provides the setting for discussing issues that will have to be faced in pursuing the notion of the 'real world' as against the 'economics world'. There is no need here to try to search for more complex or more detailed and complete presentations, to indicate the issues for the present discussion.

[5] See my earlier paper, *Economic Theory and the Natural Environment: A Historical Overview*, 1996.

Figure 2

Realm of the Market



Source: Ayres and Kneese, 1990: 96

The market in which economists interest themselves, covers only a small fraction of all 'transactions' in this total system. All kinds of resources are drawn from the natural environment and massive amounts of matter, as by-products of material production, are dumped again into the natural environment. The outputs of the production system are, contrary to the terminology of conventional economics, not 'final demands' in any meaningful sense. Instead, consumers derive services from consumption items and subsequently discard virtually all physical products as waste. In this sense not only resource extraction and production activities lead to the waste, but also consumption activities. The second key element is to note that extraction, production and consumption activities all interact, inherently, with the common property resources air, water and land. Production and consumption externalities, as economists would classify such transactions, are thus pervasive and not the exceptions as neoclassical economics had always assumed.

It will be helpful to sketch the dimensions of the various flows, to better understand what is meant by an expression such as 'the problem of the economic system is not production but waste management'. Data are for the USA only as data for other countries are not, or not readily available. But this is immaterial to grasp the nature of problems arising from a materials balances conceptualization of the economic process.

The mass of active materials extracted commercially in the USA have been estimated for several years between 1960 and 1975. Major omissions are vegetable material harvested directly by animals, for lack of data. Figures for metal ores exclude mine tailings and gangue removed to uncover ore bodies. Inert construction materials such as stone, sand and gravel have also been omitted. Inert materials account for enormous tonnages, but undergo no chemical or physical change except the extent to which they are incorporated in concrete or paved surfaces. Also are excluded soil and subsoil shifted during construction projects or lost by erosion.

The published figures show that 10 tons of active mass per person is extracted from its own territory by the US economy each year. The amount processed is somewhat larger, since the US is a net importer of many minerals and petroleum. On the other hand, a lot of grain harvested is exported, which balances the international accounts to some degree. Of the active mass processed each year, roughly 75% is mineral and 'non-renewable', while 25% is, in principle, from renewable sources (Ayres and Kneese, 1990, 92-93).

It is difficult to estimate the fraction of the total mass of processed active materials that is annually embodied in long-lived products and capital goods (durables). None of the food and fuel is physically embodied in durable goods. Most timber is burned as fuel or made into pulp and paper products. At least 80% of the mass of 'ores' is unwanted impurities (more than 99% in the case of copper). Of the final products made from metals, a large fraction is converted into 'consumption goods', such as bottles, cans, chemical products, and 'throw-away' products such as batteries, light bulbs, and so on. Only in the case of non-metallic minerals (ignoring inert materials) is as much as 50% of the mass embodied in durable goods (mainly portland cement, clays and ceramics).

The upshot is that the annual accumulation of active materials embodied in durables is probably not above 150 million tons, or 6% of the total. The other 94% is converted into waste residuals almost as fast as it is extracted. In addition to raw materials, large amounts of energy, in a high quality (available) form are also needed to drive the system. This energy is also degraded and finally discarded as low temperature heat. It is not difficult to show that the tonnages of waste residuals are actually greater than the tonnages recorded by economic statistics. Both air and water are major inputs in industrial processes and they contribute mass to the residuals - especially combustion products.

One important issue for the sustained operation of the economic system is then not only whether the resources extracted are renewable or not, but also whether the residuals are disposable, e.g. can be assimilated by nature. While renewable resources can obviously create pollution problems, such as sewage, they are almost invariably localized in nature and can be abated at moderate cost. This is, argue Ayres and Kneese (1990: 95), emphatically not the case for combustion products of fossil fuels, for the dispersion of toxic heavy metals, and increasingly for new exotic materials produced by the chemical industry.

5 THE CAUSES OF ENVIRONMENTAL IMPACTS AND HOW TO COPE?

Thus far, the discussion has been couched in rather general terms, from the abstract concepts of goods and consumption employed by economics, to the broad conceptualization of the material flows view of natural and man-designed processes in the economy. Successive clarification and precision of concepts is needed to bring issues involved in focus. Let us start with the origin of what is perceived as the environmental crisis.

Two contradictory theories have been put forward about the origin of the environmental crisis. One is that pollution originates from pressures of increased population and levels of consumption on the ecosystem's inherently limited resources. This may be called the 'congestion view', which is often associated with the outlook for (a number of) developing countries. A contrary view is based on the notion that the escalating evidence of pollution in industrialised countries after World War II, results from the introduction of ecologically harmful technologies of production rather than from impacts of increasing population or levels of consumption. This may be called the 'harmful technology view'.

Environmental impacts result from human productive activities governed by economic processes. They may be generated in different ways: (1) by exploiting biological productivity leading to selective withdrawals, loss of bio-diversity and possibly species extinction, or destructive erosion of soils; (2) by augmenting some components of the ecosystem to either dispose of waste materials (sewage) or to accelerate the system's rate of turnover and increase its yield (fertilizer nitrogen in agriculture); (3) by adding exotic substances to natural ecosystems which may disturb these natural ecosystems (many chemical products).

The impacts of pollutants on natural ecosystems are still only poorly understood, and thus in nearly all areas wide margins of uncertainties exist. This weakens appeals for quick and even more, for drastic remedial action. One consequence is that pollutants cannot often be directly linked to environmental damage, for this requires further knowledge of ecosystem behaviour and its resilience. Therefore, the environmental impact has to be taken for empirical purposes as the emission rate of pollutants to the environment, which links emissions directly to production levels in industry. This is a necessary but only first step in the chain of analyses that will have to be undertaken. Relevant follow-up questions are: How do these emissions interact among each other (such as interacting chemically in smog formation), and with different elements of the natural environment; how are such impacts to be judged to be environmentally harmful, and how do environmental effects of pollution reflect on public health and on ecosystem vitality.

Commoner (1971, 1972; repr. 1977) has attempted a detailed analysis of the growth of environmental impacts in the US economy. Environmental impact is decomposed for major commodity groups, and for each commodity group the growth in emissions of pollutants has been derived by looking into the technological processes involved and changes therein. This information has been decomposed as follows:

$$\text{ENVIRONMENTAL IMPACT} = \text{POPULATION} \times \frac{\text{PRODUCTION}}{\text{POPULATION}} \times \frac{\text{POLLUTANT}}{\text{PRODUCTION}}$$

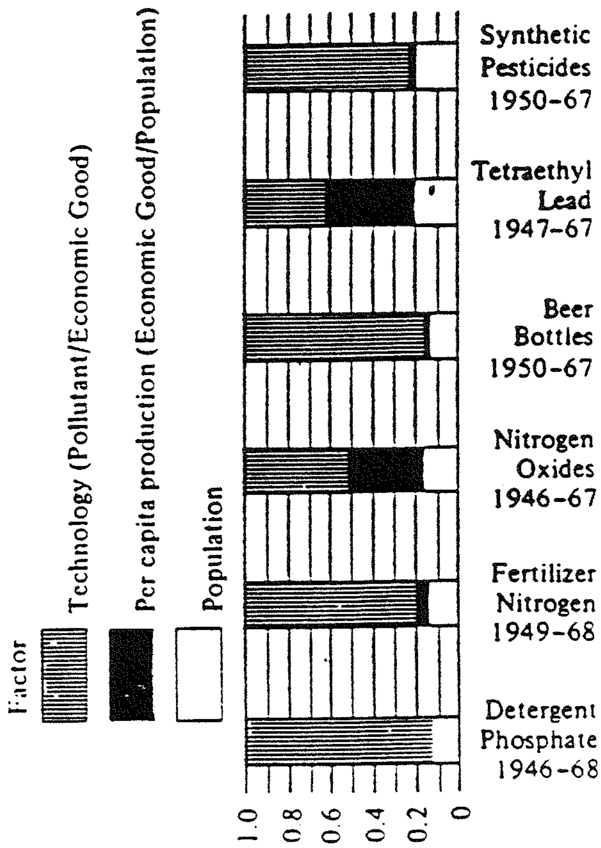
It was argued in section 2 that economics tends to be disembodied from the natural world. It would thus seem useful if economists were to learn a bit about industrial technology engineering and design, preferably already during their studies. Hence, the provision of some details of Commoner's analysis seems in order. Moreover, this type of analysis has been influential in bringing insights from the natural sciences together with those of the new economists (roughly associated with the *Resources for the Future* foundation), who were struggling with the materials balances conceptualization of the economic process in the 1960s, such as A.V. Kneese, R.U. Ayres, R.C. d'Arge, Blair T. Bower, A Myrick Freeman III, and Peter Bohm.

The pattern of growth in the 25 years since the mid-1940s may be generalized as follows (Commoner, 1977: 340). The annual production of basic life necessities, representing perhaps one-third of total GNP, grew at about the pace of the population, so that no significant change in *per capita* production took place. However, within these general categories - food, fibre and clothing; freight haulage; household necessities - there was a pronounced displacement of natural products by synthetic ones, of power-conservative products by relatively power-consumptive ones, of reusable containers by 'disposable' ones.

A summary presentation for some important types of products is given below in Figure 3.

Figure 3

Relative Contribution to Ratio of Total Environmental Impact Indices



Source: Commoner, 1977: 350.

The important point to note is that for key products the nature and direction of technological change has had a greater effect on the environmental impact than population growth and per capita income growth combined.

Broader sectoral level trends are presented below:

In agriculture, there has been rapid growth in nitrogen fertilizers and pesticides. The increased use of feedlots for the production of livestock implied that the organic waste in feedlots around 1970 exceeded the organic waste produced by all cities of the USA.

In textiles, fibre production *per capita* remained constant, but the shift to synthetics requires far more energy. A major reason for the use of synthetics is that they resist degradation by moulds which readily attack materials such as hemp or jute. Thus, the property which enhances the economic value of the synthetic fibre over the natural one is precisely the property which increases the environmental impact of the synthetic material.

Synthetic detergents have largely replaced soap. It uses phosphates which stimulate excessive growth of algae and leave phenol as a toxic residual.

Increased production of synthetic organic chemicals leads to intensified environmental impacts in several ways: its heavy power requirements results in air pollution, and organic synthesis releases into the environment a wide variety of reagents and intermediary products which are often toxic. Key elements here are intermediation by *chlorine* production leading i.a. to mercury intrusion in water sources.

Similarly, the displacement of steel and lumber by aluminum adds to the burden of air pollutants because aluminum production is extremely energy-intensive. The production of chemicals, aluminum and cement were estimated to account for about 28 percent of the total industrial use of electricity in the USA (ibid: 346).

In packaging, the displacement of returnable beer bottles by 'disposable' ones adds immensely to increased environmental impact. For instance, it has been estimated that the total expenditure of energy (for bottle manufacturing, processing, shipping, etc) required to deliver equal amounts of fluids in non-returnable bottles was 4.7 times that for returnable ones.

Finally, there is the enormous impact of the growth of the automotive industry in passenger cars and the shift from rail to road transport in freight traffic. Increasing mobility has also been a major factor in changing the spatial configuration of urbanisation and industrialisation processes on national and international scales.

Policy Uses

The above analysis is important for two main reasons. It clarifies issues relevant for the functioning of the materials balance economy, and it provides a 'handle' for policy approaches. Debates about needed changes in lifestyles for environmental reasons, and associated pleas for reductions in production and consumption levels, especially in the 'overdeveloped' countries, and to the benefit of the 'underdeveloped' countries (see Van de Laar, 1996, Section 2.6), are generally resisted by those who see perceived relative income gaps, both in the overdeveloped and underdeveloped countries. Suggestions for moderation are thus likely to be politically unfeasible, as consensus or majority policy positions cannot be negotiated for drastic changes.

In contrast, by pinpointing technological causes of major environmental impacts, the postulated link between consumption levels and negative environmental impacts is broken. The issue then to be faced more squarely is whether industrial process technologies can be redesigned to eliminate or reduce the negative environmental impacts of production. The environmental problem is to be addressed at source, rather than by designing end-of-pipe measures to mitigate the negative consequences of production. Such preventive approaches may in the long run even be more effective than curative approaches to mitigate environmental impacts of the economic process, and also at lower overall costs. Environmentalists are often in favour of such up-front and at-source approaches.

Economists, in contrast, tend to think in terms of pollution and production/consumption by 'final consumers' as complementary activities. Joint-production leads to socially acceptable main-products, but have environmentally undesirable by-products. Seen in this way, economists tend to argue in favour of strategies aiming at 'how to live with (some, much?) pollution'. For in joint-production processes, the components cannot be separated. This leads to a view of the link between environment and development as 'learning to live with pollution', or 'pollution is the price of development'. Further, a decision permitting production in a market economy implies an implicit permit to pollute the environment.

In this vein, the achievement of desirable reductions in pollution, is conceptualized as a problem of consumption demand management, achievable through pricing policy along lines of the Pigouvian tax on producers to 'internalize' negative environmental externalities (see Van de Laar, 1996, Section 2.5). The effectiveness of such measures is difficult to assess beforehand. It depends on supply and demand elasticities of the taxed production, and on behaviourial switches under the impact of such taxes, such as preferring other commodities, which in the end might perhaps prove to be more environmentally harmful than the initially taxed ones. A proliferation of individual taxes may then result. Moreover, groups negatively affected by the imposition of environmental corrective taxes, attempt, and often succeed, in negotiating income loss compensations, which undermines or negates the intended effects of trying to make environmentally harmful products relatively more expensive. The analysis of such interactions between micro- and macro-policy analysis is something with which general economists are familiar, through the theory of taxation and wage-price spiral indexation or interaction. In as far as the theory of taxation, and taxation shifting, leads to sceptical conclusions regarding the steering effects of taxation, the advocated use of the same taxation instruments ought to carry over in assessing the expected effectiveness and efficiency of environmental taxation. For response mechanisms are similar.

If environmental impact is seen as an issue of product technology, questions arise whether consumer sovereignty and the neoclassical policy approach of 'consumers signalling producers in markets' can work effectively to foster improved environmental performance of the economy. There is reason for doubts in this regard. The consumer's direct impact on producer behaviour is remote in as far as technological choices in production are concerned. While economists tend to think in terms of final products being traded in consumer goods markets, a more fruitful approach towards environmental management might be to think in terms of process technologies and trading in intermediate production among producers. When different technologies are available to produce the same final product or a very close substitute, but with widely different environmental impacts, consumer preferences in consumption decisions do not provide signals to producers on what technology to choose. The link between consumer signalling and production technology choice becomes even weaker when intermediate deliveries and foreign trade components are involved. The consumer cannot know, does not want to know and does not care. Whatever negative externalities might have been involved in all production stages leading to his decision to purchase the final product, these environmental externalities are in many cases effectively 'hidden from sight', and thus do not arouse consumer protests. In this respect, spatial segregation, as well as the process of differentiation -- adding more layers in the transformation from raw materials to final products -- is the enemy of improved environmental performance: it weakens the motivation to act, as the final consumers are not directly faced with these negative environmental externalities. Barriers exist to obtaining all relevant knowledge, and legal difficulties to instigate litigation are compounded by the multiplication of legal jurisdictions straddling the 'production column'. For such reasons some environmentalists tend to argue against international trade (Lang and Hines, 1993).

In a recent paper Commoner (1990: 155) reviewed the rather disappointing performance of environmental protection policies in the USA, a view shared in assessments made by *Resources for the Future* (Portney, 1992). He identifies only a few success stories: pertaining to lead emissions, DDT and PCBs in body fat, mercury in lake sediments, strontium in milk, and phosphate in Detroit river water. He concludes that in all cases the pollutant was prevented from entering the environment not by using a control device to recapture it after it was produced, but by simply stopping its production or use. Control measures designed to recapture the pollutant after it is produced are ineffective, is Commoner's central message.

While not necessarily subscribing to this view, I would like to point out here the apparent analytic problem in the design of effective environmental policy. It is not only a choice between Command-and-Control versus the Economic Incentives approach to improved environmental performance, but also whether environmental policy should focus on end-of-pipe solutions or to stimulate pollution-prevention technological change. In addition, some solutions may work only in the short run while other options might be available in a longer time perspective. Questions of the socio-political requirements for generating effective environmental lobbies, as well as issues of policy enforceability have to be included as well. The analytical question is therefore what type of policy or policy mix is likely to be relatively more successful and under what type of circumstances. In order to be able to contribute to such a discussion a detailed study of the environmental policy experience is the only way to learn. Such studies are in practice only becoming possible, and then only for very few countries, notably the USA, from the late 1980s. The subject of the instrumentation of environmental policies in light of operational experiences are quite complex and require a separate discussion[6].

6 TWO VIEWS ON SCARCITY

Major conflicts continue to exist between environmentalists and ecologists on the one hand, and economists on the other on the notion of scarcity of natural resources.

In this section, therefore, some of the issues involved shall be introduced. First, the case of the economics approach shall be highlighted: from presenting some key findings which are at the root of the optimism which has come to prevail among economists. The discussion then turns to issues with the measures chosen, and to wider issues of conceptualization of the nature of the problem.

Next, findings of a biophysical approach to resource scarcity are provided, which shed different light on the approach and findings of the economists position.

This section thus reports on an ongoing dialogue between social scientists (mostly economists), who generally argue for the efficacy of human institutions in mitigating scarcity, and biophysical analysts who generally argue

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[6] This will be attempted in an upcoming paper.

that basic physical and ecological laws constrain our economic choices in ways that are not accurately reflected in existing economic models. This dialogue has produced some important modifications to the models on both sides. Some of the simplifications of economists are giving way to account for instance for the economic effects of environmental degradation. Likewise, some biophysical scientists have learned that the market mechanism can stimulate potent antidotes to resource scarcity and that human tastes and preferences also are adaptable to avoid being tied in future to a single resource (Cleveland, 1991, 290-91). But it is probably a fair statement that for the time being these are still minority positions in the respective disciplines.

6.1 Economic perspectives

Evidence

The twin pillars of the neoclassical economic model of resource scarcity are Hotelling's (1931) theory of optimal depletion and Barnett and Morse's (1963) empirical analysis of resource scarcity in the United States from 1870 to 1957. As Norgaard (1990) observed, there have been no major theoretical advances in the half century since Hotelling, whose article did not attract much attention in the economics profession until the oil crisis of the early 1970s.

The neoclassical economic model of production assumes that capital and labour are the primary inputs in production. Consistent with this assumption, the neoclassical model of natural resource scarcity assumes that real resource prices or capital-labour extraction costs are the appropriate empirical indicators of scarcity, and these costs are used in historical studies to investigate empirically whether changes in scarcity occur. Figures regarding labour and output are taken from historical statistics, and capital, and the factor proportion between labour and capital taken as reproducible capital from work by Kendrick (Brown and Field, 1979). Barnett and Morse (1963) found that capital-labour costs per unit of extractive output in the metal and non-metal mining sector declined between 1870 and 1957, with forestry as the main exception.

In addition, they calculate unit extraction costs relative to non-extractive goods. This involves three steps. The price of extractive products is the price taken after extraction, and perhaps also some initial processing. It covers the stage from 'resources in nature' to 'raw materials'. This stage is followed, conceptually, by further processing of the raw materials to finished materials, and these are then converted in manufacturing into final output. Nominal prices need to be adjusted by a suitable deflator, such as GDP. But even then the figures do not mean anything, unless real natural resource prices are compared to other, non-resource use products. But the choice of the numeraire differs as to whose perspective is taken. Consumers should be interested in the price of resource products relative to other final products, which indicates a retail price index. While producers using a resource product as an input should be interested in the price of other inputs, such as labour or capital (Brown and Field, 1979, 226).

The main findings of Barnett and Morse (1963) are reproduced in Figure 4, below.

Figure 4. *Indexes of Labour-Capital Input per Unit of Extractive Output*

	Total extractive		Agriculture		Minerals		Forestry		Fishing
	A	B	A	B	A	B	A	B	A
1870-1900	134	99	132	97	210	154	59	37	200
1919	122	103	114	97	164	139	106	84	100
1957	60	87	61	89	47	68	90	130	18

Source: Barnett and Morse (1963, 8, 9, 172)

Key: A - indexes of direct unit extraction costs

B - indexes of unit extraction costs relative to non-extractive goods.

This seminal work has been updated and widened on a global scale (data permitting) by Barnett (1979). The widening involved inclusion of a range of European countries, as well as countries in Asia and Latin America. Barnett sees no reason to change the original conclusions and this update therefore would lend credibility to interpretations of a more general validity of the original findings, as the sample countries cover a wide range of per capita income levels and resource positions.

In addition, Johnson, et al. (1980) find that the trends as in Figure 4 continued through 1970, and in fact the rate of decline in capital-labour cost increases between 1958 and 1970. Hall and Hall (1984) find that the cost of ferro-alloys show no significant trend between 1960 and 1980 while the cost of non ferrous metals increased in the 1960s and than decreased in the 1970s (cited in Cleveland, 1991).

On the basis of this type of evidence the doctrine of increasing economic scarcity is rejected by many economists. The explanations for these trends are said to include the following: (1) substitutions of economically more plentiful resources for less plentiful ones; (2) increased discoveries of domestic mineral resources; (3) increased imports of selected metallic minerals; and (4) a marked increase in the acquisition of knowledge and socio-technical improvements relevant to the economics of resource discovery, development, conversion, transportation, and production. These factors have made it possible for the economy to produce larger and larger volumes of extractive goods at declining real marginal costs (Barnett, 1979, 164).

Smith and Krutilla (1979, 277) find these arguments intriguing, for they suggest that the very factors which give rise to heavy materials demands also provide strong incentives, through the market, to meet them. Thus, Barnett and Morse conclude that there is no resource problem in a limitational sense. Rather, they argued that the issue is best viewed:

> ... as one of continual adjustment to an ever changing economic resource quality spectrum. The physical properties of the natural resource base impose a series of initial constraints on the growth and progress of mankind, but the resource spectrum undergoes kaleidoscopic change through time. Continual enlargement of the scope of substitutability - the results of man's technological ingenuity and organisational wisdom - offers those who are nimble a multitude of opportunities for escape (1963, 244).

Measures of measurement

Whether natural resources are growing more or less scarce in an economic sense depends on the adequacy of the measures chosen to analyze resource use. Brown and Field (1979) review the three most common measures: unit cost (omitting the cost of natural resources), extractive natural resource product price, and natural resource rental price. All three have flaws!

The Unit Cost measure of Barnett and Morse, the most commonly cited index of scarcity among economists, is an ambiguous indicator of scarcity for the following reasons:

* In a dynamic world it mistakes certain types of technological progress for growing natural resource scarcity.
* Under all conditions it mistakes ease of adjustment to increasing scarcity (a good thing) for increasing scarcity itself (a bad thing).
* It is a lagging, not a leading indicator, and future costs of extraction are not included.
* It does not warn us of impending physical exhaustion.
* It is difficult to measure precisely.

The Real Price of natural resource-intensive products is relative superior to Unit Cost as an indicator of scarcity:

* The real price is forward looking in so far as it reflects the expected future cost of exploration, discovery and extraction.
* Technical progress distorts the scarcity signal provided by real price. Timber became physically more scarce in the late 19th century in the USA, but technological progress was responsible for maintaining stable product prices.
* Real price does not presage impending exhaustion for resources which have close substitutes.
* The real price of a resource can rise or fall, indicating increasing or decreasing scarcity, depending upon which particular price deflator is used to adjust the nominal resource price. Therefore, this measure gives mixed scarcity signals.

The Rental Rate of natural resources, or the value of resources *in situ* may indicate scarcity while the other indexes do not. The rental rate on timber in the USA generally rose during the past 60 years; the unit cost generally fell during this period while the product price (lumber) fell relative to the rental rate. Rents on a mineral resource might be approximated by the marginal replacement cost, that is the cost of discovering new deposits. However:

* So little data are available, that often the rental rate is not a practical measure in the short run.
* It anticipates growing scarcity in an economic sense, but impending physical exhaustion is compatible with any prior path and level of rental rate.

Brown and Field also note (1979, 219) that all of the above indexes may be biased because futures markets do not really exist and because they fail to reflect the pressure of non-market demands associated with environmental quality.

A final point needs to be made which may invalidate the whole testing procedure of Barnett and Morse and their followers. In fact, there may be no *constant* association between relative prices and time, as assumed in the simple trends fitted to several point data. It has been shown that a reworking of updated figures from the Barnett and Morse analysis indicates that there is considerable instability over time when used with the indexes of extractive sector prices relative to both the wholesale price and consumer price indices over the period 1900 to 1973 (Smith and Krutilla, 1979, 28).

Broader conceptualization issues

Beyond the issues discussed above, there are wider issues of conceptualization of economic scarcity, which have the effect of further weakening the validity of the empirical findings. They will be introduced here to illustrate that also among economists attempts are being made to work towards integration with wider geobiophysical perspectives.

The *conceptualization of resources* as a source of materials inputs in production leads one to consider the environmental side effects of extraction and conversion activities as phenomena to be distinguished from resource utilization and depletion. It follows that environmental damage can be treated separately from scarcity measures, by evaluating the costs associated with meeting air and water pollution standards.

Smith and Krutilla (1979, 5) argue that the most appropriate definition of natural resources is to include *all* the original elements that comprise the earth's natural endowments. In a broad sense, they may be thought of as life support systems. They contend that this more general viewpoint will identify an array of economic issues associated with the use of endowments which are overlooked when the focus is too narrow.

All natural resources are assets which yield service flows. The economic literature on natural resources has focused, for the most part, on a subset of the natural resources: primary commodities produced by extractive activities, as raw material inputs into production and consumption. Materials policy could then be construed as addressing the problems of natural resource scarcity.

A broadened definition that includes common property or open-access resources provides for diversity of uses (to include life support functions) and the corresponding complexities for economic analysis. Even within the traditional framework, the distinction between renewable and non-renewable resources is not enough, as the non-renewable resources need to be further distinguished in those that are recyclable (such as metallic minerals), and those that are not, such as the conventional energy commodities. This distinction points at a *hierarchy of commodities* and is in line with natural science concepts of the linear economy.

One could go further, and *classify technological progress* in ways not normally done by economists. In economics, primary inputs are labour and capital, and technological change is defined as either labour saving or capital saving. The separating case is 'neutral' technological change, which leaves the proportion between labour and capital inputs constant over time and over scale of production.

Environmentally, an analytically more powerful classification is to distinguish different forms of technological change:

a. *Economy innovations*, which achieve a net economy of low entropy - be it by a more complete combustion, by decreasing friction, by deriving a more intensive light from gas or electricity, by substituting materials costing less in energy for others costing more, etc.

b. *Substitution innovations*, which substitute physico-chemical energy for human energy. For instance, gunpowder did away with the catapult. Such innovations enable not only to do things better, but especially to do things which could not be done before - to fly in airplanes. To convert the Haarlemmer Lake into a polder, in mid-19th century, became only possible due to steam-driven pumping stations (imported from England), as the traditional Dutch windmill technology could not cope with the expanding size of the Lake, which was threatening both Amsterdam and Leiden, 'through the back-door' so to speak, protection from the sea being the foremost concern of Dutch society through the ages.

c. *Spectrum innovations*, which bring into existence new consumer goods. Most of the innovations of this group are at the same time substitution innovations. In fact most innovations belong to more than one category (Georgescu-Roesen, 1993, 93).

The relevance of looking at technological change from both perspectives is to consider the mechanization of agriculture. To an economist this is a capital-labour substitution allowing larger land areas being brought under the plough with differentiated production, employment and income effects. To an environmentalist, the issue is seen differently. The ox or the water buffalo derive their mechanical power from solar radiation caught by chlorophyll photosynthesis. In contrast, the tractor is produced and operated with the aid of terrestrial low entropy. The result is a shift of the low-entropy input from the solar to the terrestrial source, and the substitution of a scarce source of energy for a more abundant one. This is the opposite of what economic reasoning assumes and recommends!

The limited conceptualization of terrestrial resources as inputs in production incurs the risk that private property resources services may be increased at the expense of common property resources. The wider framework identifies this potential for conflict in alternative allocations of natural resources: commodities exchanged in organized markets versus the conjunctive use effects on common property amenities and life supporting natural resource services. In the wider conceptualization as advocated by Smith and Krutilla, the view of Barnett and Morse, and nearly all economists in their wake, that pollution problems can be dealt with separately from resource input use is misguided and has the character of being merely 'damage control'.

The *institutional dimensions* of the market process. While there is an array of institutions which potentially influence the allocation of resources, economists have tended to focus on the market to the exclusion of many others. But institutions are important. Institutions serve to set ground rules, directly or indirectly, for all allocation processes: it makes market transactions feasible by providing parties with reasonably sure expectations of performance, and lowers transaction costs.

Key institutions for obtaining non-market information on resource use decision making are the legislative, public administrative and judicial systems. While these institutions are clearly important in environmental management, there is too little information on whether such institutions link effectively and efficiency policy goals and the means used, to intended (environmental) ends, neither in the aggregate, nor at the margin of expanding or contracting systems of regulations (Smith and Krutilla, 1979, 282-3; Randall, 1978, 1986).

In *conclusion*, the evidence on which neoclassical economists generally feel that natural resource scarcity does not appear to be a real issue, is not really convincing. Yet, with observed declining real natural resource prices for sustained periods of time, and seeing future projections which also do not seem to indicate a major turnabout in prices, they argue that no major problems are in sight, although there may be temporary and short-lived disturbances, usually of a political nature, to upset the minerals market. They would argue that individuals and their governments are jolted into action by such 'crises', and they further believe in the popular saying that 'Necessity is the mother of invention'. These opinions of economists are also popular with politicians, because it offers the prospect that no problems are to be foreseen and that ugly choices, due to natural resource scarcity blocking or perhaps reversing economic growth paths, need not be made. But, as shown in this section there are a number of conceptual, statistical and interpretational issues which would require much more research, if these conclusions are to be better founded.

6.2 Biophysical perspectives

A central element in the interpretation of the findings of Barnett and Morse (1963) regarding the future of scarcity of materials, is the assumption they make about the occurrence of physical resources. Two positions can be taken: resources may be scarce in the aggregate: fixed stocks, which cannot be augmented. Alternatively, the supposition is that as higher grades are exhausted, lower grade sources are found in greater abundance. Moreover, the qualitative differences among various stocks diminish as the grade of the materials declines. This is the assumption of Barnett and Morse, and it argues for relative scarcity: rising prices provides the incentive for substitution and for technology development to utilize progressively lower grade ores, which are also much more abundant than high grade ores. Lower grade deposits are often assumed to be located in the neighbourhood of existing mining sites, and exploitation develops as an extension thereof.
But how reliable is that hypothesis?

The assumption on occurrence of resources raises two issues: how much do we know generally about the location, amount and quality of various deposits of materials? Equally important, what are the characteristics of the earth's crust where these deposits occur and to what extent can we expect similar occurrences elsewhere? Not all areas of the earth have been explored for deposits of minerals, and those that are may not provide a good sample for extrapolation on a global scale.

Geological evidence indicates that there is an alternative view to the occurrence of materials. A number of resources may have the pyramidal form of low volumes of high grade ores at the top, and high volumes of low grades at the bottom, as is the conventional wisdom. But for some crucial resources, which may be increasingly demanded in future, an alternative hypothesis may hold: that after the richest grades are exploited, the quantities available at lower grades will decline rather than increase (Brobst, 1979). This may be called the *inverted pyramid* of resource occurrence.

Govett and Govett (1977), for instance, look at the issue of natural resources from a geological supply-side perspective. Five developed countries - the USA, the (former) Soviet Union, Canada, Australia and South Africa - produce the bulk of the world's economically important minerals with the exception of cobalt, tin, tungsten and bauxite. Future production will depend to a very large extent on continued and intensified exploration in already known districts and on the development of techniques to exploit very low-grade sources of minerals. The reason is that, while conceptually the earth's resources are enormous, a geographic concentration of elements in the earth's crust which make it economic to mine is an abnormal and rare geological event. For the period 1950 to 1970 the Govett's demonstrate (ibid. 47) that the probability of discovery a new mine has sharply declined, while the exploration costs in real terms have sharply increased.

Ecologists have developed methods to measure resource use trends not by price indicators as is done by economists, but by calculating 'energy cost' per unit of output, using physical units of measurement and starting from the key non-recyclable and non-renewable resource as *numeraire*. In the economic analysis man-made capital and labour are considered the basic factors of production. From a biophysical perspective these are no more than intermediary inputs.

A biophysical model of scarcity posits that direct and indirect energy costs of resource extraction increase with depletion because lower quality deposits, and deeper drilling to find exploitable ores, require more energy to locate, upgrade, and otherwise transform deposits into useful raw materials. Technological development will have to be directed to that end. If, however, the inverted pyramid holds for some key resources further exploratory search might be futile in the end anyway. Little will be found despite the development of new extractive technologies.

The economic advantage of switching from low-quality animate sources of energy such as biomass, human labour and draft animals to high-quality, inanimate energy sources such as fossil and nuclear power, is rooted in the simple thermodynamics of energy conversion. Humans convert the chemical energy in food to mechanical work with about 20 percent efficiency. A labourer consuming 3000 kilocalories per day can thus perform about 600 kilocalories of useful mechanical work per day. An internal combustion engine burning gasoline at 10 percent efficiency can perform an order of magnitude greater amount of useful work. A labourer subsidized by an energy convertor burning fossil fuels can obviously mine more coal, cut more timber, catch more fish, and harvest more fish per day compared to earlier un-subsidised efforts of labour (Cleveland, 1991). The energy standard is then presented as inherently superior to study scarcity in materials. One does not have to appeal to the nebulous and empirically unsupported concept of 'self-generating technological change', to 'explain' the unexplained residual in production function analysis of economics. Instead, the adepts of the energy standard maintain that societies with access to fossil fuel sources experienced unprecedented rates of economic growth, while those without access to cheap energy sources do not develop.

Biophysical methods are regularly used by energy specialists, when they want to measure the energy efficiency of alternative machines, of wood use in (improved) stoves, or by agronomists when calculating conversion efficiencies of food production, of plant material for human consumption directly, or by using plant materials to first feed animals, the products of which eventually enter into food energy of humans.

The most extensive recent effort to assess resource use trends based on the energy standard, is that of Cleveland (1991). He repeated the Barnett and Morse exercise from this biophysical perspective. His findings are that energy costs per unit of output increase with depletion. Results show that labour and capital costs declined *because* large quantities of surplus fossil fuel substituted for and increased the productivity of labour and capital. Substantial increases in energy costs were found in agriculture, fisheries and the mining of metals and fossil fuels. Energy costs per unit output in forest products declined.

Cleveland's results generally support the economists' findings for non-metals but contradict the unit cost results for metals. Metals show a distinct increase in scarcity beginning between 1939 and 1954. Cleveland's results are generally consistent those of Slade (1982) who fitted a U-shape time trend model to real resource prices and found that most metals are on the upward sloping portion of the long run price path, and the results are also consistent with Hall and Hall's conclusion that coal and petroleum grew scarce in the 1970s.

Examples of physical output trends per energy unit (BTU) needed to produce these outputs from the analysis of Cleveland (1991) are presented below in Figure 5. For the energy sector itself an EROI index is employed. This index is the Energy Return On Investment, which is the ratio of fossil fuel energy produced to direct and indirect energy costs of that production.

Figure 5a

Output per energy input ($Q/E_d + E_i$) for the metal mining sector. Output for total metal mining is measured by the Federal Reserve Board production index. Output for individual metals is measured by tons of metal produced.

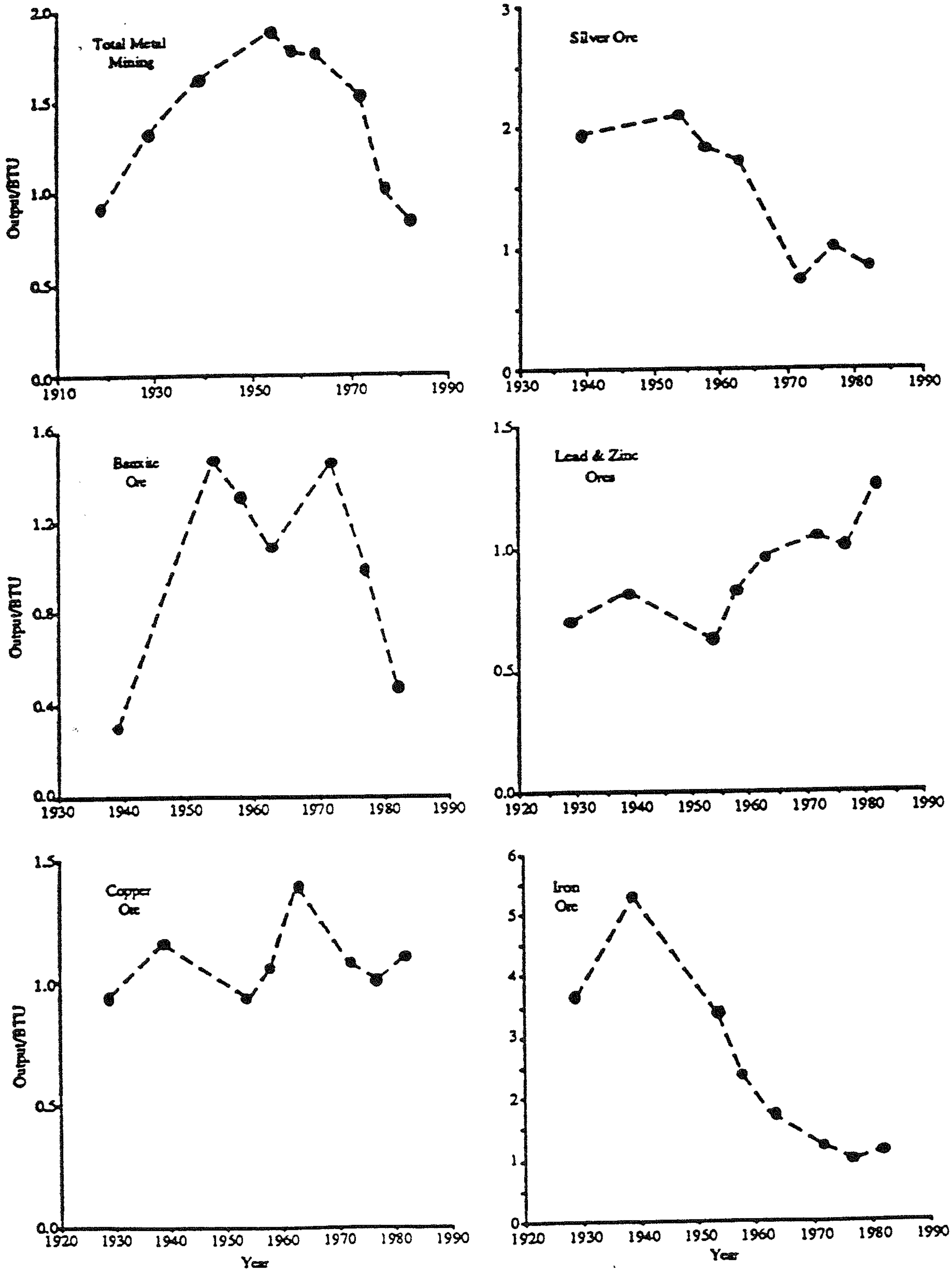


Figure 5b

Output per energy input (Q/E_d+E_i) for the nonmetal mining sector. Output for total nonmetal mining is measured by the Federal Reserve Board production index. Output for individual nonmetals is measured by tons of mineral produced.

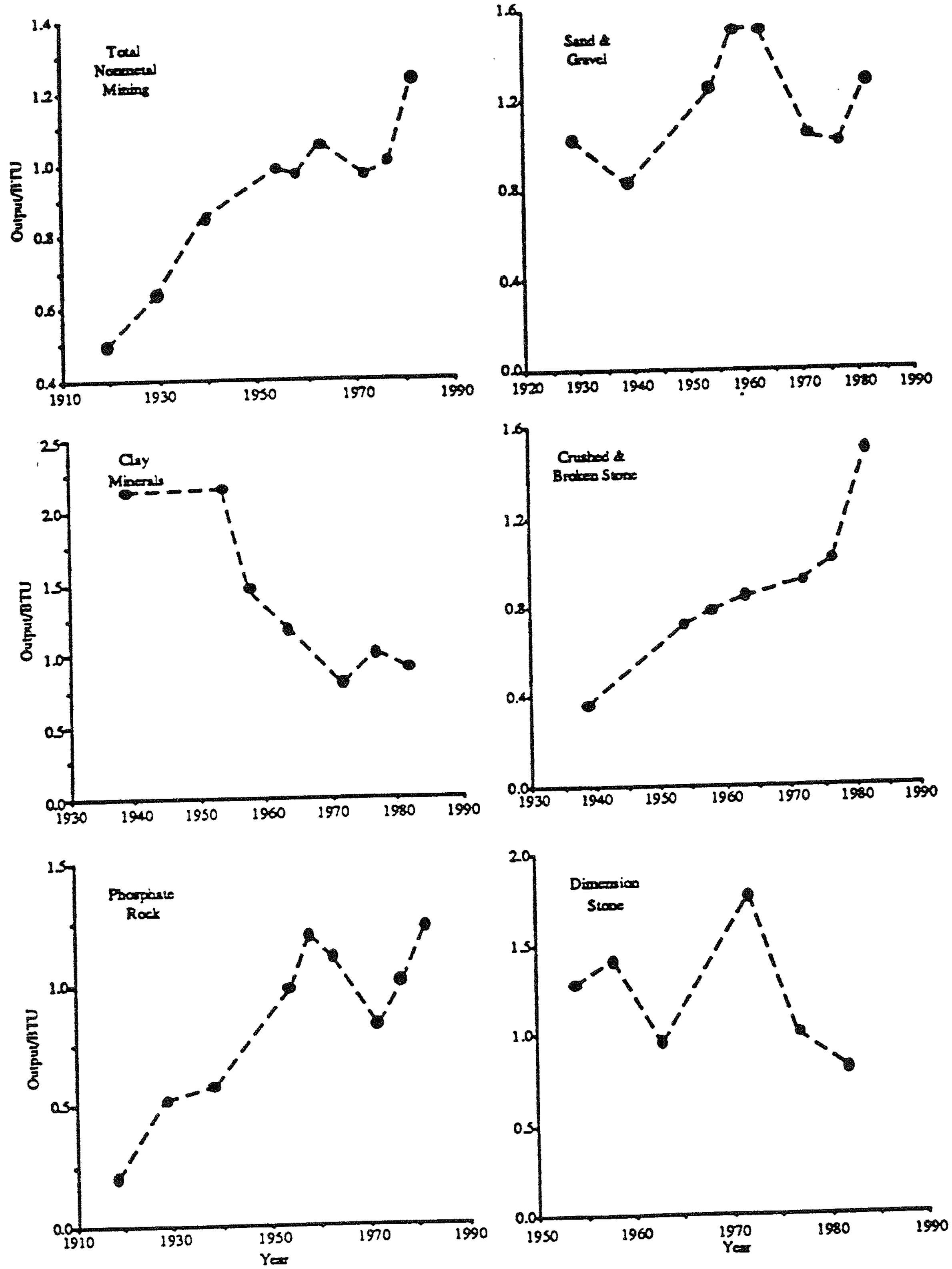
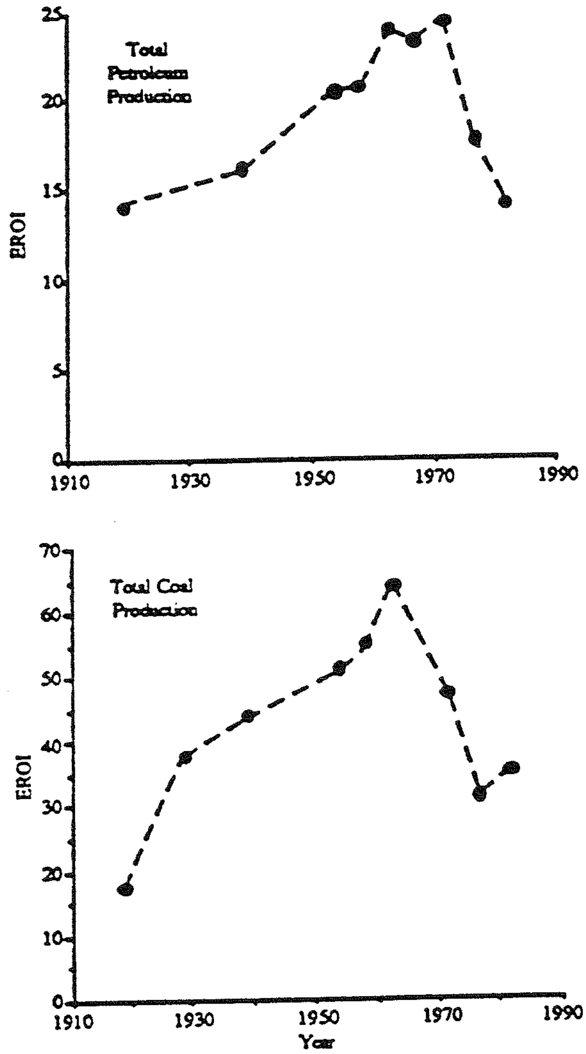


Figure 5c

Output per energy input (Q/E_d+E_i) for the fossil fuel mining sector. Output for petroleum is measured by thermal equivalent of crude oil, natural gas and natural gas liquids produced. Output for coal is measured by thermal equivalent of bituminous and anthracite coal produced.



Source: Cleveland (1991, 300-302).

The remarkable decline in labour costs of extracted resources documented by Barnett and Morse was made possible, or is explained, by a simple physical substitution: fossil fuel energy was substituted for labour in the resource transformation process. This is the 'real' driving force behind the transformation to industrial society. To be more precise: the period covered by Barnett and Morse coincides with the rapid transition of the (American) economy initially driven by low quality wood, to one powered by high-quality fossil fuels. In 1870, wood accounted for about 20 percent of total US fuel use. By 1910, coal had almost completely replaced wood, and by 1957 oil and natural gas had largely replaced coal as the dominant fuel source. The period spanned by Barnett and Morse's analysis was therefore dominated by two complete cycles of substituting high-quality fuels for low-quality fuels with corresponding spread effects in multiple directions, and in an interactive manner. It is not surprising therefore that the product price and capital-labour cost of other resources declined. Larger energy surpluses of ever higher quality fuels reduced the labour-capital cost of extracting all other resources (Cleveland, 1991; Rosenberg, 1973).

Comparing this model with that of economists, and in light of the discussion above on the adequacy of measurements employed by economists, it is not difficult to show that economists may not be impressed by this energy standard. In particular they will take issue on the interpretation of the upward trend in energy costs as the 'real scarcity' indicator. Economists will query Cleveland's findings, because they would argue that this apparent rise in real energy costs should be compared to other costs such as to arrive at *relative* real cost. For economists real resource cost trends, whether up or down, but in isolation, have no meaning. They gain meaning only in comparison to other costs. Economics compares resource-intensive to resource-extensive products. The dispute will then remain unresolved because the economist's *numeraire* (labour or capital) shows ambivalent results, while the environmentalists deny that there is an acceptable alternative to the energy standard as the 'ultimate' commodity.

7 FOOD, ENERGY AND SOCIETY

The biophysical model of the energy standard can also be applied fruitfully to the agricultural sector. It provides a framework for looking at agriculture and agricultural development in a different light compared to the way economists and other social scientists look at agricultural development and related development policies. The implications for development and policy of looking simultaneously at both perspectives are potentially many.

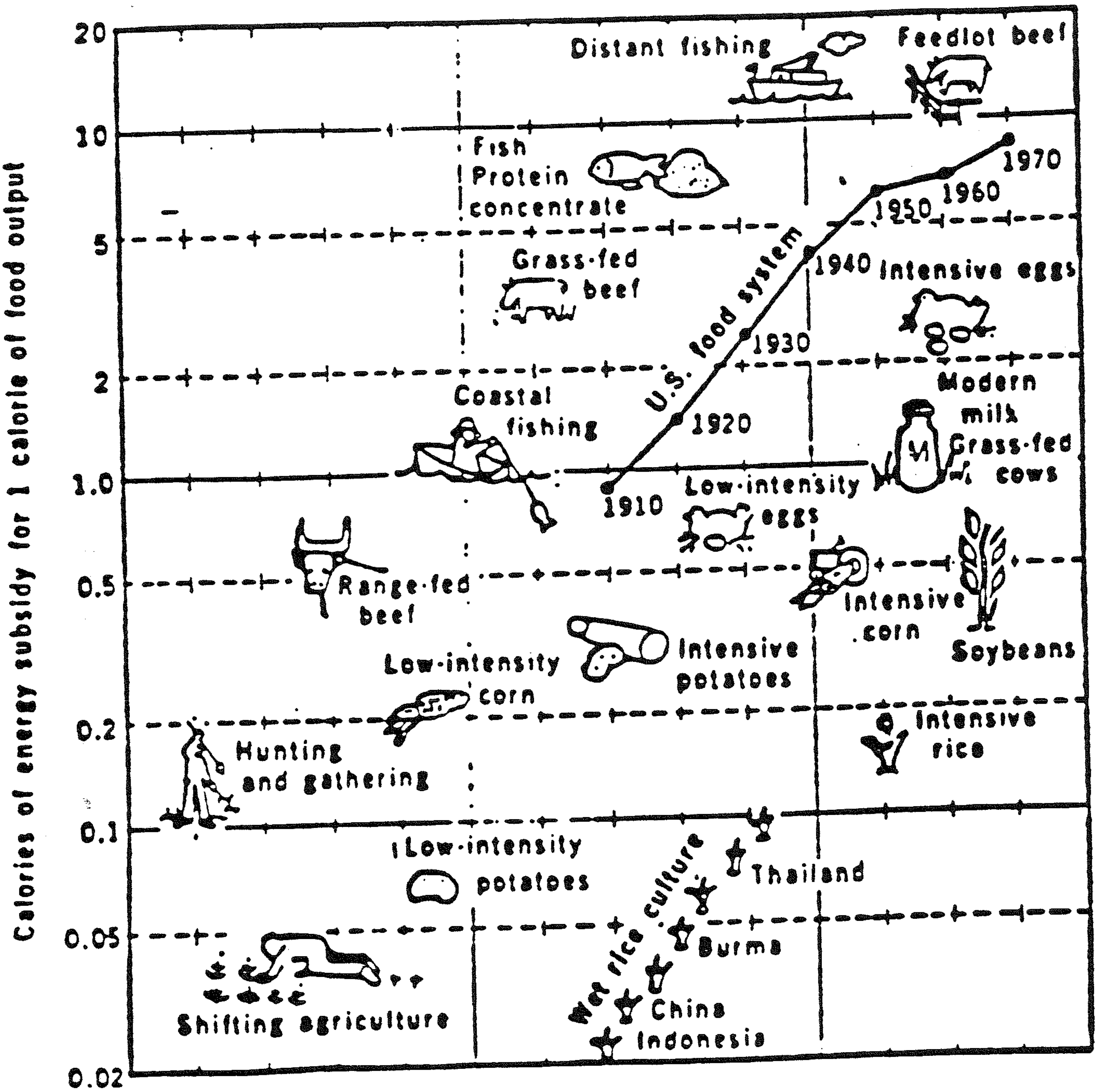
Three examples will be given here of applying biophysical methods to agricultural change. First is the analysis of the Steinharts (1974). It shows the evolution, in energy terms, of US agriculture and compares this with the energy characteristics of a range of farming systems elsewhere and especially in developing countries. Second, the main findings of Cleveland (1991) for agriculture are presented, because he extends the energy analysis of US agriculture by nearly 20 years. He finds that there has been a sharp trend reversal in the energy characteristics of US agriculture since the 1970s. This raises questions as to why this occurs and what the implications are for policy and the environment. To complement these findings, and thereby add to the 'riddles', some findings are added of comprehensive studies on soil erosion in the USA. Third, the analysis of Smaling and Stoorvogel (1990) is presented on the nutrient balance implications of FAO's long term projections for agricultural production for Sub Sahara Africa. They show alarming net nutrient losses to be expected from their analytical model. The 'doomsday' future suggested by these findings, however, can also be supplemented and contrasted by data which would offer a glimmer of hope for the future of Sub-Sahara Africa. Such information is derived from careful longitudinal historical studies of rural change in high density population areas in Africa. Such studies demonstrate that the process of land intensification is well under way, in a framework pioneered by Boserup and Ruthenberg which links agricultural change to population pressure. Unfortunately, such studies cannot demonstrate that this positive experience can be repeated again towards the future, when the rate of population growth will be about double the rates implied in most of these historical studies. These sets of findings, therefore provide as a minimum some *food for thought* on questions of agricultural development strategy and sustainable development.

Energy characteristics of food systems

As recently as 1940, four-fifth of the world's population were still on farms and in small villages, most of them engaged in subsistence farming. The question which Steinhart and Steinhart (1974) asked was: How does our present food supply system compare, in energy measures, with those of other societies and with the US past? They distinguish three levels of energy use: on farm (with 7), processing industries (also 7), and commercial and home (with 4 categories of energy use). All these energy inputs are required to produce food output, measured as the calorific value of the food consumed. The food sector is thus seen as a linear energy input-output model. The calculations have been made for the period 1910 to 1970. The key finding is that in 1910 the energy inputs into the food system were roughly equal to the energy output of food production. However, by 1970 the US system had evolved such that for each energy unit of food output, nearly 10 energy input units were required. This trend is associated with the development of types of agriculture which became increasingly energy intensive, and thus showed sharply declining energy efficiency characteristics.

These results are presented in Figure 6 below, superimposed on the input-output characteristics of a range of other agricultural systems widely practised in different parts of the world, mostly in Asia and Africa.

Figure 6. Energy subsidies for various food crops



Source: Steinhart, 1974.

The analysis raises large questions on the feasibility and viability of agricultural development trajectories for the developing countries: will they develop also by sharply increasing the energy intensity of production, and substitute capital for labour which has accompanied this trend in the developed countries? Looking at the record, where increases in agricultural yields have been achieved since the 1960s, one comes automatically to the high external input model followed in Green Revolution technologies for wheat and rice. It was a model which could only be successfully applied in well-irrigated areas. Most dry-land agricultural areas of the world have not experienced any sustained yield-growth. To the contrary, yields have been declining in many instances. The relatively successful observable development path has thus indeed been along the lines of rapidly increasing energy intensity: the development of high cost irrigation systems and use of fossil fuel-based external inputs in fertilizer and pesticides. There is however growing evidence of declining yield growth trends and deteriorating irrigation infrastructure in the major Asian countries with high dependency on irrigation for their food supply (see for the evidence: Van de Laar, 1994).

Additional implications can be envisaged for land use competition resulting from dietary change towards higher shares for animal products, which are statistically associated with higher per capita incomes. Such issues may best be introduced in a specific regional planning context, if only to point at the intricacy of the issues arising. For instance, the introduction of dairy cattle in East and Central Java (in Indonesia) has sharpened land use conflicts in high population density areas. The stark choice, in the absence of spare land, involves devoting farm land to produce food for people in direct energy conversion, or devoting land to fodder for imported dairy cows to produce milk in indirect energy conversion (Borgstrom, 1973). Moreover, the bulk of this milk would be consumed in urban areas. Private profitability calculations favour devoting land to fodder. To simple-minded economists it would thus be a good thing to shift to dairy: the shift represents the very substance of induced structural development and change in the agricultural sector following market signals.

However, the introduction of higher quality dairy cows tends to have the effect of making the rural countryside even more of a food deficit area than it already was. As the effective owners of the new dairy cattle were economically powerful, they could implement their investment plans. Further, the new dairy cattle required higher quality fodder, and regional fodder resources were being rearranged by preferred nutritional value to support the new, high potential dairy cows, with negative effects on the fodder situation of traditional animal units in the region. One dairy cow deprived three traditional animal units of their subsistence fodder to function in multiple roles in small scale farming units.

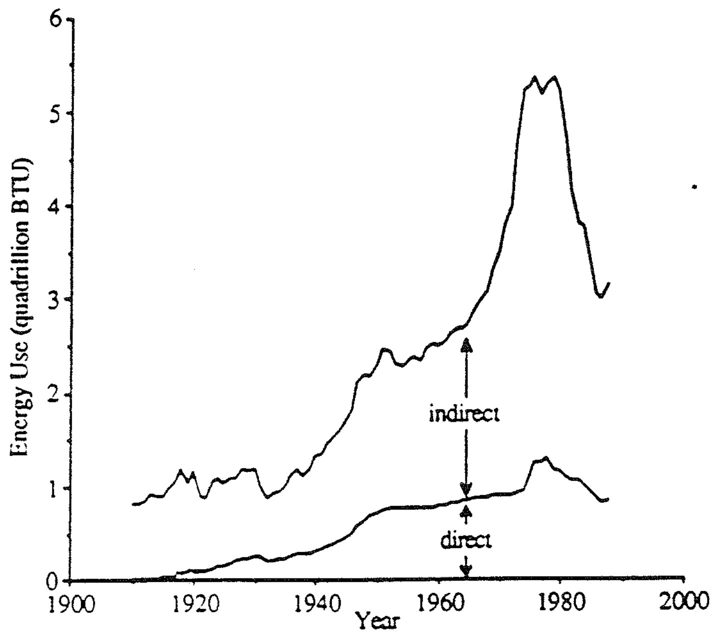
By itself, a decline in (sub)regional food self-sufficiency need not be a bad thing, if the food shortage can be covered from interregional trade in food stuffs. But close-in regions where food surpluses were or could be produced cannot readily be identified. And if there were to be such surpluses elsewhere, it appears unlikely that these would flow to the food deficit area where falling per capita incomes were being expected for lack of alternative broadly-based income (Van de Laar, 1985).

Changing energy intensity in agriculture in the USA

It should, however, not be assumed that a secular growth in the energy intensity of agricultural production in the course of development is inevitable, as may be shown in recent trends in the USA. Cleveland's (1991) analysis is more limited than that of the Steinhart's because he confines his analysis to the farm level only, excluding agricultural processing and the energy implications of commercial and of home consumption of food. This is a pity, because the energy intensity of food at those levels in the production-consumption chain may well continue as before. In the aggregate energy increases in processing may even outweigh energy input reductions at the farm level stage of agricultural production.

Direct fuel use in agriculture is derived from farmers' expenditures on fuel and electricity. Indirect energy derives from farm inputs such as mechanisation and fertilizer; both categories require considerable amounts of energy for their production, and the main energy source is fossil fuel. The heterogeneity of agricultural production is obviously a problem, as can be seen also in the Steinhart analysis, but the aggregate energy trends, by direct and indirect energy use, are presented below.

Figure 7



Total energy use in the U.S. agricultural sector, 1910-1988, in 10^{15} BTU.

Source: Cleveland, 1991, 309.

Significant changes have occurred in US agriculture in the last twenty years. The energy price shocks of the 1970s had a major impact on the way US farmers use energy on farms. Total energy use declines 42% between 1974 and 1988 after increasing more than 100% between 1960 and 1974. There is a pronounced relative shift away from indirect energy use, due principally to the severe curtailment in the use of energy-intensive chemical fertilizers and pesticides. On the other hand, the reduction in energy use did not cause a diminution in output. In fact output increases between 1974 and 1988. Unfortunately crop-wise energy-output trends are not provided or have not been calculated.

One interpretation (Cleveland, 1991: 310-11) of these data is that farmers have clearly improved the efficiency with which they use energy to grow crops and produce livestock through reduced tillage, more controlled and timely applications of inputs as fertilizer, pesticides and irrigation water, heat recovery systems and other recovery practices. However, that conclusion must be tempered with the fact that government payments to farmers in price stabilization programmes increased dramatically in the 1980s. One result was large fluctuations in the number of acres harvested.

An alternative way to thus measure the relationship between energy use and output in agriculture is to scale both inputs and outputs by the number of acres harvested. This relationship (not shown here) indicates that prior to the oil price shocks agriculture was experiencing diminishing output per acre as a function of energy use per acre. Between 1974 and the early 1980s, energy use per acre and output per acre declined at about the same rate as they had increased between 1910 and 1974 (Cleveland, 1991).

Cleveland's very useful analysis of energy trends is not linked to the effects of economic indicators such as input and product price trends. Conceivably, an analysis might be attempted to incorporate physical and economic indicators in such a way that any residual might be interpreted as 'growing environmental awareness of farmers as land managers', to influence farmer behaviour. Such type of analysis would lead to further collaboration between economists and biophysicists with the hope of leading to a better understanding of interaction between different sets of variables, and on the effects of government agricultural policies: market-conform or other types of regulations.

A problem with the energy analytic approach by both the Steinhart's and Cleveland is that no indications can be derived about the question whether variations in measured external energy input use in any way have been compensated by trends in the nutrient balance in the agricultural lands. Thus, the issue is whether the recent observed reduction in external energy use in US agriculture has been compensated by increased nutrient-mining of the soil.

The more popular literature about ecology and world agricultural development routinely features soil erosion as a major threat to agricultural sustainability (Brown, et al. 1990). But hard evidence on soil degradation is rarely available anywhere, and much of the data is anecdotal or site specific. Broader-based in-depth analysis does not generally confirm these popular notions.

The USA first acquired reliable comprehensive estimates of erosion with the 1977 National Resource Inventory (NRI) A second, more intensively sampled NRI taken in 1982 confirmed the 1977 data. These data have been used by several groups, such as the US Department of Agriculture, soil scientists at the University of Minnesota and Resources for the Future to estimate the effect on crop yields of 100 years of cropland erosion at 1982 erosion rates. The results showed that in the year t+100, yields would be 3% to 10% below what they otherwise would be. At the higher end of this range, cumulative crop production costs over the 100 years would be about 5% higher than they otherwise would be. This estimate takes account not only of the erosion-induced loss of yield but also the cost of the additional fertilizer needed to replace soil nutrients, and the cost of additional energy needed to plough less tillable land (reported in Toman and Crosson, 1991: 20-21). Does this make the discussion of soil erasion the equivalent of a storm in a tea cup? On the other hand, a significant amount of irrigation water is pumped from non-rechargeable aquifers, for example, the Ogallala Aquifer which underlies much of the American Great Plains. That region also faces increasing competition for water for nonagricultural uses.

Riddles from Africa

The third example relevant for the present discussion is the major and pioneering study on nutrient balances in African agriculture; the only region in the world where per capita food production has not risen in 25 years. Stoorvogel and Smaling (1990, and Smaling, 1991) made a detailed study of soil nutrient trends for Sub-Saharan Africa, on the basis of projections made by FAO for the year 2000. They distinguished five categories of addition and five categories of withdrawal of the macro-nutrients nitrogen, phosphorus and potassium from the rootable soil layer for six Land/Water classes. They conclude that nutrient depletion is quite severe in almost all 38 countries in the study. Nutrient depletion rates in East Africa are more than four times the average for SSA. The FAO 2000 projections resulted in an increase in nutrient depletion in all countries, particularly in the countries which already had a high depletion rate. The high increase in fertilizer consumption projected by FAO does not help in lowering the depletion, as it is more than offset by increased nutrient withdrawal. The model is sensitive to changes in soil fertility classes and erosion, but a cross-check with long-term fertilizer experiments in East Africa confirm the conclusion of declining soil fertility even on fertilized land (Stoorvogel and Smaling, 1990: 8). Under these conditions the outlook for agricultural development would seem bleak indeed, as persistent mining of soil-nutrients is not environmentally sustainable. Evidently, more studies of nutrient balances in diverse agricultural systems are desirable, especially from the perspective of the sensitivity of results to changes in the model specifications.

However, reality is not all 'doom and gloom' when we turn from the above analytical models of nutrient balances to careful historical research on land use trends, population growth and agricultural intensification. For instance, let us consider the recently published results of the Land Resource Management study in Machakos District, Kenya 1930-1990 (English, et al. 1994; Tiffen, et.al., 1994), against the alarming soil nutrient losses calculated by Smaling and Stoorvogel (1990) for Sub-Sahara generally and for East Africa in particular, as discussed in section 2.6 of this paper.

In the late 1930s Machakos District, a semi-arid area of East-Central Kenya not far from Nairobi and inhabited by the Akamba people, was considered by the colonial administration to be degrading alarmingly and to be rapidly approaching, if not exceeding, its capacity to support its inhabitants and their livestock. Today, the area has a population five times as great and the value of agricultural production per head (at constant prices) is estimated to be three times larger than it was then. At the same time food production in the area is less susceptible to drought than before, although still subject to it. The rate of erosion has been sharply reduced, although it does still occur. While soil analysis shows that the chemical contents of the soil (nitrogen, phosphorus, potash, etc.) is lower than in the soils under natural vegetation, their productive capacity has clearly been raised substantially, and there is no evidence to suggest that their quality is declining under current use practices. The rangelands areas appear to have a higher proportion of woody species than earlier, and this could indicate poor grazing practices and reduced capacity. However, it is not clear that this is the cause, as prohibitions on bush fires, reductions in game populations (especially of elephants), and auctions by users to encourage tree growth have all played a part. There are certainly more trees than before and they are being actively managed by farmers. Projections made in the 1950s, the 1960s and again in the 1970s all foresaw severe fuel wood shortages, but there is no evidence that such have occurred. Therefore, the conclusions of the study are that the agricultural growth which has occurred has not been accompanied by resource degradation (English, et al. 1994: ix). The types of development found in the area are closely in line with the hypotheses of Boserup and Ruthenberg and others on the changes and intensification induced by population growth. Some 45 new technologies have ben adopted, half of which are new products. Some agricultural innovations have resulted directly from government efforts, e.g. breeding early maturing varieties. Others have had virtually no official support. To the contrary, the report documents a range of policies pursued by the colonial and post-colonial governments which have been strongly resisted by farmers and which have been generally counterproductive (ibid: x).

The detailed longitudinal study of Machakas is of interest in that it shows the conflict between the manner in which environmentalists diagnosed the situation which they extrapolated to disaster, and the reality of environmental recovery which was provoked or induced under the pressure of growing population numbers not willing to abandon the area but to do something about its natural attributes. The Machakos study thereby demonstrates the power of thinking in terms of challenge and response mechanism, analogous to the line of reasoning of economists who analyzed relative scarcity of natural resources.

The Machakos case does not stand alone. Turner, Hyden and Kates (1993) designed a project whereby 10 (sub)regional, and high population density areas in East Africa and in Nigeria, were analyzed with a common methodology by recognized area specialists. This focus on sub-national entities differs from the analysis of Lele and Stone (1989), who took a 6 country perspective in the framework of the MADIA Project[7], for the national perspective usually consists of developments in different agro-ecological zones, whereby important differences in experiences may be lost due to aggregation. Turner, et.al. reach the conclusion that long-term population growth and economic development usually do not take place without intensification and agricultural growth, although intensification and agricultural growth do not inevitably follow population growth and are not necessarily beneficial or sustainable. It is then critical to define the circumstances under which agricultural intensification does follow population growth, benefits its practitioners, and is sustainable for the long term. (ibid, 21).

The point to make here is that adherents of different disciplines tend to use different methods of analysis of phenomena related to the state of and trends in the natural environment and come up with different kinds of findings on which they base extrapolations. A better understanding of the premises of the different disciplinary approaches and at least a basic familiarity with the major findings of alternative approaches would be necessary first steps in appreciating actual trends, and in understanding the conditions under which certain trajectories may follow. (See further Pingali and Binswanger, 1988; Van de Laar, 1996, Section 2.3).

8 PRODUCTION MANAGEMENT AND WASTE MANAGEMENT.

The materials-balance principle for depicting and measuring the economic process involves a straight-forward application of the first law of thermodynamics. This method is widely used in the design of chemical engineering systems. Applied to the national economic system it requires that attention is to be given to the useful portion of materials processing, in what is called by economists 'production output', and also to the 'non-product output': the flows of waste materials. There is thus a clear need to approach the economic system as an integrated linear flow system, where the nature of, and the scope for closure of the system need to be actively explored. What in economic systems, such as in Input-Output models, are considered 'final demands',

[7] MADIA stands for a multidonor-funded project to study the Management of Agricultural development in Africa, to counter the excessive levels of generalisations contained in the studies of the World Bank of the agricultural and general development crisis in Sub Sahara Africa.

are in the reality of a materials-balance approach only intermediate throughput elements, rooted in the natural environment of the earth and affecting the global commons of land, air and water in volume and quality.

Not infrequently a combination of input data (obtainable from economic statistics), together with technical process data available from engineering analysis, gives a more reliable estimate of waste residual outputs than direct measurements could be expected to do (Ayres and Kneese, 1990: 112). An orientation in production technology would therefore seem to be essential for economists, if their theoretical discussions of abstract production, as in production function analysis, is ever to become more realistic.

The structure of production

Let us present structured materials balances flows in the economy in some detail, to be able to explore some of the issues which then arise for economic theory and analysis.
Consider Figure 8 below.

The production process in economics is directed to producing economically valuable outputs to meet consumer demands, e.g. outputs which can be marketed and sold to the general public. However, in producing Production Outputs (POs), also Non-Product Outputs (NPOs) are (jointly) 'produced'.

No production or use activity converts 100% of the material and energy inputs into desired products and services: product outputs. There are five possible fates for the non-product outputs: (1) material/energy recovery; (2) by-product production; (3) discharge into one or more of the three environmental media - land, air, water - with or without modification; (4) processing to obtain materials for use as subsequent inputs to production or energy conversion; and (5) re-use in the same form, as in markets for 'second-hand' capital goods and consumption goods.

Of these five possible destinations of NPOs, the first four are often neglected in most standard textbook economic analyses. The fifth option has received explicit attention. The option of re-use in production has emerged in the development economics literature, in terms of its potential contribution to the initial industrialisation in developing countries, while the re-use in consumption is usually considered in the framework of a social safety net for those with low incomes. Some processing before actual re-use in either form is often involved such as cleaning and minor repairs.

Proponents of using 'second-hand' capital goods in development policy see a learning process associated with spreading industrial technology at low cost, while antagonists argue that product standards achievable with second-hand technology will not be able to meet changing product standards in international trade, and its output will thus not be competitive. In this view, second hand technology creates more permanent international dependency of those adopting it. In reality, of course, selective use of second hand technology in segmented markets could be beneficial in promoting the former while avoiding the latter. But only specific analysis of concrete situations of mixtures of technology in time and place would be able to resolve these initially antagonistic viewpoints.

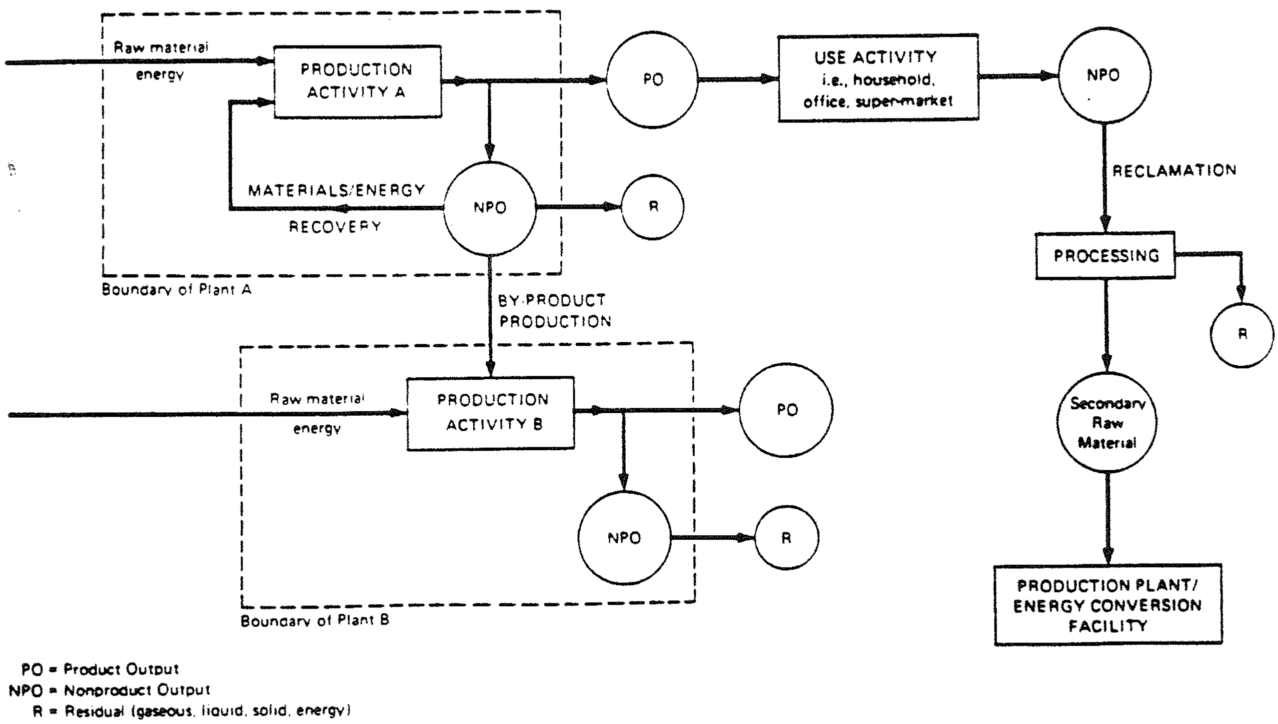
From an environmental point of view this type of economic analysis is, however, seriously deficient for it neglects the possibility that different technologies will have different energy demands and environmental side effects. Where modern Western technology, under the impact of environmental regulation, begins to be more environmentally friendly, the case for exporting second-hand technology, though cheaper in financial terms, is weakened on environmental grounds: if spreading technology is desirable in itself, it would be better to start the process with cleaner technology rather than with dirty forms of technology.

The re-use of second hand goods in consumption tends to be centred on the growing trade in second-hand clothing. The collection and distribution of second hand clothing is often inspired by humanitarian concerns, and is pioneered by NGOs or individual family-based relationships, to meet poverty, or to accommodate the consequences of political and/or military turmoil. Such commodity flows originate in the developed countries and are focused on especially Sub-Sahara Africa, and, after 1990, also on (parts of) Eastern Europe. If targeting on the poor is effective, it will meet its distributional and welfare objectives. On the other hand, the distribution of second hand clothing for (nearly) free does compete with, and possibly undermines emerging local textile industries in the developing countries which were set up in the 1960s and 1970s. These have first been struggling to get established and pass through their own learning cycle, then have to face macro-economic instability during the 1980s and early 1990s, and at present have to contend with competition from free hand-outs. How can such industries ever gain strength from growth?

But let us return to the general case of alternative disposal options for NPOs, and their implications for economic analysis. The different flow options are illustrated in Figure 8 below.

Figure 8

Definition of materials and energy-recovery, by product production and reclamation.



Source: Bower, 1977: 5.

The real problem with NPO flows is that until recently simple discharge into the environment was often the least expensive option for the individual production activity, given that any resulting externalities were borne by other production activities (cleaning polluted inputs), other individuals as consumers, or by environmental processes. In many cases direct discharge - or discharge with minimal modification - is still the least expensive option, even in social terms. The issue is not that cost/benefit analysis of NPO disposals are not made at all, but rather that where they are made, the outcome is biased as the costs are readily identified, while the benefits for the environment may be partially unknown, effects are diffuse and manifest themselves only in the long run; and whatever positive effects may be imputed, these cannot be captured by those incurring the disposal costs. These are the typical problems of external diseconomies in a non-market setting. However, in normal cost/benefit analysis where the benefits cannot be readily identified, such as in social sector investments in education and health, it is generally accepted that in such cases the analysis is limited to seeking least cost solutions for providing the service, and this approach could also be taken for the environmental effects of NPO disposal to meet externally (e.g.government policy) determined environmental standards.

In thinking more systematically about the economic analysis of various stages of recycling four basic 'facts of life' will have to be considered in each case:

* The value of any raw material is a function of location, quantity and quality.
* The extent of use of secondary materials (and thus the extent of recycling) in national and international contexts is a function of relative prices in respect of these three elements, as factor inputs in economic activities.
* There are economies of scale in material recovery and by-product production, just as in basic production processes.
* Because all factors affecting relative prices of secondary and primary materials are dynamic, the extent of recycling changes with time, in both the short run and the long run. Even the quantity of ores and crude petroleum and natural gas 'in place' vary, economically speaking, as a function of exploration, discovery and technological development.

There are important general issues which have to be addressed in considering recycling policies in this broader spectrum. Most issues play at the level of interindustry relations of production (Bower, 1977). The issues are only listed here for the range of possible research questions that may be derived there from, and to point at what should become a more vigorous research area in inter-industry analysis by teams of economists and engineers jointly:

* Product output specifications are an important determinant of the extent of recycling. To the extent that material content specifications are used in stead of performance specifications, use of secondary materials may in some cases be inhibited. Changes in product specifications can, but do not always, reduce the total materials throughput in a society. The 'sacrificial' uses of materials relate to end-uses which result in wide dispersion (as in vaporization) or in combining with other elements such as to make separation infeasible. The larger this component in final demand, the larger is the absolute drain on resources, or the 'losses' in the integrated material flow.
* For a given final demand, recycling policies should be developed in a 'total systems' context, encompassing all possible flow paths of materials and energy to produce the set of products desired, including the residuals discharges and their environmental consequences at each point in the system. This requires an optimization approach over often complex production systems.
* It is often contended that the prices of secondary materials fluctuate more than the prices of virgin materials. Differences in industrial structure are seen as important determinants in these differential price fluctuations:

primary markets for natural resources tend to be dominated by vertically integrated industries and oligopolist behaviour; it implies some implicit market regulation. Secondary markets, in contrast, are said to resemble competitive small industries competing with each other, and where companies focus on a single raw product for a single use.

* Competition is presumed to exist between primary and secondary markets. For identical products, the relevant comparison is at the relevant point in the system, including all costs of all processing and residuals management up to that point in the overall system, not forgetting locational differences. Competition could also exist between close substitutes, where products from secondary materials are often of slightly lower perceived quality. Examples are white paper, versus usually somewhat greyish recycled paper.

* The assumption is often made that increased recycling is environmentally desirable. This is not necessarily valid as all secondary materials need processing which requires inputs, and may lead to the creation of other residuals which are more harmful. Processing of materials to reduce diffuse emissions in the air may result in the production of concentrated pollutants being disposed in water or on the land, where it may lead to larger but delayed environmental problems. A classic example which demonstrates many of the complications of recycling and disposal is the public discussion regarding the disposal options of the Brent Star, an oil-platform of Shell company and used in the North Sea oil fields, but currently judged to be economically obsolete in view of the situation in world oil markets.

* Sharply increasing energy prices could affect primary and secondary materials markets differentially, because recycling activities are often less energy intensive than primary production. A case in point is the aluminum sector. The high energy prices in the 1970s increased recycling efforts everywhere, but the sharp fall in primary energy prices from the mid-1980s had the opposite effect.

A final general point is that policies not specifically directed towards recycling can have important effects on recycling itself, such as taxation and pollution control policies. While such measures are often taken on a piecemeal basis, their effects should be traced through the relevant set of interdependent markets. This need not be a general equilibrium analysis, but a scoping exercise of the major options and affected alternatives is clearly needed.

In the relatively short, some 35 years, history of environmental policy, the dominant policy approach taken has been to take action on a piecemeal and *ad hoc* basis. The accumulation of measures per subject or product area, and the proliferation of new measures across a widening range of environmentally sensitive areas and of measures and related policy enforcement mechanisms, have led to pleas for more integrated policy effect analysis, and for the design of more integrated systems of enforcement of such policy, nationally and internationally (WRR, 1992, SER, 1993, and OECD, 1992). In this process, the economic incentives-based approach to environmental regulation begins to compete with the traditional legal approach (Command-and-Control) to environmental policy.

Materials flows, natural resources and international trade.

Within the paradigm of the earth as a space ship, resource depletion and pollution are joint plagues which inevitably accelerate each other. Recycling is an approach that promises to fight simultaneously the battle against pollution and materials depletion. Recycling is to be understood as the recovery and re-use of basic materials from the stream of waste products (secondary materials) that are generated by the economic activities of production and consumption.

Natural resources as well as pollutants have international dimensions involving voluntary and involuntary trade. In the context of resource economics, recycling has an obvious international dimension for two major reasons. First, the worldwide proven reserves of many 'virgin' materials may be declining rapidly and might be exhausted over a period measured in decades rather than centuries (see also Sideri and Johns, 1980; Govett and Govett, 1977). Recycling then has the effect of economizing the world's global reserves of basic materials. Secondly, these reserves are distributed extremely uneven between countries, so that for many countries the recycling issue has received great attention as a means of reducing the dependence on possibly uncertain foreign supply, as was evident during the oils crises of the 1970s, and most emphatically in the case of Japan (Van de Laar, 1990).

It is therefore necessary to conceptually come to grips with the international comparative advantages of recycling on environmental pollution and basic materials management (Pethig, 1977). In other words, what does the materials flows perspective have to offer for rethinking international trade theory and commercial policy?

Starting point is the by now well-known fact that the bulk of trade in the real world is in intermediate products, and that a rising share of international trade is intra-firm trade. This trade takes place within the growing global system of vertically integrated transnational corporations. This has implications for price formation as well as for the mechanisms which control and direct these international trade flows. It has also been shown that a non-negligible part of international trade consists of waste products or secondary materials which typically are intermediate products. These include products which are unwanted and which producers would like to get rid off without too much of a fuss being raised as to ultimate location. Preferably some producers would prefer to dispose of these nuisance products secretly and in the dark.

Relevant and important questions to ask are then: (1) what are the determinants of this empirical pattern of trade; (2) how does trade in secondary materials affect the national and international rates of recycling; and (3) what is the relationship between international markets for materials and national environmental management programs (Pethig, 1977, 192).

The prior question may be asked: is trade in secondary materials and recycling any different from trade in primary materials, such as to warrant separate attention? Superficially, one may argue against separate treatment, but this overlook some key issues.

In general, the factors which affect the movement of secondary materials in international trade are, indeed, essentially no different than those affecting primary materials. But there is a key difference: export supplies and import-competing supplies of secondary materials are a function of *past production* of goods (and imports), unlike primary materials as current production. There is thus an inter temporal link between relevant flows.

Further complications arise in international trade when, for instance, primary extraction activities take place in developing countries and recycling takes place in the developed countries, as is the case with many metals. Recycling then can also be used as an instrument for strategic behaviour in changing sources of supplies of what are initially earth-based, and thus locationally determined resource occurrence patterns of mineral products. The recycling option could be used to break natural resource cartels if these were to form, by developing new supplies in the consuming countries from recycled first-use resources.

To illustrate some of the complexities, a little historical anecdote may be of some interest. In the early 1970s, the World Bank was considering what role it should adopt in the mining sector in developing countries, in the preparation of a Mining Sector Paper. Following the first oil price increase of OPEC, the Bank became concerned to assess whether natural resource cartels, in addition to OPEC, could be formed to threaten crucial input needs for the developed countries' economies to function smoothly. Clearly, the nature of the game was seen to be changing, in the wake of pressures in the United Nations for a New International Economic Order, no less. Such a natural resource cartel threat was not foreseen. The argument was that while indeed many minerals were geographically located in few countries, fortunately in most cases reserves and production was split between developed and developing countries, and this was seen as making it politically unlikely that North-South liaisons could emerge to 'gang up' against the developed countries as OPEC was seen to stand up to the West.

The OPEC threat was handled by Keynesian means of demand management: the encouragement of petrodollar recycling. This process was also 'encouraged' for the required speed of recycling, by sabre rattling in military terms to encourage that many petrodollars were recycled in arms purchases and also quickly! Arms sales would absorb large sums of money and did not run the risk that in due course newly set-up non-military industries would compete with established enterprises in international markets. The minerals issues was handled politically, but without much explicit attention then being given to minerals recycling to undermine or forestall other cartels forming, through developing alternative supplies of recycled materials.

For the reasons indicated here, national resource policies will not only influence the use rates of materials, but also the rates of materials recycling. In turn, this influences international trade in primary 'virgin' materials as well as trade in secondary materials. From a materials flow perspective, international trade statistics have to be organised along different lines to be able to identify flow patterns in associated inputs, product outputs and non-product outputs. Thus, standard international trade and commercial policy will have to be rethought in light of the new insights brought out in a materials balances perspective of the international economy.

Turning from resource extraction, as inputs in the production process, to pollutants as unwanted by-products from the production process, additional interesting issues arise that are increasingly attracting attention. Many pollutants are 'transported by the wind' and represent, in effect, 'involuntary' trade.

Emissions from factory stacks have always been quoted in discussions about production externalities: it smells bad and the laundry hanging to dry in the open is less white than the detergents industry would like us to believe, because during drying soot and other particles dirty the wash again. In the early years of environmental regulation, policy tended to be inspired by a desire to dilute emissions: requiring plants to concentrate their different emission flows and dispose of them by building a few new and generally much taller high stacks. In this way the environment near point-polluters will be less polluted than before and, allegedly, the quality of the environment improves. In many cases dilution allows negative environmental effects to be mitigated to become harmless. It has been insufficiently realised that disposal via high stacks brings the emissions into the higher layers of the atmosphere and that harmful emissions are travelling over much wider distances.

These latter problems have been recognized and in 1979 the *Convention on Long Range Trans-boundary Air Pollution* was signed in Geneva. It came into force in March 1983. It was the first major attempt to secure concerted action on acid rain.

There are four major areas of air pollution: SO_2 and NO_x emissions, acid deposition and ground-level ozone. The latter two are secondary pollutants which are formed through chemical reactions of SO_2 and NO_x in the case of acid rain, and NO_x and VOCs (Volatile Organic Compounds) in the case of tropospheric ozone.

At present, input-output tables can be constructed of patterns of imports and exports of harmful emissions between countries. It requires information on emissions by source and accurate information of patterns of air movements in different seasons, as the directions of the flows are a function of prevailing winds. In the table reproduced below an example is provided, showing the origins of sulphur depositions in Europe in 1991.

Figure 9. Origins of sulphur depositions in Europe, 1991 (1000t SO_2)

	EMITTERS							
RECEIVERS	UK	GER	SCA	WEU	FSU	EEU	O/U	Total
United Kingdom (UK)	1052	38	2	52	3	15	69	1232
Germany (GER)	95	1951	14	205	8	304	122	2699
Scandinavia (SCA)	134	173	251	39	140	137	277	1151
Oth. W.Europe (WEU)	218	429	7	2477	30	476	533	4171
Ex- Sov.Union (FSU)	53	359	93	62	3785	953	1142	6446
East Europe (EEU)	59	1014	25	231	236	4701	441	6707
Other/unknown (O/U)	1295	743	211	1676	561	1041	2819	8345
Total	2906	4705	604	4741	4763	7628	5404	30751

Sources: cited in Pearce et al. *Blueprint 3* (1993). London:Earthscan, p. 55

These figures show that a clean-up exercise cannot be simply a unilateral decision, for, in addition to own generated emissions, countries receive involuntary imports of harmful emissions from other countries. In fact, the proportions of own versus imported or exported pollutants differ from case to case, as can be seen by inspecting the table. There are net-importers and net-exporters. In as far as countries try to avoid own initiatives when others can be obliged into forceful clean-up activities, difficulties of international negotiations, and issues of burden sharing and international compensation requirements can be envisaged. In fact, the whole issue to combat Climate Change on a Global Scale, as was agreed in the Earth Summit Conference in Rio de Janeiro in 1992, centres around such issues as the allocation of abatement charges, and cross-subsidization of local efforts there were the environmental improvement per dollar expended would seem to be highest. Transfers of technology for effective abatement will have to be made in a number of cases, especially towards developing countries, and such technologies may have to be subsidized to overcome reluctant governments or industries into action. Resistance to action can be easily envisaged as the essence of an externality is that it falls mostly on others than the polluter himself. This is thus an entirely new sort of policy problem which has to be addressed for the future.

In addition to these general aspects of recycling for the composition and determinants of production and inter-industry flows, and international trade in primary and secondary products, and in pollutants, three additional problems need specific attention: (1) recycling versus durability; (2) managing waste from consumption activity; and (3) issues concerning the toxicity of solid waste.

Recycling versus durability

It is often thought that by making products last longer, the generation of discards and the demand for replacements can be reduced; the 'thickness' of throughput flows will then be reduced, and thereby the environmental burdens of production. This issue has not been systematically researched by economists until rather recently. Several theoretical issues arise. First is the question whether a monopolistic or a competitive industry is likely to produce more durable products. One may think of the early years of the automobile industry. Ford built one model, in one colour black, which was designed to last 'for ever'. In contrast, General Motors introduced annual (cosmetic) model changes and (major) face-lifts for an expanded series of automobiles to boost sales and production. These changes shortened the economic life of cars, and may have reduced technical specifications: why build for eternity, when consumers could be persuaded to buy a new car every few years? Through this strategy GM overtook Ford in growth and profitability. The latter approach focusing on product innovation (real and imaginary) has since set the pattern for the subsequent development of the industry on a global scale. Planned obsolescence and changing fashions drives the automobile industry, and also many other types of industries.

Second, only some of the relevant factors are clearly under producer control - such as technical designs, reparability, degrees of quality control and testing, marketing strategy and spare parts policy affecting availability and prices. On the other hand, consumers have control over elements such as their decision on the timing of their purchase, or the treatment of the product in use. The decision to repair or discard is a function of spare parts and labour costs involved, and the product's use, and prices in the second-hand market also plays a role. On all these issues empirical information is needed to assess what the consequences of requiring more durable products are likely to be.

The dynamic relationships between product lifetime and materials flow is by no means straightforward (Conn, 1977). On the production side, and for a single product, the materials flow for producing a more durable product may be larger or smaller than the aggregate material flows required for the successive production of less durable products.

Stockholding characteristics of consumers are also significant in determining adjustments to an increase in the product's average lifetime. With longer use life of products, maintaining current rates of replacement would lead to increased consumer stocks, and delayed discharge; in contrast, when consumers want to maintain current stocks they reduce their rates of purchase and disposal. These behavioral options affect producer markets differently: in the former case production levels are maintained, while in the latter case production drops with associated losses of employment and incomes.

In addition to product costs one should also consider operating cost of owning and using a product, such as the automobile and consumer durables such as refrigerators, washing machines, etc. A more durable car may have low mileage per gallon (an environmental bad), and a less durable car may be replaced by a newer model with lower fuel use (which is environmentally desirable). Thus, optimization needs to include capital *and* operating costs of such products. If then total cost of a product's services increases relative to income levels, consumers are likely to reduce their stock, while a drop in this (total operating cost) price is likely to result in consumers increasing their stock of products.

System-wide adjustments, across a wide range of relevant products and close substitutes, have to take account of associated effects in primary and secondary markets and this further complicates matters immensely. Because all the adjustment effects could be in different directions, the overall effect of environmentally inspired policies requiring more durable products could be counterproductive.

The *conclusion* on this issue must therefore be that what appears to be at first sight intuitively attractive environmental policy, opens up a Pandora's Box of complexity. It implies that a lot of research needs to be undertaken to be able to suggest a workable policy on product durability that is environmentally effective after all adjustment processes are worked out in the markets.

Managing household waste materials

Thus far in this paper the attention on opportunities for controlling materials flows through the economic system focused on industrial design and processing technologies, which play mostly at the level of inter-industry deliveries of intermediate products. In this subsection, attention shifts to analytic and policy issues in the management of household waste materials, for it was shown in section 4, that consumers derive consumption services from what economists call 'final consumption', but discard the bulk of the commodities consumed very quickly as waste materials in different forms. Consumer waste is mostly seen as an urban problem, as in rural areas the nature of waste products and the disposal or dispersion over land areas differ.

The management of urban household or post-consumption waste is complicated, both economically and environmentally, because a wide range of different waste materials is continuously being discarded by numerous consumers in small quantities. Hence, waste collection costs tend to be high (and even more so in rural areas). Conventional solutions to the household waste problem have been to burn it or to use it for landfill. If landfill areas are located close-in, this reduces transport costs, and the drained and filled-in new land areas are often subsequently used for urban expansion. Economically, part of the waste collection and disposal costs can then be capitalised in the establishment cost of new land preparation, which lands are then given out and sold to real estate developers. In countries where the municipal government is actively involved in both activities through urban planning and zoning, and with waste collection and new land preparation, cross-subsidization between the different government departments involved can and does take place.

Landfill areas can be used for new urban housing, the establishment of newly to be developed industrial and commercial areas, but are also in recent years used to develop new recreational areas. Former urban waste disposal areas have sometimes been covered by a layer of sand and are then converted to recreation facilities such as golf courses. This is also happening in the Netherlands in recent years.

Under the impact of environmental concerns attempts are made to develop Integrated Solid Waste Management (ISWM) systems, enforced by newly enacted environmental laws. Common elements in such systems are waste reduction, recycling, including composting, waste-to-energy and landfill disposal activities. This list does not present a hierarchy of goals and it should be realised that there can be conflicts in strategic choices among the elements. For example, is it better or worse to choose a light-weight package that cannot be recycled but reduces waste bulk and transport economic and energy costs, or a heavier one that might be recycled, although with associated additional costs?

There are further problems. It is questionable whether waste reduction and recycling can divert sufficient volumes of waste materials from disposal to affect substantially the fixed and some variable operating cost of a waste disposal facility. Figures of some 25% recycling targets for industrialised countries are often mentioned for OECD countries (Potier, 1977). But this figure is roughly the equivalent of normal fluctuations in the amount of waste generated and collected locally over a year in a community. Thus, the waste disposal facility may have little opportunity to reduce its variable cost and this affects its willingness to recycle, for it increases its total costs of operation.

Further, recycling requires extensive sorting efforts into homogenous categories of waste materials. This is a very costly operation for the waste processor, and therefore considerable efforts are being made to let the sorting be done at the level of the household itself. But the success of this shift in emphasis critically depends on the degree of participation of households. Research in the USA has shown that participation can well be below 40%. Moreover, a relationship appears to exist between participation and income and housing density. In higher income and single housing areas participation is considerably higher than in high density dwellings and lower income areas (cited in Alter, 1991). Such findings may act to dampen enthusiasm to promote household efforts in waste collection and sorting, or it may lead to more targeted campaigns to promote participation. Low levels of household participation may be non-viable as the need for systematic sorting at an intermediate processing or final recycling facility level is then not substantially diminished. Where recycling is practised such as in composting, questions arise whether there is a market for the products of recycling efforts. Historically, the market price for compost materials has always been low or even negative, which is not surprising as people engaged in farming and gardening activities can and do make their own compost from available, self-supplied raw materials. For this reason, the processing of surplus manure of intensive pig raising turns out to be an economic failure in the Netherlands (Dietz, 1992). School-based programmes, which have historically been active in waste paper collection to supplement dwindling income or to finance non-funded school activities, have often not been able to sustain these efforts over time because of the variable and often low prices being offered for the waste paper collected. The market for such locally collected waste paper may also be negatively affected by international trade in waste paper products, and other interactions between the new paper and recycled paper product markets. School collection efforts thus show a cyclical pattern, which leaves as problem what to do with waste paper when school collection efforts wane for lack of price incentives. Sometimes a floor price is offered to sustain school collecting efforts organisationally to sustain the environmental objective of waste collection. But this may lead to stockholding costs. Alternatively, the waste materials are left uncollected at (un)certain times, with undesirable environmental and social effects in densely populated urban areas. The economics of waste paper and packaging materials recycling is a frequently studied topic because of the large volumes of waste products generated by the paper, packaging and pulp industries, and the further effects of these industries on deforestation. For an early, but still methodologically relevant comparative study of waste paper recycling in a number of OECD countries see Turner, Grace and Pearce (1977). A general finding of such studies is that the key to successful recycling is the availability and stability of markets for the separated materials. These are tough requirements to meet in practice. Forcing markets into existence under government environmental regulations may lead to uneconomical technical requirements for products.

Evidence is becoming available that some 25 years of environmental legislation in the USA and in some other countries is having an effect. The waste intensity is decreasing, implying that it is unlikely that future waste generation will grow at rates projected by extrapolation of historical trends or simple macroeconomic model assumptions. Per capita municipal solid waste (MSW) generation in the USA has been statistically nearly constant from 1970 to 1984, but the composition is changing. The content of most forms of packaging (metals and glass containers) are decreasing, and this reduces the amount of food residues in MSW. Proposed national recycling targets of about 25% or more for the US are, however, not likely to be achieved. The view has even been expressed recently (Alter, 1991), that the changing composition of waste, coupled with likely shortages of labour to process separated waste, will lead people to think that source separation is not worth the bother and recycling effectiveness will therefore decrease for the future. In as far as some of the underlying structural features of waste collection trends may apply in other developed countries, the momentum in household waste treatment may diminish there as well. A careful study of the experience in household waste disposal policies and practices in developed countries may well be instructive in the design of ISWM systems in the cities of developing countries.

The toxicity of solid waste

A problem of increasing concern is posed by the public recognition of the toxic (poisonous or environmentally harmful) nature of much contemporary waste materials: under the impact of technological change, numerous new and non-organic substances are developed which enter the natural environment. Such products often cannot be assimilated by nature and they may actively harm the natural environment and natural ecosystems. It is often not known what the precise environmental effects of new chemical products are in the short and long run, and thus there is much new uncertainty being introduced in the scientific and public debate.

But the recognition of the possibly toxic nature of solid waste materials already has profound effects on public policy. The old and familiar cycle of using urban waste for landfill to enable urban expansion is threatened if not broken. For when landfill materials are harmful they cannot be used as building sites for urban development. There is an intergenerational issue as well. Urban renewal is associated with changing locational patterns of housing and industry. A relocation of old, in-town industrial sites to more modern out-of-town locations, is often followed by reconversion of such sites to housing/offices, with high population density. This process can be seen in down-town areas, and in the refurbishing of old water fronts of harbours which have become increasingly unsuitable for handling containers and bulk cargo, and to allow access of related in- and outward rail/road transport.

The implication is that old, often discarded industrial sites and many landfill areas of the past have become 'chemical time bombs', which are being activated when delayed corrosion leads to seepage of harmful materials affecting soils, ground water and public health generally. In nearly all developed countries inventories have by now been made of what need to be considered dangerous sites. Increasing awareness of the characteristics of many chemical compounds and improved detection methods imply that the number of identified dangerous sites tends to increase with each inspection survey. This is a very disturbing trend, to which many government are still struggling to formulate and develop a coherent policy approach at present. This process involves difficult choices in priority setting, in deciding what can technologically be cleaned up and what should be cleaned up for the environment or for public health; to what standards of purity should the clean-up go, and at what costs and how are these costs going to be paid for? A further complication is presented by the fact that in many cases clean-up cost increase sharply as the contaminated sources develop harmful spread effects over time.

Many of these sites need to be cleaned up, and this turns out to be a very costly and long running affair. In the US, the National Priority list totals about 1200 sites. Between 1980 and 1989 work to clear them up under the so-called Superfund (CERCLA) had been completed at no more than 41 sites, but only 26 of these had been removed from the list (Portney, 1992: 278). In the Netherlands the situation is no different. In several cases recently constructed sub-urban expansion housing projects had to be destroyed completely (Lekkerkerk) after a few years because poisonous landfill materials (from Rotterdam harbour slush containing many heavy metals and harmful chemicals such as toluene) had been used to develop the building sites less than a decade earlier. Rising trends in contaminated sites and exponentially rising costs is having effects on the shape of a feasible abatement policy. In some, but probably rapidly increasing numbers of cases in the future, it is or will be decided not to clean up places due to associated costs; one then tries to isolate the spot by, for instance drilling a steel wall around it.

At a wider historical level, the US has experienced periodic apparent 'garbage crises' since about 1880, as a result of mismatches between waste being generated and the preparation of new disposal facilities (cited in Alter, 1991). An increasingly serious problem is that resistance against the establishment of new sites is sharply increasing, as awareness increases about the hazardous character of such sites in the longer run. Hence, community resistance against the development of new disposal sites is becoming more articulated and persistent, in what is known as the NIMBY reaction: disposal facilities must be made but Not-In-My-BackYard. Consequently, new sites at present are not being prepared fast enough, leading to increased disposal cost due to longer transportation distances (even to overseas locations in developing countries), and increasing risks of people exposure to delayed final disposition.

The socio-political implications of waste disposal deserve more attention as well, and they have been the object of studies on the geographic locational pattern of waste disposal sites. In particular, the charge has ben levied that in the USA the geographic distribution of hazardous waste facilities may disproportionably expose neighbourhoods with greater numbers of racial and ethnic minority residents to potential risks arising from such industrial activities. Though the extent of damage has not been established, the issue is important in that it points at the problem that recognized 'public bads' are shifted on economically less-advantaged and politically less-influential population groups. The sort of counter- arguments employed in defense of such locational choices are that yes, there may be increased risk, but on the other hand new employment is being created in areas with high unemployment levels. In consequence to such charges of discrimination, the US Environmental Protection Agency now requires that data on risk to minorities be submitted in environmental impact statements on such waste disposal facilities. New studies are under way with more disaggregated population data to ascertain the validity of the claims. See Anderton, et al. (1994) for a review of the relevant studies.

In *conclusion*, it can be stated that the recognition of the possibly toxic nature of modern industrial waste complicates the problems of solid waste disposal in many as yet not fully understood and analyzed ways. It raises many complex issues of policy design and implementation, to which only few economists have turned their attention.

9 'GREENING' GDP, AND ENVIRONMENTAL INDICATORS

The reality of the economic process is to be (re)conceptualized as a materials balance model in a finite (though currently unknown) linear physical environment. To monitor trends in the rapidly expanding world economy in such an environment, it is necessary to pay attention to stocks of resources as well as resource use rates. The sustainability of the economic system on planet earth depends on how resources are used in relation to stocks and what the impact is of resource use on the quality of remaining stocks of resources. The necessity to become concerned with stocks increases when the scale of the economy, e.g. the presence of mankind in the ecosystem is large, as is increasingly the case.

The question then arises whether the indicators which are currently used to monitor the economic process in aggregate terms are adequate. What is measured, and what is not measured in current indicators; how are variables measured, and what sort of data need to be additionally provided if the indicators in common use at present are to become more relevant for the future? If major new types of data are to be generated to increase the relevance of progress indicators, the question also cannot be avoided whether existing indicators are possibly misleading and the policy approaches recommended or practised at the present time in light of these indicators might possibly be misguided as well.

The relationship between the rate of economic growth, as conventionally measured, and its impact on the environment is not straightforward, but rather complex as has been demonstrated above (in section 5). Economic growth is conventionally monitored in the Gross Domestic Product (GDP), a statistical notion systematically being developed from the 1930s, and propagated on a global scale since the 1950s. The United Nations Statistical Office tries to make sure that consistency is being promoted worldwide in the concepts used, and the whole process is codified in the Standard National Accounts (SNA), first promulgated in 1953, revised in 1968, and again in 1993. GDP and its growth is widely interpreted as proxies for welfare of the population in different parts of the world.

Greening GDP

Conventional criticisms of the concept of GDP in SNA have been numerous. Issues concern the neglect of income distribution aspects of these aggregate figures, the fact that many products are measured at market prices but that public or collective goods are measured at costs; for developing countries major problems arise in dealing with the subsistence sector in agriculture and with small-scale and micro-industrial enterprises, while feminists have criticised the concept from the point of view of the near total neglect of women's work. Voluntary work inputs in maintaining community level institutions are also not recorded. Analytic shortcomings relate, for instance to the definition of capital, where physical capital is considered investment but the development of human capital is considered as consumption. This is illogical when economists are wont to consider capital and labour as the primary input factors of production. International comparisons of GDP are complex because exchange rates used do not reflect purchasing power parities. Even disregarding major conceptual shortcomings in the concept of GDP, there are vast statistical problems in developed and especially in developing countries to generate and produce the required statistical measures. One cannot even be sure whether the quality of statistics being collected improves or deteriorates over time. In many developing countries, especially in Africa, statistical traditions are weak, and little priority is given to develop systematic data sets. But also in the developed countries statistical systems may miss out on new dynamic developments in the economies concerned. A classic example is the emergence of the Global Current Account Deficiency (IMF, 1987) as calculated from the IMF Financial Statistics. Exports from all countries should equal imports of all countries, after appropriate adjustments have been made for the difference between f.o.b. and c.i.f. conditions. In reality, a statistical 'gap' has been growing during the 1980s, to an order of magnitude of $100 billion per year. In aggregate terms this statistical difference is much larger than the fluctuations in individual country accounts which give rise to perceived imbalances and subsequent IMF-type policy interventions to 'restore' the balance of payments position of individual countries. In view of all these shortcomings of the concepts of GDP and SNA it is difficult not to be disappointed or even dismayed to note how many economists continue to use national accounts data, as published, for all sort of projections and alleged policy work, and especially in developing countries where the underlying data are so weak and unreliable, conceptually and empirically. As if the quality of the underlying data does not matter, and as if the quality of economic analysis is to be measured by the refined mathematical and statistical processing techniques that are employed.

From an environmental point of view three additional criticisms of conventional GDP measures are important and need concern us in the present paper:

* The flow concept of GDP contains elements of stock reductions in natural resources. For non-renewable natural resources (mining and fossil fuels) this is self-evident. For renewable natural resources, such as biota, stock depletion is only evident if off-take exceeds natural resource regeneration.

* The concept of GDP includes production activities which aim at 'damage control' of negative impacts of production and consumption activities on the natural environment. These are called 'abatement expenditures'.

These may refer to current production and consumption activities, but they may also include dealing with accumulated 'backlog' in environmental maintenance investments, to compensate for past neglect of such activities. This affects the interpretation of time trends in aggregate statistics.
* There is a near total neglect of 'external effects' of production on the vitality and resilience of natural ecosystems. Externalities in economics are non-marketed and unrecorded flows. The environmental view of the economic system has demonstrated that externalities are not marginal occurrences but are pervasive, and thus cannot be ignored. The state of health of natural resource stocks is increasingly important to assess permissible future use rates, and to assimilate the rapidly growing waste flows of production and consumption activities world-wide.

The current statistical agenda for the newly revised national accounts attempts to deal with a number of these criticisms (UNSO, 1993). The details of the 1993 revision of the SNA need not concern us. This has become a complex statistical issue in its own right, to be dealt with by specialists. The text of the revisions themselves runs into hundreds of pages, compared to the thin leaflet first produced in 1953. Moreover, many of the accompanying statistical procedures manuals are still being written. Even then, and assuming that countries are willing and able to invest the necessary statistical resources for sustained periods of time, it will be at least another 10 to 20 years before data sets become available for national and international analytic work.

For illustrative purposes two examples will be given here of attempts to come to grip with the environmental costs of economic growth and their implications. The first adjusts the rate of growth of GDP in Indonesia, to account for the use of natural resources stocks in current production (Robert Repetto and Associates (1989). The second deals with abatement expenditures, e.g. expenditures incurred to mitigate the negative environmental impacts of economic growth. The dimensions of these adjustments give an indication of whether conventional GDP can be maintained as at least a plausible indicator of the performance of the economy.

Natural resource depletion: the case of Indonesia

A good and early example of accounting for the use of natural resources stock in adjusting conventional measures of GDP growth is provided by the well-known case study on Indonesia. It is an example of one country, out of many others at low per capita income levels, which derives a considerable part of its current rapid economic growth from the exploitation of its natural resources.

Repetto, et.al. (1989) calculated a series of Net Domestic Product to reflect depletion and degradation in Indonesia's natural resource sectors of petroleum, forestry, and soil (on Java) for the period 1971-84. The net adjustment to Indonesia's GDP for environmental 'depreciation' amounted to *minus* 9% of GDP per year on average, while the growth rate of the unadjusted GDP series had to be reduced from 7.1% to only 4.0% *per annum*.

As an experimental exercise the methodological issues in arriving at these corrections to GDP are of greatest interest. One group of authors uses a concept of 'depreciation', in analogy to depreciation on man-made capital assets. Others reject this approach since non-renewable resources cannot be restored or maintained, it does not make economic sense to view the decline in their stocks as depreciation to be deducted from gross income. This would wipe out from the net product the entire contribution of the activity to income. El Serafy (1993, 11-12, 40-42) proposes a *user cost* concept to be deducted from the net proceeds of the selling of an exhaustible resource, to arrive at the 'true' income as sustainable income in the Hicksian sense (John Hicks, 1946, *Value and Capital*), and to avoid the mixing of asset sales from value added. His methodology applied to the petroleum sector leads to an even larger deduction in the national accounts: an average of *minus* 14.6% against the WRI figure of *minus* 9.0% per annum.

Yet others feel that adjusting only the capital account for natural resource contribution and stock changes is inadequate. Hicks (1946, Chapter 14) defines income as the maximum real rate of consumption which is expected can be sustained 'indefinitely'. In this connection Maurice Scott (1995, 86) has argued that, at least for developed countries, net investment for a whole country is better approximated by human investment plus conventional *gross* material investment than by this minus so-called capital consumption, which gives conventional net investment. The reason for this is said to be that *depreciation* (capital consumption) of material assets is due almost entirely to obsolescence and *not to physical deterioration*, and is offset by an equal and opposite *appreciation* of human assets as real wage rates rise. The latter is omitted from conventional accounts, which are therefore biased downwards.

The economic interpretation of a downward adjustment of investment for natural resource use differs, and this is directly related to the discussions in section 6 on the work by Barnett and Morse (1963). Environmentalists would argue that the economic growth rates boosted by the inclusion of natural resource stock depletions, is akin to thinking oneself rich for having sold the 'family silver' and mortgaging the future. Economists, such as Scott, would argue that the decline in natural resources is overcompensated by the growth in human capital, and that by taking both components one sees effective factor substitution in action, the process which the developed countries appear to have followed and continue to follow in their development path. Selling off natural resource assets initially, and conversion of the proceeds in human capital development could (though not necessarily would) facilitate a growing contribution of human capital to growth to occur over time.

Whatever the precise figures for correcting the SNA for environmental use of resource stocks, the magnitudes involved are quite significant, and have wide-ranging implications for other macro-economic statistical aggregates, and thus for the formulation of economic policies and strategies.

Where an economy derives significant parts of its prosperity from natural resource exploitation, and where this resource depletion is not properly reflected in the national accounts and the balance of payments, (1) income will be overestimated; (2) savings and investments exaggerated; (3) fiscal deficits underestimated; and (4) if natural resources are exported, the current account may in reality be in deficit, but papered over by unsustainable exports of assets. Where such phenomena are not recognized, the domestic currency would then be seriously overvalued with wider implications for the development of the structure of the economy in question.

The related analytical economic policy problems are rather well known in economic theory (Corden, 1984; Gunning, 1987). The chapter has become known as 'Dutch disease' economics, i.e. the analysis of the problems befalling a country which acquire sudden large 'windfall' gains such as oil price increases for OPEC countries or mining booms as in Botswana or South Africa, or large natural resource contributions in Indonesia. The OPEC countries, for instance, have experienced major and unsustainable development trends when it turned out that the sharp increase in international oil prices in retrospect turned out to have been a temporary 'bubble'. Policy adjustment in oil importing countries and export competition amongst the oil producers led to volume reductions in oil use and a sharp price fall in 1985, and persisting since. At a wider level, many of the historical growth rates of GDP in such countries as the USA, Canada or Australia may well have to be significantly revised, as much of their past growth may have contained a relatively large component of natural resources stock depletion. Such environmental stock adjustments imply a corresponding decline in the role of alleged superiority of their economic and political institutions in fostering economic growth.

Several pilot studies to adjust the national accounts of other developing countries have been initiated in recent years: Mexico (Van Tongeren, Schweinfest, et al. (1991); Papua New Guinea (Bartelmus, Lutz and Schweinfest, 1992). Conceptual papers, accessible to non-specialists, and dealing with problems and issues in the revision of the national accounts to incorporate natural resource accounting, in a context of developing countries are: Lutz and El Serafy (1988); Schramm and Warford (1989); Peskin and Lutz (1990); Lutz, Munasinghe and Chander (1990); Harrison (1992); El Serafy (1993) and Hamilton (1994) for a recent overview of the various controversies. A summary of the major elements in the revised SNA (1993) is Bartelmus, Stahmer and UNSO (1991).

Abatement expenditures

Concerns about the environmental impact of economic growth inspired various environmental protection policies, and the setting of environmental standards for clean air and water. The issue became of considerable concern in the late 1960s, leading to the establishment of the Environmental Protection Agency (EPA) in 1970 (See Portney, 1990, for a review and assessment of environmental policies during the 1970s and 1980s. Also Susskind, 1990, for major changes in environmental regulation in the US). These environmentally corrective measures involve compliance costs for producers.

In the early 1970s the OECD formulated the Polluter Pays Principle (PPP), stating that the polluter should bear the cost of measures to reduce pollution decided upon by public authorities (OECD, 1975). Contrary to optimum principles, however, the PPP does not specifically address the allocative efficiency of specific pollution control policies - that is the question of *what* the polluters should pay. For instance, if the cost of mandated abatement measures exceeds the social cost of pollution at the margin, the application of the Principle will involve an over-optimal level of pollution control expenditure. Rather, the Principle is basically a 'non-subsidy principle', according to which the costs of pollution *control* - not necessarily the costs of pollution - should be paid by the polluter.

The economist's views have had little impact on the initial surge of legislation for the control of pollution. In fact, the Amendments to the Clean Air Act in 1970 and the Clean Water Act in 1972, *explicitly prohibited* the weighing of benefits against costs in the setting of environmental standards (Cropper and Oats, 1992: 675). Only in 1981 were all major regulations in the United States subject to a compulsory cost-benefit analysis. In other OECD countries similar techniques have been introduced, though not in systematic ways (Nicolaisen and Hoeller, 1990:19).

The value of attempting environmentally-relevant cost-benefit estimates - despite uncertainties on the benefit side, and of putting values on public goods - is that it helps to:
* make the real dimension of environmental pollution clear;
* make the environmental debate more objective;
* direct scarce financial resources to those areas of the environment where they are most urgently needed;
* make polluters aware of the costs arising from their actions; and
* further develop statistical measures of welfare.

Abatement expenditures have remained rather limited and are in the range of 0.5 to 1.5 percent of GDP for many OECD countries, and they seem not to have generally risen between the late 1970s and the mid-1980s. Measured as investment shares for specific sectors, however, the picture is different. Environmental protection investment in energy-intensive industries was in some cases well above 10% of total investment, notably for energy production in Germany (19%), for the refining industry in the Netherlands (22%) and for the steel and metals industry in the United States (11%). Some estimates are available of environmental damages: for Germany, a high estimate of 6% of GDP was calculated for the mid-1980s, half of which are disamenity effects. For the Netherlands, estimates range between 0.5-0.9%, and exclude disamenity of air pollution and of noise on property values (Nicolaisen and Hoeller, 1990: 16, 43-44). Methodologies for calculating these effects vary widely, and most studies are still experimental.

The fact that in some sectors the burden of coping with environmental regulations represents a sizeable share of gross sector investment naturally begins to fuel criticisms of this environmental burden. In particular when industries operate in an internationally competitive environment, differences in environmental regulations are seen to affect competitive positions and comparative advantage. Thus the twin pressures of industries having reached the upward sloping part of the abatement cost curves, and concerns about international competitiveness exert strong pressures to come to some internationally agreed environment standards setting and to formulate environmental policy in an international perspective.

Environmental indicators

The 1993 revision of the SNA by UNSO can be seen as an attempt by the economics profession to 'open up' the existing accounting system for socio economic data to other emerging information needs to monitor the environment. This approach, as sketched above, has not remained without cogent criticisms. For the emphasis on accounting systems runs the risk that only a 'container framework' has been created for the collection of data for their own sake, but without clear indication of what policy use might eventually be made of these data and by whom.

If policy relevance should be the touchstone for monitoring the environment, new ways of clustering statistics into indicators are needed. There is, however, surprising little quality data with which the condition and trends of important environmental sectors can be assessed. Yet, there is a strong demand for high-quality data with which to inform policy-makers, decision-makers, and resource managers. They need indicators that can communicate complex findings on the conditions, trends and impacts to policy makers and to the public at large, so that they can act or demand action. Data collection thus needs an audience to solicit action, and many large information gathering activities do not define their audience, except in a very general way (Rodenburg, 1995).

The discrepancy that has been observed between expectations and observed monitoring patterns has led to a subtle but profound change in the type of documentation that emerges from international meetings of statistical experts. In the past, experts produced ever expanding lists of items to be monitored. Current attention has shifted toward analytical clustering of items around issues, which entail using models of natural processes and how humans impinge on them. Composite indicators are being developed in a so-called PSR frame work, which focuses on indicators of Pressures or causes of environmental impacts (P), indicators of the State of the environment (S), and on Responses (R), in terms of policies. This approach leads to the development of so-called Sustainability Matrices, which may take the following form. The presentation is a shortened version of the one developed by the OECD (Trzyna, 1995, 96-97; OECD, 1994). For developing countries the identification of environmental issues may well need to be rather different to be policy relevant. For instance, Winograd (1995) developed a similar sustainability matrix for Latin America and the Caribbean, with extensive treatment of indicators for agriculture and food, energy and materials, land use, forests and pastures, biodiversity, waters and coasts, and atmosphere and climate. The World Bank seems to move in a similar direction in its planned annual series on indicators to monitor Environmental Progress with emphasis on the developing countries, but in approach consistent with the approach taken by the OECD for the rich countries. It thereby opts for 'optimally inaccurate' indicators (O'Connor, 195, 103)

The basic idea is to define a set of key issues and for each issue one or more indicators for each of the columns. While it is not difficult to identify economic and social indicators, as there is a rich tradition in these areas, the new challenge is to define a set of critical environmental issues, and to identify appropriate indicators. Statistical and research efforts then should concentrate on these indicators.

It is critical in this policy oriented approach to data collection and presentation that requirements are written in the approach itself on the periodicity and manner of reporting, the nature of the audience and the reaction to the reporting findings regarding needed policy changes. If then the response is to reject or ignore, this may itself lead to pressures on policy makers by public opinion.

Figure 10: Indicators for a (tentative) Sustainability Matrix

ISSUE	PRESSURE	STATE	RESPONSE
Economic			
Production	Intermediate Inputs	Value added per capita	Efficiency of
Expenditures	% of GNP		production
		GNP	Savings
Income	Inflation		Safety nets
		Inequality	Education
	Population Growth	Human Capital	expenditures
Labour	Wages		
Social			
Urbanisation	Pop. density	Urban Population	Exp. on Housing
Health	Energy demand	Dissolved Oxygen	
Nutrition	Disease		Exp. on Health,
		Life expectancy	Vaccinations
Transport			F/M ratio in
			Sec.Schools
Status of Women	Maternal		
	Mortality	Fertility	

Ecological Global Commons Ozone Marine Resources Biodiversity Marketable assets Gas, oil, coal Minerals Forestry Carrying Capacity Eutrophication Acidification Contaminants Waste	 Emissions of CO_2 Consumption of CFCs Land use changes Extraction rates Soil degradation Phosphates Hazardous waste by main type	 Green House Gases Fish Species Threatened species Proven Reserves Proven reserves Concentrations of harmful materials	 Energy efficiency of GDP Water efficiency measures I/O ratios Recycling rates Waste treatment Abatement expenditure
General legal institutional		Opinion polls on the environment	Pollution controls

10 SUSTAINABLE DEVELOPMENT AND POLICY

The possible misuse of natural resources (including the environment) and concerns about the natural legacy being left for future generations has been long recognised and bemoaned. Forty years prior to the *Limits to Growth* publication (Meadows, et al., 1972), one could find the following quotation:

> Contemplation of the world's disappearing supplies of minerals, forests and other exhaustible assets has led to demands for regulation of their exploitation. The feeling that these products are now too cheap for the good of future generations, that they are being selfishly exploited at too rapid a rate, and that in consequence of their excessive cheapness they are being produced and consumed wastefully has given rise to the environmental movement.

This quotation is from Harold Hotelling' seminal paper on the *Economics of Exhaustible Resources* published in 1931. This article is widely recognised as the origin of a new field in economics: natural resource economics. It was neglected at the time of publication, but the field experienced an explosive revival of interest in the 1970s (Devarajan and Fisher, 1981; Solow, 1974).

10.1 Sustainable Development

The concept of sustainability has been increasingly invoked since the publication in 1987 of the Brundtland Commission Report (World Commission on Environment and Development). That report asserted the need for '...development that meets the needs of the present without compromising the ability of future generations to meet their own needs' (WCED, 1987: 43). For instance, the September 1989 issue of *Scientific American*, entitled 'Managing Planet Earth' was devoted to sustainability issues. The journal *Futures* also had a special issue (December 1988) on sustainable development, and the concept now is found in textbooks on resource and environmental economics (Tietenberg, 1988; Pearce and Turner, 1990).

As has been shown in this paper, economists and ecologists generally have very different interpretations of resources and of the implications of scarcity. The discussion in this final section of the paper is to clarify three issues which seem crucial in debates between ecologists and economists about sustainable development.

Following Toman and Crosson (1991), these issues are:
* the nature of the responsibility to future generations, i.e. the requirements for intergenerational equity;
* the definition of what has been termed 'social capital', i.e. the legacy to be provided to future generations;
* the total scale of human resource-using activity relative to global resource capacities.

These issues are approached from the standpoint of economic well-being, broadly defined. It is anthropogenic but with concern for the natural environment.

Intergenerational equity

The standard approach to this issue in economics extends the logic of time preference for members of one generation to an intergenerational preference ordering in which the utilities of future generations are discounted (See also the compilation of papers published as part of the March 1990 issue of the *Journal of Environmental Economics and Management*). This approach is broadly consistent with the philosophical principle known as methodological individualism, which underlies both utilitarian value systems and contract (rights-based) value system underlying democratic political liberalism. Under this principle it is logically difficult if not impossible to assess benefits and harms, and thus define rights and obligations for amorphous individuals in a 'hazy' future. Such benefits and harms can only be defined for the present generation.

Intergenerational discounting can imply ruination of future generations exposed to the prospect of resource exhaustion, in the absence of countervailing technological progress, or the risk of large, irreversible, long-gestation environmental damages. The discounted present value criterion for intergenerational welfare gives absolute power over resource use to the present generation. This can lead to dynamic inconsistency in plans for resource management and use when future generations would seek to revise the plans of the current generation if they were able to.

A sharply contrasting view to methodological individualistic logic is expressed by 'organicist' (Toman and Crosson, 1991: 5) philosophers, ecologists, and an occasional economist. They acknowledge the logical difficulty of assigning rights to potential individuals in the distant future, but they see the obligations of the present as going beyond individual rights to entail protection of entire systems - ecological systems and the human species as a whole. This position emphasizes the safeguarding of evolutionary, ecological processes which contribute to human survival and advancement, quite apart from the consumption or existence values individuals might place on specific resources. It is relatively hostile to the notion of intergenerational discounting of all values. (See also Kneese and Schulze, 1985).

The organicist position also has been justified by extending the logic of Rawls' 'veil of ignorance'. Individuals who did not know what position in life they might occupy would adopt a social contract to protect the least well off. Extending this reasoning to an intergenerational time frame: if individuals do not know what generation they might occupy, and whether that generation might face resource impoverishment or ecological catastrophe as a result of its predecessors' actions, they will seek to protect a viable ecological system and a resource base capable of meeting human needs, allowing for the possibility of technical progress to increase natural resource productivity, and otherwise economize on use of the scarcest resource inputs. This view does not imply the necessity of avoiding discounting across generations. However, discounting would be limited to the rate of growth in the capacity of the resource base to support economic activity, through augmentation of renewable and technical advance. A high rate of discount would imply excessive resource use in the presence.

In such a perception it can be readily imagined that religions which emphasize reincarnation, social systems stressing the value of tradition and cultural homogeneity of population groups, could contribute in fostering a set of values aiming to preserve eco-systems in specific geographical areas, the 'home' of the community. These features reflect the attractiveness of this perspective. Outside interference might weaken these multiple community bonds and thereby the community's ability or willingness to protects its natural environment across generations.

There are, however, also serious problems with this organicistic approach. Since market-based democratic societies are built upon basically individualistic institutions, non-individualistic obligations to the future may not be easily expressed by such institutions (especially markets). The principle of resource base preservation also is a coarse filter that begs many questions. While it may screen out ecological catastrophes, how do we cope with smaller-scale harms? How are threats of ecological degradation to be balanced against the threats of economic stagnation which may result from excessive risk aversion in resource use? How does this view cope with cultural diversity in an increasingly 'opened-up' world, and how does it deal with cross-cultural interpenetration, where separate cultural factors are being seen as promoting social cohesion in 'wise' long term resource use of the ecological home, to counteract the expansionist behaviour of individuals within any community?

The composition of social capital

The legacy of resources left by the current generation to its descendants consists of many things - natural resources and the environment, man-made physical, and human knowledge and abilities. Given this diversity one has to contemplate which resources will be used up, saved or augmented. Many ecologists emphasize the need for special protection of natural resources, and natural systems to safeguard ecological robustness and vitality, and thus the continuation and quality of human life. In this view there is particular concern with damages which are not only large but also irreversible. It asserts a basic lack of fungibility between ecological resources and other components of social capital, and is sceptical about the importance of technical innovation in augmenting social capital.

The standard approach in resource economics is to emphasize man-made capital and human skills development, and down-play the role of natural capital, by pointing at such historical phenomena as the declining natural resource use content per unit of Gross Domestic Product. It points out that none of the doomsday scenarios as in the classical economics analysis of Ricardo and Malthus (See Van de Laar, 1996) has come to pass, due to technical progress. Further, they emphasize response mechanisms which are provoked when signs of scarcity in some particular desired resource area appears. The flexibility of modern society is further demonstrated when national goals are set differently, such as in waging alleged 'just' wars, in reaching the moon, or in adjusting to sudden oil price shocks as in the 1970s. The power of embodied human capital has also been demonstrated by the speed with which the German and the Japanese economy could rebuild themselves at unprecedented rates after 1945, compared to the much longer lasting impact of major wars in earlier centuries. This view allows maximum scope for substitutability among the components of social capital. It derides the resource preservation drive especially for the developing countries which lack the flexibility to adjust due to past neglect in human capital development.

One consequence of these differences in perspectives is that economics and ecologists often operate at different levels of aggregation when considering social capital and sustainability. The standard economic approach tends to lead to aggregation across resources, regions and time, where optimization of utilities are achieved when the factors of production are mobile, nationally and internationally. In contrast, ecologists often emphasize specific resources (soils, habitats) in specific regions (poor agricultural developing countries) and with specific communities (threatened tribal groups).

Aside from their differences, both attitudes toward the definition of social capital confront serious implementation problems, and both approaches face deep uncertainties about those elements of social capital which more distant generations are likely to value more highly. As in family inheritance: is it better for parents to save money to give their children a lump sum as dowry, or is it better to try to give them a good education, even if this absorbs all their financial resources? Moreover, what constitutes a good education where cognitive knowledge is easily forgotten or is obsolete under rapidly changing societal change?

The scale of human activity

This area of controversy between economists and ecologists is in many ways a corollary of disagreements of intergenerational equity and the legacy to be left to the future. On the one hand are those, often ecologists, who argue that eco-system carrying capacities already threaten human well-being, even before allowing for the large added demands of future population growth. In contrast, many resource economists argue that global ecological 'carrying capacity' is not an exogenous given, but depends on a host of human interactions on use patterns and on technical progress. They argue : 'Resources do not exist, they become'. A middle ground in this debate is illustrated in the work by Ayres and Kneese (1969, 1990), who operate in a materials-balance framework which allows them to combine concerns of production and consumption with aspects of waste management in the closed system of material flows and the laws of thermodynamics. They advocate less 'dissipative patterns of materials use.

In respect to scale, economic analyses tend to emphasize not only resource substitution but spatial mobility of resources and people. This type of analysis de-emphasizes constraints on sustainability faced by specific regions. In contrast, ecologists tend to put more weight on the autonomous sustainability of particular resource sectors and regions, reflecting a combination of concerns about anthropological and non-economic values, and about the wider implications of involuntary resettlement or migration.

10.2 Policy perspectives.

Sustainable development has become a public issue. Enough evidence has become available over the last 25 years to give food for thought and to cause concern, both in the developed and in the developing countries. While the evidence is not always conclusive and, as shown, often contradictory, the issues raised bring new perspectives to bear on discussions about the manifold relationships between population growth, resource use and development. With enormous diversity of viewpoints it may well be thought that effective collective action may not be possible. This may be so, but it would go too far to suggest that nothing has been achieved in the last 25 years. Awareness of issues and problems with the way mankind is treating the natural environment has certainly increased, and this is perhaps the greatest advance made.

In several countries future scenarios are being developed on the question whether future development, towards the mid-21 first century, will be affected or constrained by environmental factors, and this implies that the manner in which research problems are formulated differ from research questions in the past. Above all it would now be required that the confusing and confused discussion on sustainable development be better structured than hitherto has been the case: it is a necessary condition for a sustainable discussion of the issues involved.

Because there exist wide differences in perceptions of what the future may bring: cornucopia or disaster, the policy options may be approached in a 'pay-off matrix' for approaches to environmental uncertainty.

Figure 11. A 'pay-off matrix' to environmental uncertainty.

		Actual State of the World	
		Optimists Right	Pessimists Right
Type of Policy	Optimistic	HIGH	DISASTER
	Pessimistic	MODERATE	TOLERABLE

This pay-off matrix suggests that if the technological optimists are right and a policy of relative indifference to the environment is pursued, then society might make high gains. If the optimistic policy is pursued and the pessimists turn out to be right than some form of disaster might occur. Pursuit of 'prudent pessimism' on the other hand, results in moderate gains, or at worst tolerable gains (Pearce, et.al. 1989, 11).

In structuring one's thinking about sustainable development and policy perspectives it is helpful to distinguish between different perceptions of the vitality of the natural environment or segments thereof, which are thought to determine the risks societies dare to take with regard to the environment on the one hand, with the efforts needed for changed behaviour for improved environmental policy making on the other hand. Basic postures are risk-avoidance versus risk-taking. Different combinations between these two sets of factors could be argued to lead to different emphasis in the policy focus and effort.

The resulting scheme is presented below. It is taken from Wolfson (1993: 325), building on earlier work by the Netherlands Council for Government Policy to develop the instrumentation for future environmental policy formulation (WRR, 1991).

Figure 12. Basic postures and policy perspectives towards the natural environment.

	Basic posture towards		
	Natural Environment	Behavioral Adjustment	Emphasis in policy scope
Vitality of the natural environment: 1 Fragile 2 Robust 3 Robust within limits	 risk-avoiding risk-taking risk-balancing	 risk-taking risk-avoiding risk-balancing	 coordination free market equilibrium & coordination
4 Unknown	risk-limiting	no-regret	

The prudent, risk-avoiding posture is eco-centric in orientation. It sees nature as fragile: it wants to maintain biodiversity, minimize claims on non-renewable resources and is restrictive in the use of renewable resources so as not to overburden regenerative capacities. Sustainability requires stringent ecological boundaries and results in more sober lifestyles. There is some scepticism on the role of technological change.

The risk-taking posture is the opposite of the previous one. It is anthropocentric in orientation, sees the natural environment as robust and not man but nature should adjust. Ecological considerations are not side-conditions but challenges to human ingenuity, and there is a strong belief that technology will resolve problems and society should take some risks if technology occasionally does not work out as intended. No major economic restructuring is justified, though an exception is made for the rapid growth in world population.

These policy postures, and their differential outcomes depending upon whether the resilience of the natural environment to absorb impacts is better or worse than initially expected in decision making, are presented and intended for societies as a whole, especially at the level of the nation state. This is rather restrictive, especially where the nation state itself is a rather fragile concept as in many developing countries. Perhaps one should allow for the possibility that these attitudes towards the natural environment can, and often differ by socio-economic groups, or social classes at different scales in society, from village level to regional scales and perhaps only occasionally extend to the national scale, if the nation state is not an artificial construct with vast numbers of multi-ethnic groups. It is also useful to consider that such attitudes towards risk can be inspired by design or are revealed by default. These considerations will limit the chances that coherent environmental policies can and will be designed for the future. Because the interest is in attempts to reconcile environment and development objectives, it is only natural that the next step should be to critically look at alternative policy approaches to environmental policy.

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