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ROUND TABLE ON SUSTAINABLE DEVELOPMENT

Science, the Environment, Economics and Sustainable Development

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The views expressed in this paper do not necessarily represent those of the OECD or any of its Member countries.

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Introduction[1]

The publication in 1987 of 'Our Common Future' provided the most commonly used definition of sustainable development as development that "meets the needs of the present without compromising the ability of future generations to meet their own needs."[1] This formula has enormous human appeal and has stood the test of time.

For such a high-level concept to be more than just words, however, signatories to the 1992 Rio Declaration appreciated that they had to be able to measure progress towards the objective of sustainability. Thus, in *Agenda 21*, they urged countries to "develop the concept of indicators of sustainable development"[2] in a way that would "contribute to a self-regulating sustainability of integrated environment and development systems." Ten years later there is still no internationally agreed method of measuring sustainability and at the World Summit on Sustainable Development (WSSD), countries again committed themselves through the *Plan of Implementation* to further work on the subject.[3] It is anyone's guess, however, as to whether more progress will be made in the coming decade than has been achieved since Rio.

When one reflects on how to measure sustainable development, it is important to be clear and precise about the questions being asked. In broad terms there are two groups of questions. The first set encompasses the 'environment and development systems' as postulated by Agenda 21. Such questions lend themselves to integrated economic and scientific analysis. The second group of questions relate to what has become known as the 'social pillar' of sustainability. This, depending on one's definition – which in itself may depend on where you live – goes to the heart of fiercely contested political ideals that defy consensus conclusions (such as equity and social cohesion).

This paper focuses on the first type of questions, i.e. ones where it is possible to link economic analysis with hard science. The way in which economics can inform thinking about sustainable development analysis is outlined and three key indicators of the global environment are identified. These are selected for their strong relationship to global economic development. In each case it is suggested that certain science gaps urgently need to be filled to assist policy-makers seeking to reach Pareto optimal trade-offs on the sustainability continuum. Finally, the paper concludes by making the case for the use of trans-boundary measures as a *complement to* traditional nationally-based indicators. Such an approach provides important insights to sustainable development and, in a political sense, may encourage a greater interest in sustainability indicators on the part of developing countries.

Economics and Sustainable Development

Economic theory suggests that increasing preferences for the environment should lead automatically to the right levels of preservation.[4] In the real world of course, this has few proponents. A reliance solely on the economics can be problematic. Devising economic instruments to manage a resource like biodiversity, for instance, without understanding its function within the ecosystem of which it is a part may be a recipe for disaster. More generally, the conditions under which environmental services would reach equilibrium are sufficiently restrictive that it is likely to be the exception rather than the rule. Most environmental amenities are non-marketed and their characteristics are such that they are unlikely to be properly priced as inputs without some form of intervention in the market. In most circumstances therefore, a reliance on economics alone can result either in a "tragedy of the commons" (e.g., the deterioration of global fish

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stocks[5]), or that (for instance) biologically diverse areas will succumb to low-economic value “slash and burn” farming practices.[6] Importantly too, particularly in the case of OECD countries, the environmental Kuznets curve suggests that individuals in developed economies will have a strong preference for environmental services.[7] Such preferences have already manifested themselves in, for instance, the setting aside by Governments of considerable amounts of protected areas in an effort to maintain and sustainably use regions of unique diversity.[8]

Economics as a discipline has a long tradition of using mathematical models to try to make sense of these kinds of issues and has tended to regard sustainable development problems to be primarily the product of market failure.[9] Resolution of such failures requires a conceptualization of trade-offs between the three pillars of sustainable development and the use of economic instruments to ensure the efficient implementation of such trade-offs. The question is what level of protection? What should be the trade-off between environmental protection and social and economic development? Economic instruments can include, among other things, the application of polluter pays policies; the establishment of property rights; agreed standards of liability; or other regulatory measures. If sustainable development is constrained by clear ecological thresholds then it follows that the substitution between natural and manufactured capital will be limited with implications for the way in which economic instruments are designed.[10] Against this background, the real policy question must be about the trade-off between the amount of protection that should be given and the economic costs of doing so.

For an economist seeking to make sense of the environment/economics interface that is sustainable development the key question will be: is our economic growth pattern one that can be sustained without being overwhelmed by negative feedbacks of our own making? In this regard, the discipline of economics can assist the policy-making process in two inter-related ways: first it can help identify the necessary trade-offs that arise when the impacts of differing policy options supporting different pillars of sustainable development inevitably clash. These will occur in a particularly acute form in the face of thresholds which scientists have determined as ‘non-negotiable’. Second, and flowing on from the identification of trade-offs, economics can help design efficient least-cost measures to implement policies designed to improve the efficiency of the trade-offs.

What Should We Measure?

Contemporary concern about sustainability is focussed on the ability of the planet’s *renewable* resources to sustain life in general *and* human development in particular. One over-riding concerns that has always been present is that the pressure of human claims (particularly by developed countries) on some key elements of the bio-physical environment, place us at risk of crossing thresholds beyond which lie very significant environmental perturbations with high economic, social and environmental costs;[11] and that the testing of those thresholds will be hastened if developing countries follow a similar path to that taken by developed countries before them. The main question must therefore be can we identify which human claims on some key elements of the bio-physical environment place us at risk of crossing thresholds beyond which lie very significant environmental perturbations with high economic, social and environmental costs?

The truth is that while we know something about these thresholds our knowledge remains sketchy at best. This is a problem because one of the key assumptions in economic analysis is the concept of ‘perfect information’ as a driver of perfect equilibrium outcomes. Yet our current indicators of sustainability are not shaped by anywhere near this level of information. Policy-makers are struggling with limited, weak and often contradictory information. Making economic policy decisions on this basis is not only bad economics; it is potentially catastrophic in sustainability terms.

Improving scientific knowledge in a handful of core areas in a way which may contribute to raising the information component for economic thinking and thereby inform enhanced policy making is therefore an urgent priority. Indicators about environmental process with development-related effects therefore – at least to the extent that they shed light on globally significant problems – must be grounded in a hard scientific quantification of trends or trajectories that, if not mitigated or even reversed, will spell trouble.

While integration between economics and science for sustainable development is important, there are tensions between the two. This is present in divergent interpretations of sustainability. Most indicator sets generated to date may be categorised as falling into one of two broad approaches to sustainability. These are frequently referred to as "weak" and "strong" sustainability.[12]

'*Weak sustainability*' may be defined as an economic value principle. It requires that some suitably defined value of aggregate capital – including human-made capital and the initial endowment of natural resources – must be maintained intact over time. This is somewhat unclear, however and various applications of the concept have different consequences. What we might, in very narrow terms, call '*very weak sustainability*,'[13] for instance, requires that the generalised production capacity of the economy be maintained, thereby allowing a constant consumption per capita over time. In more general terms, 'weak sustainability'[14] requires that the welfare potential of the overall capital base remain intact.

By way of contrast, the idea of '*strong sustainability*' emerged from the perception in ecological economics that the economy is an open subsystem of a finite global eco-system. This essentially biophysical principle is drawn from the laws of thermodynamics, and requires that certain properties of the environment must be sustained. It has been variously interpreted in the literature. In the most restrictive version, '*very strong sustainability*'[15] calls for a set of stationary-state constraints that must be imposed on the scale of the macro-economy.

This is an overly restrictive approach and thus the concept of 'strong sustainability' is frequently preferred for indicators utilising this framework. Strong sustainability may be defined as an eco-system principle and better corresponds to our general understanding of the concept of sustainable development as outlined by the WCED.[16] This imperative can either be translated as maintaining ecological capital intact over time, or restricting environmental degradation above some critical level of resilience beyond which the eco-system could not recover from shocks or stress. The question of thresholds becomes critically important under such an approach.

The weak-strong sustainability conceptualisation brings one to the question of *uncertaint*y. Rather surprisingly, this is typically ignored in most economically-grounded discussions on indicators. Given the different communities involved in such work, this may be unsurprising, but it is worrying. Scientific *uncertainty* is after all a dominant feature of many important environmental problems. There is, for instance, very real *scientific* uncertainty about: the concentration of greenhouse gases at which the danger of significant climatic instability increases markedly; vulnerabilities in atmospheric chemistry which can affect human life and so on.

Quite apart from the basic lack of scientific knowledge on such matters, there is also fundamental *uncertainty* over both the *size and value* of resource stocks and flows in our economies. An economy dependent on exporting natural resources, while consuming at a sustainable level vis-à-vis its economy and environment, for instance, may encounter difficulties in the future when resource prices negatively effect rents, yet such price movements contain stochastic elements.[17]

Clearly, we need to urgently devote more thinking and resources to these kinds of science-related issues. Environmental economists are already paying greater attention to self-organisation and feedback effects, as well as non-linear dynamics.[18] More, however, needs to be done. Environmental discontinuities remain the main point of uncertainty and are the key to understanding the complex interactions between the economy and the bio-sphere where it is embedded.[19]

Notwithstanding this, even if we had perfect scientific knowledge, this would be insufficient for an elaboration of efficient and effective policy on sustainability. While an improved knowledge of the science may assist us in understanding the environmentally preferred level of pressure, it cannot tell us whether the *economic* costs to human society of achieving a certain level do not exceed the benefit of doing so. Nor does science help inform our decision-making about trade-offs or about the design of least-cost measures. In short, it is imperative that we better integrate what we know about the science with economics to ensure improved policy making.

The Concept of Decoupling

Against the background of the economic versus ecological perceptions of sustainability, decoupling can be seen as an attempt to help policy makers improve their understanding of the policy interface between developments in the two spheres. The concept refers to the causal link between relative growth rates of environmental variables and economic variables. There are a range of approaches in vogue on this subject, including the use of the Kuznets curve noted earlier. Other approaches are even more ambitious and take an economy-wide perspective on the problem. One perspective which is of growing interest is to show the decoupling of damage to the domestic environment from domestic economic growth is indicated when the growth rate of environmental degradation is smaller than the expansion of GDP over a given time period.[20] The terms weak and strong decoupling are used to offer policy makers a feel for the extent of progress achieved over time. *Weak decoupling*, for instance, is present when the expansion of environmental pressures is positive, but less than the growth of GDP. *Strong decoupling* on the other hand occurs when the growth rate of environmental degradation is zero or negative.

Proponents of decoupling indicators argue that they can assist in enriching our understanding of sustainability. Certainly, such indicators may assist by complementing standard national accounting, thereby allowing policy makers to assess the prospects for those long-term developments that are essential for progressing sustainable development. It is not surprising therefore that OECD Ministers at the 2001 Ministerial Council Meeting gave a strong mandate to the Secretariat for the inclusion of decoupling indicators in its wider work on sustainability, including the peer review process.

Notwithstanding the enthusiasm for decoupling indicators, there are numerous difficulties inherent in them. Not least of course, is the point that there are numerous environmental variables where the externalities are simply not linear. Thus, continual pressure on a resource (or species) can be applied with no apparent effect for a considerable time until suddenly a threshold is crossed and the negative effects begin to rise sharply. Indicators that fail to take these essentially scientific relationships into account risk concealing potential future problems. This problem is compounded by the essentially national/domestic focus of most decoupling analysis which treats environmental externalities as if they can be contained within the borders of the nation-state. In this way it is quite possible for a country to argue that its economic growth is characterized by decoupling by only calculating environmental externalities occurring domestically. This rather misses the point that an economy may shift its production processes to other countries and through imports transfer its environmental externalities into the global bio-sphere or at least to other countries and regions. This is a point to which the paper returns below.

One of the other difficulties with decoupling is the use of inappropriate data sets. There are cases where attempts to use particular data may send misleading signals, unless they are carefully explained and set in specific contexts.[21] Decoupling data sets therefore, if they are going to be at all meaningful, run the risk of being drowned by the explanations and caveats required for substantive interpretation purposes. Worse, there is a risk that apparent decoupling may mask inherent problems and encourage national policy makers to conclude that there is not a substantive difficulty with their policy settings.[22]

Filling some of the Science Gaps[23]

In the context of the integration of economic analysis and scientific knowledge, the basic scientific question on indicators of environmental sustainability can be crystallised as follows: are there thresholds beyond which natural systems, on which everyone relies, will cease to deliver the so-called ‘ecological services’ needed to sustain life? Formulating the question in this way does not imply some absolutist definition. Nor does it deny the possibility of very significant on-going use and transformation of natural resources. These will be made on the basis of the trade-offs that have always been made. But indicators of sustainability designed with some grasp of the science would be in a position to warn of the accumulation of externalities that could impose heavy or unpredictable future costs, or both. With more knowledge bringing them to a situation of ‘perfect information’, economists can better assess how to make trade-offs on the sustainability continuum.

Notwithstanding the international treaties that have been signed in a number of fields, a coherent account of just what thresholds we should be worrying about simply does not exist. On the other hand, scientists have learned much more about the nature of the services provided to human society by the Earth's environment, and the ways in which human activities are affecting these. This is particularly true about some aspects of the ‘global commons’. It has been established, for instance, that: (i) biological processes and structures, including biodiversity, play a far more important role than previously thought in stabilising the global environment; (ii) the ocean circulation pattern in the North Atlantic can change suddenly, switching the climate of Northern Europe from warm to very cold in a decade or less; (iii) the chemistry of the atmosphere is potentially one of the 'Achilles heels' of Earth's life support system.

The following section focuses briefly on each of these and highlights some of the main science gaps which if filled would help improve policy making for sustainable development.

Biodiversity[24]

Experiments have shown that species diversity is important for critical ecosystem functioning, such as nutrient cycling and primary production. The terrestrial biosphere therefore can not be considered simply as 'one big leaf' or as 'green slime', as portrayed in earlier climate and Earth System models. Moreover, there is a growing feeling amongst scientists that, even up to the scale of the Earth itself, the complex webs of life on land and in the sea are not only aesthetic, but they also are crucially important in maintaining the habitability of the planet.[25] In this regard, where are the main science gaps in biodiversity?

The *first* gap remains a lack of data, both historical and current.[26] Data is required to provide policy makers with information about trends over time and to understand the processes leading to loss of biodiversity. Most significantly perhaps, biodiversity data is weakest in areas outside national jurisdictions, including in particular oceans and polar regions. The important point is that both the quantity and quality of biodiversity need to be monitored, as both can illuminate our understanding of the state of biodiversity. Notwithstanding the pious hopes of the CBD,[27] the fact remains that high quality data is missing in both quantity and quality of ecosystems. Indeed, OECD countries have already concluded that habitat quality indicators for the major habitat types of the CBD will take years to develop simply because data is not available.[28]

The *second* knowledge gap is the influence that pressures (especially multiple pressures) actually have on biodiversity. Here, modelling of the future development of the major pressures has to go hand in hand with empirical studies on the reaction of ecosystems to these pressures.

The *third* difficulty is that we just do not understand enough about the linkages within and between eco-systems. The loss of one ecosystem may well be the gain of another (e.g. wetland becomes forest). Most obviously we do not yet know enough about the spill-over effects changes in food chains can have. Statistics on fish landings over the past ten years, for instance, indicate that there has been a marked reduction in the numbers of larger predatory high-seas fish. This has increasingly shifted the balance of fishing activity down the food chain. Indeed, most assessments of the status of high seas fisheries stocks do not currently include a stock-recruitment relationship assessment and are therefore unable to account for the effect of reductions in spawning stock biomass on future recruitment. Scientists are only now beginning to understand these kinds of impacts.[29] Consequently, the negative effects of changes on population levels (etc) and thus on reductions in the stock may be further underestimated.[30]

A *fourth* problem relates to weighting of data. Put bluntly, are all species or aspects of biodiversity of equal importance? In theory, the genetic material of any species might become important in the future, and thus prudence would lead one to try to save all species.[31] Given economic development imperatives, however, priorities will have to be set. Factors that assist in determining priority targets include economic cost, logistics, chances of success, the taxonomic distinctiveness, morphological attributes, functional/ecological attributes[32] as well as the value placed on the species by society ("Save the butterfly" will find more support than "Save the mosquito").[33] While many of these factors depend on policy questions, scientific understanding is needed for such factors as chances of success, functional/ecological attributes and taxonomic distinctiveness. In essence, whether indicators weigh species according to some criteria may be a policy question, but the data for such weighting need to come from the scientific community.

Chemistry of the Atmosphere

A sobering and instructive lesson about how close humanity actually came to crossing a dangerous threshold in the global environment can be drawn from the international experience in dealing with the hole in the ozone. The development of the 'ozone hole' was an unforeseen and unintended consequence of the widespread use of chloroflurohydrocarbons as aerosols in spray cans, solvents, refrigerants and as foaming agents. If the industries involved had used bromofluorocarbons instead, the result could have been catastrophic. In terms of function as a refrigerant or insulator, bromofluorocarbons are just as effective as chlorofluorocarbons. On an atom-for-atom basis, however, bromine is about 40 times more effective at destroying ozone than is chlorine.[34]

As Nobel Laureate Paul Crutzen has written "This brings up the nightmarish thought that if the chemical industry had developed organobromine compounds instead of the CFCs – or, alternatively, if chlorine chemistry would have run more like that of bromine – then without any preparedness, we would have been faced with a catastrophic ozone hole everywhere and at all seasons during the 1970s, probably before the atmospheric chemists had developed the necessary knowledge to identify the problem and the appropriate techniques for the necessary critical measurements. Noting that nobody had given any thought to the atmospheric consequences of the release of Cl or Br before 1974, I can only conclude that mankind has been extremely lucky."[35]

The measurement of the ozone concentration in the stratosphere over Antarctica was, in effect, the "indicator" that helped societies recognise that they were approaching a potentially dangerous situation. Without a detailed understanding of the chemistry of ozone in the upper atmosphere, however, such an indicator would have been worthless. It could not have been interpreted and appropriate policy action could not have been taken. Ironically, in this case, the appropriate scientific work had been undertaken, but for quite a different reason - the fear that a fleet of supersonic aircraft then under development would alter the chemistry of the stratosphere. Fortunately and coincidentally, that chemistry was also applicable to the ozone hole issue. It is easy to understand therefore why scientists describe the atmosphere as the 'Achilles heels' of Earth's life support system.[36]

The international scientific consensus is clear on at least one aspect of the chemistry of the atmosphere: global climate change *is* occurring as a consequence of human activity. It has been established that atmospheric carbon dioxide concentration, for the last half-million years at least, has oscillated between tightly bound limits of 180 and 280/290 ppm. We also know that human activities have broken these bounds, with current carbon dioxide concentration approaching 370 ppm and that these have risen to that level at a rate at least 10 and possibly 100 times faster than at any other time during the last half-million years.[37] But we do not yet know the full implications of this change for the stability of the climate. Nor do we actually know whether we have crossed or are poised to cross a threshold that will lead to rapid climate change.[38] This lack of knowledge is hampering economic assessments about what can be done.[39] In short, the science is uncertain about whether we have crossed or are poised to cross a global threshold that will lead to rapid climate change with attendant consequences for human life.

There are a range of gaps in our knowledge about the chemistry of the atmosphere. One of the most pressing relates to climate change. While simple predictions are fairly straightforward (e.g. an increased atmospheric CO2 content raises global temperatures), other judgements with economic implications depend on the nature and extent of greenhouse gas (GHG) increase, as well as local and global responses of the ecosystems to this increase. Climate change has a potential impact on crops, freshwater resources, animal stocks and biodiversity among others.

In this regard, the relationship between science and economic policy can be further underlined by noting that changes in global CO_2 are likely as production in developing countries responds to market access improvements. In China, for instance, sharp rises in production, partly as the consequence of improvements in international market access levels, have markedly worsened urban air quality with spill-overs to the global environment.[40] The cost of the resulting health problems and property damage has been conservatively estimated at more than $20 billion a year in China's main urban centres alone.[41]

The point of seeking information about the wider effects of improved market access is not, however, to deter policy reform (i.e. improved market access) but to improve policy makers' awareness, in developing and developed countries, of its broader impacts. In this way, when market access improvements are initiated they can be developed in tandem with (for instance) focused technical assistance and technology transfer to mitigate spill- overs (e.g. air pollution).

Ocean Circulation

Another potentially catastrophic perturbation is the apparent slowing or shutting-down of the North Atlantic thermohaline circulation and an accompanying shift in the Gulf Stream. A great deal of heat is transported globally by the movement of ocean water. The eastern North Atlantic region, for example, is a recipient of heat in this process that makes life at 60^{o} N a much more pleasant experience in Scandinavia than it is in northern Canada or Siberia. The circulation that delivers heat to the North Atlantic is driven by the formation of ice in the Greenland and Arctic Seas and consequent release of heat to the atmosphere by the water as it cools and forms ice. Were this circulation to weaken or reverse, the effect on climates, especially those of northern Europe would be pronounced. Such abrupt shifts are known to have occurred naturally in the past.

Can the current pressure placed on this by human consumption patterns and behaviour trigger a similar change in the coming decades? Model simulations suggest that, at the present rate of human activity and consumption patterns, this circulation could indeed weaken or reverse towards the end of the century. Furthermore, very recent work by Norwegian oceanographers has shown that the rate of formation of cold, sinking water that drives the Gulf Stream has slowed by 20% over the last 50 years.[42] This was a one-off measurement, however, not the result of a systemic set of measurements or indicators that would monitor this critical issue.

Moreover, there are divergent interpretations of the situation. At the present time we know that there is a natural cycle that has been operating for the last eight hundred thousand years. The length of the natural cycle is generally believed to be around one hundred thousand years and at the end of these cycles there is generally an ice age which lasts about ninety thousand years and then a warm interglacial period lasting about ten thousand years. Scientists believe that at present we are in a 'warm period' that began something like twelve thousand years ago. In other words, the onset of a new ice age is actually overdue.

If human activities were not disrupting the climate, a new ice might begin at any time within the next couple of thousand years, or might already have begun. Rather worryingly, we do not know how to answer the most important question: does our burning of fossil fuels make the onset of the ice age more or less likely?

In fact, there are good arguments on both sides. We know that carbon dioxide levels in the atmosphere were much lower during past ice age than during the warm periods so its is reasonable to expect that an artificially high levels of carbon dioxide might prevent an ice age from beginning. On the other hand, some oceanographers[43] have argued that the present warm climate in Europe is highly dependent on a circulation of ocean water with the Gulf Stream flowing north on the ocean surface and bringing warmth to Europe while a counter current of cold water flows south in the deep ocean. In other words, a new ice age could begin whenever the cold deep counter current is interrupted. This could happen at any time when the surface water in the Arctic becomes less salty and fails to sink. The water could become less salty when the rise in global temperatures increases the Arctic rainfall. In this way we have a paradoxical situation where a warm climate in the Arctic could actually trigger an ice age.

Until scientists come closer therefore to definitively understanding the causes of ice ages, we simply cannot know whether the increase of carbon dioxide in the atmosphere is decreasing or increasing the danger. All of the above underlines the obvious point that the biosphere is the most complicated of all the things we as policy makers have to deal with. The science of planetary ecology is still young, frail and under-developed and it is now an urgent priority to seek to deal with the gaps in our knowledge such that we have clarity on which policy settings are best placed to increase our prospects for sustainability.

Towards a Global Set of Environmental Indicators

These examples point to the urgent need for an incisive and focussed set of global environmental indicators. An absolutely basic requirement in the development of such indicators must be the filling of some of the science gaps on which the indicators are based; particularly those concerning biophysical thresholds at the global scale that humanity should not cross. In short, we must know how much biodiversity we can lose or destroy before the stability of the Earth's environment is seriously affected, and we must have 'early warning indicators' that will tell us in time if the Gulf Stream is likely to weaken or shift southwards.

For any global set of indicators to be meaningful, they would need to possess the following characteristics:

- They must be backed by solid scientific understanding. That is, we must be able to measure them at regular intervals, and we must have sufficient scientific understanding to interpret them, particularly when they change.

- They must be able to distinguish human interference from natural variability. This is absolutely crucial, as it would be counterproductive to ask societies to make major changes in response to a natural variation in an indicator. This suggests that the palaeo-sciences must play a stronger role in the development of indicators and their interpretation.

- They must be timely; that is, they must be able to give societies enough time to act to avoid crossing a critical threshold. Indicators which only show change after a critical threshold is passed would be of much less use. This criterion is actually very difficult in practise, as there is likely considerable momentum built into much Earth System functioning and it may be very difficult to detect a significant change before it is too late. This suggests that decision-making on the basis of the precautionary principle and risk analysis may still be required, *even if a set of indicators* is in place.

- Finally, the set of indicators must be flexible. Science is never static, and it is always improving our understanding of the Earth System. There must be an ongoing dialogue between science and the policy sector so that we can improve the indicator set and their interpretation as scientific understanding advances.

This paper's central proposition therefore is that policy makers need to work more closely with scientists to pursue an integrated approach which offers insights into policy settings for global impacts. The examples cited above indicate that policy makers need better information about the pressure of human activity, not least, consumption patterns on the global biophysical environment.

Complementing National Indicators

Most countries' indicators of sustainability are focussed at the national level. It is, for instance, the sustainable development of individual developed-country economies that is examined in the OECD's prestigious EDRC review process.[44] Similarly, the European Commission's structural indicators are aimed at measuring progress in individual member states.[45] The interesting thing of course is that one has only to look at the extensive (and impressive) work on indicators undertaken in the UK or Denmark to see that the trend of their indicator sets is overwhelmingly positive. There is the nagging doubt, however, that positive overall trends at the national level belie the rather different perception most of us have about the global trajectory we are on.

Such a nationally-based approach certainly helps decision-makers. It sheds light on potential trade-offs at the national level between policy choices at the intersection of the three pillars of sustainable development. This can facilitate the design and identification of policy instruments to improve national-level outcomes in sustainability terms. Furthermore, a comprehensive analysis of national progress in moving onto a more sustainable development path is critically important for national regulatory and legislative purposes and the OECD and the Commission certainly offer a useful way forward in this regard.

It is against this background that we can ask, is the current focus on national indicators of sustainable development sufficient? Such approaches treat countries as if they were stand-alone closed economies for the purpose of measuring sustainable development. This point of departure contains a significant flaw. It does not recognise that there are aspects of the three pillars of sustainability, which are global in nature. Simply put, many policies on sustainable development may have trans-boundary effects. Indicators along the lines proposed by the European Commission, or the perspective adopted by the OECD will find it difficult to offer any meaningful *policy* insights into the impact (positive or negative) that member economies are having on global sustainability. Such measures cannot, for instance, provide policy makers with an assessment of the environmental and social externalities generated by economic growth that are imposed beyond national borders. Nor can they provide a persuasive framework for understanding situations on the sustainability interface where policy shifts occur as a consequence of changed production processes as opposed to decoupling.[46]

In this era of globalisation and cross-border flows, it is not just investment, but pollutants and environmental externalities generally that require a global frame. After all, biophysical processes do not respect national boundaries. What may be required therefore is to *complement* the national-level picture with indicators which *inform* us about the pressure of human claims on the global bio-physical environment and concomitantly *indicate* whether such pressures place us at risk of crossing thresholds beyond which lie very significant environmental perturbations with high economic, social and environmental costs. Ideally, an indicator set should be able to provide information about the impact of resource use regardless of the location of recorded economic activity. The European Commission acknowledges this point. Its outline of a European Union-wide strategy for sustainable development includes a reference to the effect that "many of the challenges to sustainability require global action to solve them." It goes on to observe that, "as EU production and consumption have impacts beyond our borders, we must also ensure that our policies help prospects for sustainable development at a global level."[47]

It is precisely this international dimension which is of concern to many people. The citizens of developed countries are conscious that they have managed to make real progress in restoring the quality of air and water that had been compromised in the developmental trade-offs of the industrial revolution and its aftermath. Indicators showing positive trajectories in both the EU and the OECD frameworks confirm this. There is, however, unease about the negative impact their consumption decisions may be having at the global level – something that cannot be ascertained from nationally derived data sets. Moreover, it is the *international* dimension of sustainability, particularly on the environmental pillar, where countries spend inordinate bureaucratic resources to negotiate multilateral agreements to control, restrict and otherwise reduce behaviour which may negatively impact the global commons. National trajectories of sustainable development in developed economies may be progressing in the right direction, but the impact of those countries on the global environment may not be quite so benign.

The Effects of Trade

Against this background, and assuming that we will soon have sufficiently meaningful scientific knowledge about critical global environmental thresholds, how can we complement nationally based indicator sets in a way which gives meaning to the concept of sustainable development in a truly *international* sense? Human impact on these pressure points can be charted through consumption patterns, which are reflected in trade flows. Trade generally improves the allocative efficiency of the countries involved. A failure to take trade into account in consumption patterns therefore distorts the picture of a particular country's sustainability.

An Example: Measuring Embedded Carbon Flows

An example of what might be done in this regard is to examine embedded carbon flows. In fact, CO_2 emissions and their impact on the environment and economic consequences happen to be one area where we have some reasonably sound scientific knowledge about the impact of human consumption on the global atmosphere. Carbon emissions also have a range of negative effects on human life and the wider environment. Not surprisingly therefore almost every indicator project underway internationally includes a country's carbon emissions (measured by production output) in its set of indicators of sustainability. And it is precisely the global nature of the issue that has prompted many countries to participate in a multilateral arrangement to address the impact of carbon emissions on climate change.

Yet the current focus on country carbon emission levels alone may tell only part of the story. Conclusions about a country's sustainable development and its impact in a global sense may be distorted by a failure of current measures to take into account the carbon intensity of trade flows. A country's measured emission levels, for instance, may be misleadingly low if it imports significant quantities of carbon embedded in non-energy products (i.e. carbon generated in the production of these goods). A national-level indicator that fails to take into account trade flows can easily underestimate the emissions caused by a country's consumption habits.[48] The magnitude of this problem is underlined by the rapid expansion of international trade.

The problem has already received some analysis, as have ways of measuring it.[49] The very latest work by the OECD[50] suggests that the largest net outflow of emissions embodied in exports bound for OECD countries came from China and to a lesser extent Russia. In these countries, emissions from production exceeded those from consumption by over 10 and 15 per cent respectively. Combined, these differences between *production* and *consumption* in China and Russia exceed the emissions in 1990 of all but 4 of the countries listed in Annex I of the Kyoto Protocol. Moreover, the size of CO_2 emissions embodied in gross flows of imports and exports is significant, both in relative terms and absolute terms. Emissions associated with imports or exports are usually above 10 per cent of *domestic production*, and often above 20%. Indeed for Denmark, Finland, France, Netherlands, Korea, New Zealand, Norway and Sweden, emissions embodied in imports are over 30% of *domestic production*. Therefore relatively small changes in response to changed competitive conditions or relative prices could imply significant changes to the net balances. Not surprisingly, the carbon embedded in a country's imports of manufactured products tends to reflect the country's patterns of trade. Indeed, many fossil-fuel-rich developing countries generated more emissions in producing goods for export than they generated overseas in producing goods for import. The reverse is true for many fossil-fuel-poor countries (among them many OECD members). The extent of carbon-intensive trade underlines how misleading and arbitrary is an indicator that measures only the carbon generated in domestic production processes.

There are two distinct advantages inherent in an approach designed to complement national-level indicators with measurements of the impact of an economy on certain global issues. First, it would result in an improved picture of global sustainability. Second, and just as importantly perhaps, such a perspective may help place the global debate about the purpose and use of indicators on a more constructive footing.

This latter point is all the more important in view of the commitments made at WSSD. Many developing countries are understandably nervous about any proposal for indicators which is likely to shed a rather grim light on the developing world's levels of sustainability as measured by developed-country criteria. Many would not relish, for instance, measurement against many of the social indicators used by the European Commission and the OECD. Issues like the sustainability of pension provision or adult education provision in, for instance sub-saharan African countries where the life expectancy is not much above 47 are simply not at the top of most developing countries' list of priorities.[51] Nor would many enjoy the application of the proposed indicators of air or water quality which are unable to account for the reasons for such changes (i.e. as the consequences of rapid economic development, not least through the production of goods for export to the developed world.)

Moreover, there is considerable resistance in both developed and developing countries to any 'beauty contest' approach to indicator sets. A particular anxiety is that a nationally based indicator set may lead to critical comparisons being made among developing countries with the logical extension perceived to be some form of conditionality in which the future delivery of development assistance might be linked to positive progress on sustainability.

One way to encourage a greater interest in indicators of sustainability internationally therefore might be to complement national indicator sets with measures that can pick-up some of the trans-boundary spill-overs. Such a complementary approach would result in a more meaningful perspective on sustainability. It would also illuminate the point that the consumption patterns of the developed world have a significant impact on global sustainability. Moreover, such an indicator set would provide a useful balance to the generally positive progress on sustainability being made by most developed countries at the national level. In this way, such an approach would underline the essentially integrated and global nature of economic activity that is making inter-country comparisons in this sphere less and less meaningful.

Conclusion

It has been this paper's contention that we need to tackle our lack of scientific knowledge about a short list of environmental problems that have trans-boundary effects. Improving our scientific knowledge of some of the global thresholds, while simultaneously ensuring that cross-border impacts of consumption and trading patterns are reflected in measurement systems, may improve our understanding of some of the global trends that currently fill many of us with unease.

Such an approach may also help encourage developing countries to see sustainability indicators as something other than yet another thinly concealed attempt by the developed world to hamper efforts by developing countries to strive for the living standards of OECD members. At the very least, by adopting a more flexible and global perspective in our indicator development programmes we might move some way towards responding to the exhortation in Agenda 21 and reiterated in the Plan of Implementation to "contribute to a self-regulating sustainability of integrated environment and development systems. Importantly, such an approach would increase policy makers' understanding of the inter-linkages between the economy and the environment – or sustainable development for short.

END NOTES

[1] World Commission on Environment and Development (1987) *Our Common Future*, Oxford University Press, Oxford.

[2] The Rio Declaration is available at http://www.un.org/documents/ga/conf151/aconf15126-1annex1.htm. Agenda 21 is available at: http://www.un.org/esa/sustdev/documents/agenda21/english/agenda21toc.htm. Chapter 40 of Agenda 21 is available at: http://www.un.org/esa/sustdev/documents/agenda21/english/agenda21chapter40.htm.

[3] The WSSD Plan of Implementation agreed at Johannesburg contains numerous references to indicators and science, including, inter alia, in paragraphs 14 (a), 34 (a) and elsewhere), 102, 103, 104 (a and c in particular). The Plan of Implementation is at: http://www.johannesburgsummit.org/html/documents/summit_docs/2309_planfinal.htm

[4] R. H. Coase, (1960), The Problem of Social Cost, *Journal of Law and Economics*, vol. 3, pp. 1-44.

[5] The most recent study by scientists in Canada reveals that commercial exploitation can cause a catastrophic and irreversible decline in stocks. According to their research fish stocks collapse by about 80% within the first 10-15 years of commercial exploitation and then stabilise at around 8-10% of the original numbers. Crucially, this research also indicates that conservation of the current stocks based on recent data alone is flawed as it seriously underestimates the magnitude of the problem (R. Myers and B Worm (2003) *Rapid worldwide depletion of predatory fish communities*, Nature Vol 423, pp. 280-283). This problem is replicated in regional fisheries like the North Atlantic cod (Mayo , R. and L. O'Brien (2000) *Atlantic Cod*, Northeast Fisheries Science Centre http://www.nefsc.nmfs.gov/sos/spsyn/pg/cod). Moreover, most assessments of the status of high seas fisheries stocks do not currently include a stock-recruitment relationship assessment and are therefore unable to account for the effect of reductions in spawning stock biomass on future recruitment. Consequently, the negative effects of IUU fishing on population levels and thus on reductions in the stock may be further underestimated (See for instance, CCAMLR (2000) *Statistical Bulletin*, Vol 12, CCAMLR, Hobart)

[6] Oregon State University (2001), C*onservation Battle Faces Long Odds In Brazilian Amazon,* http://oregonstate.edu/dept/ncs/newsarch/2001/Jan01/brazil.htm

[7] Kuznets hypothesised an inverted U-curve relationship between inequality in the distribution of income and economic development. Some authors have posited a similar relationship between the environment and development that has come to be known as the "environmental Kuznets curve". In neither case does such an *empirical correlation* imply that development will bring the *right* amount of improvement. *G. M. Grossman and A. B. Krueger (1995), Economic Growth and the Environment,* Quarterly Journal of Economics, *vol. 110, 1995, pp. 353-378.*

[8] The measurement of biodiversity comprises three approaches: *scale*, the *component* aspect and the viewpoint aspect. The viewpoint aspect is most relevant in economic terms since it refers to the sources of value of a species, ranging from the practical, through to the moral and aesthetic i.e. how can we ensure that biodiversity conservation and preservation can be achieved while simultaneously pursuing economic objectives? Viewpoint approaches are of course subjective, so a theoretical and framework is needed to ensure consideration of their widest possible range (see in particular OECD 2002).

[9] See in particular the useful outline on these issues contained in OECD (2002), *Special Session on Biodiversity, Issues Paper*, OECD, Paris ENV/EPOC(2002)6

[10] Additional constraints would be imposed if the suggestion proposed by E H Daly ((1991) in *Sustainable Development: From Concept and Theory towards Operational Principles, Steady State Economics,* (2nd edition) Island Press, Washington D.C.) was adopted as a principle for sustainable development *viz.* that the depletion of stock resources should be limited by the investment in enhancing renewable sources. However, the precise nature of the pairing is not clear. For example, must the investment in renewable natural capital (e.g. solar energy) be a close substitute for the exploitation of non-renewable capital (e.g. natural gas)? Or should the investment yield an equal value of sustainable consumption (e.g. electricity)?

[11] See for instance V Smil (2003) *The Earth's Biosphere: Evolution, Dynamics and Change*, MIT Press, Boston and for an earlier analysis at the turn of the century by the Russian thinker Vladimir Vernadsky (1926) *The Biosphere*, Leningrad Press, Leningrad (now available in an English translation by D B Langmuir (1998) Copernicus Press). Vernadsky was arguably the first to make use the concept of the 'biosphere' as the unifying component in the integration of the global environment and the study of human development.

[12] R. K. Turner, P.M. Doktor and N. Adger, (1994) *Sea-level Rise and Coastal Wetlands in the UK: Migration Strategies for Sustainable Management*. In Janson, A.M., Hammer, M., Folke, C., Costanza, R., (eds) Investing in Natural Capital: The Ecological Economics Approach to Sustainability. Island Press, Washington DC, pp. 267-290; and W. Hediger (1999) *Reconciling 'Weak' And 'Strong' Sustainability*, International Journal for Social Economics volume 26, pp. 1120-1143.

[13] This concept is introduced by Solow (1986).

[14] D.W. Pearce, G.D. Atkinson and W.R. Dubourg (1994) The Economics of Sustainable Development, in *Annual Review of Energy and the Environment*, volume 19, pp. 457-474 outlines the concept in greater detail.

[15] R. Costanza, H. E. Daly, J.A., Bartholomew, (1991) *Ecological Economics: The Science and Management of Sustainability*. Columbia University Press, New York, pp. 1-20

[16] WCED (ibid, p. 47) notes that sustainable development "requires that the adverse impacts on the quality of air, water and other natural elements are minimised so as to sustain the eco-system's overall integrity."

[17] Norway illustrates the point. In some years during the period 1973-1990, it experienced changes in its petroleum wealth, due to price changes, which were greater than GDP (Asheim, G.B., and Nyborg J., (1995) On the Interpretation and Applicability of a 'Green National Product' *Review of Income and Wealth* 41 (1), pp. 57-71). It is of course possible to argue that anticipated discoveries of new stocks would be incorporated into existing prices. On a more general level, however, unanticipated structural shifts in an economy (due, for example, to unanticipated technological changes or changes in population) may alter such 'shadow' attempts at pricing, thereby greatly reducing the value of any measure attempting to indicate such changes as a predictor of future welfare.

[18] R. Norgaard (1992) Coevolution of Economy, Society and Environment, in Ekins P., Max-Neef, M (eds), *Real Life Economics: Understanding Wealth Creation*, Routledge, London

[19] R. Muradian (2001) *Ecological Thresholds: A Survey*, Ecological Economics, vol 38, pp. 7-24

[20] See for instance OECD (2002) *Indicators to Measure Decoupling of Environmental Pressure from Economic Growth*, OECD, Paris, (SG/SD(2002)1/FINAL

21 There is excellent data available, for instance, on the per capita consumption of fish stocks. On the face of it, this would present a useful source of decoupling comparison. Yet the use of such data sets in a decoupling analysis may add little of value. Norway, for instance, has a very high level of fish consumption per capita but it is also renowned for its fish stock management systems. Linking the data to consumption/GDP therefore would not be particularly revealing. To underline the point, Japan has similarly high consumption figures, yet it looks at the question of fish stock management somewhat differently to Norway. Some reference to the impact of fish subsidies on stock management and the stress this places on a resource we simply do not know enough about, for instance, would need to be woven into the analysis to make it meaningful.

[22] The use of water stocks, for instance might be rising at a slower rate than GDP, thereby implying decoupling, but we just do not know if that is true. Certainly, if this usage continues at the same trajectory there will come a point

where the resource will be exhausted with obvious economy (and environment) wide effects. Yet, in most analyses of countries, such trajectories are characterised as being weakly decoupled.

[23] An initial outline of this section is contained in V Vitalis (2001) *Measuring What?* OECD, Paris.

[24] The following sections on biodiversity, ocean circulation and climate change draw on the research undertaken by Katrin Hagemann for the Round Table in September 2002. This is gratefully acknowledged, but all errors and omissions are the responsibility of the author alone.

[25] J Lawton, S Naeem, L Thompson, A Hector, M Crawley (1998) *Biodiversity and Ecosystem Function: Getting the Ecotron Experiment in its Correct Context*, Funct Ecology, vol. 79, pp. 848-852

[26] P Vitousek and J Aber, R W Howarth, G E Likens, P A Matson, D W Schindler, W H Schlesinger and G D Tilman (1997) *Human Alternation of the Global Nitrogen Cycle: Causes and Consequences*, Issues in Ecology, 1

[27] The Convention on Biodiversity establishes a Biosafety Clearing-House to facilitate the exchange of information on living modified organisms and to assist countries in the implementation of the Protocol. The text of the Convention is available at: http://www.biodiv.org/biosafety/protocol.asp

[28] Ten Brink, B. (2000) *Biodiversity indicators for the OECD*: Environmental Outlook and Strategy, RIVM.

[29] FAO (2002) *The State of the World Fisheries and Aquaculture*, Rome, FAO.

[30] See for instance, CCAMLR (2000) *Statistical Bulletin*, Vol 12, CCAMLR, Hobart

[31] Ten of the top twenty-five top selling pharmaceutical drugs worldwide, for instance, were derived from natural sources and the global market value of pharmaceuticals derived from genetic sources is estimated in the range of US$75,000-150,000 million per year (UNDP, UNEP, World Bank, WRI (2000) World resources 2000-2001, WRI, Washington DC)

[32] See in particular, P. H. Williams, K. J. Gaston and C J Humphries (1994): Do conservationists and molecular biologists value differences between organisms in the same way? *Biodiversity Letters,* 2: 67-78 and the work of IUCN on the same broad issue available at http://www.redlist.org/info/categories_criteria.html

[33] Though there is general agreement that biodiversity is being lost, some biologists disagree arguing that, since it remains unknown precisely how many species exist (around one million have been documented, whereas it is believed that between 3-100 million are thought to exists), it is not easy to estimate how many are being lost. Additionally, some biologists argue that extinction rates are natural and that there is a standard “background rate” and therefore distinguishing the rate of human intervention is nearly impossible. Notwithstanding this, scientific estimates have improved to account for these criticisms, including on background rates. In short, while estimates have changed, it is clear that the rate of extinction is higher than it has ever been. For a good outline of the main arguments see OECD (2002) *Special Session on Biodiversity: Issues Paper,* Environment Directorate, Paris (ENV/EPOC(2002)6. See also the useful summary in W W Gibbs (2001) On the Termination of Species, *Scientific American*, November.

[34] See in particular: http://www.gtz.de/proklima/Methyl2.htm

[35] Crutzen, P., (1995) My life with O3, NOx and other YZOxs. *Les Prix Nobel* (The Nobel Prize) 1995. Stockholm: Almqvist & Wiksell International, pp. 123-157

[36] Crutzen (ibid).

[37] CO2 emissions from OECD countries are projected to rise by 33% by 2020 (Figures based on data contained in: International Energy Agency (2000a) *World Energy Outlook*, IEA, Paris; IEA (ibid); Burniax, J. M. (2000) “A Multigas Assessment of the Kyoto Protocol, *Economics Department Working Paper* No 270, OECD Paris; OECD

(2001b) *OECD Environmental Outlook*, OECD, Paris) The situation with regard to developing countries is similarly significant: CO2 emissions from these countries are projected to rise by 100% by 2020 (Figures based on data contained in IEA (ibid), Burniax (ibid) and OECD (ibid).

[38] IPCC (2001), *"Climate Change 2001: The Scientific Basis"*, Working Group I Third Assessment Report, IPCC, Geneva. See also, the report by the US National Research Council (2001) *Climate Change Science: An Analysis of Some Key Questions*, USNRC, Washington. The report notes that "Greenhouse gases are accumulating in the earth's atmosphere as a result of human activities causing surface air temperatures and subsurface ocean temperatures to rise." The report is available at http://www.epa.gov/globalwarming/publications/actions/us_position/nas_ccsci_01.pdf

[39] See for instance the debate crystallised by S Schneider and C Azar (2001) *Are Uncertainties in Climate and Energy Systems a Justification for Stronger Near-Term Mitigation Policies?* Pew Centre on Global Climate Change, October.

[40] Demand for energy in China will expand more quickly than anywhere else in the world at a rate of more around 2-3% per annum (International Energy Agency (2000) *World Energy Outlook*, IEA, Paris

[41] T. Panayotou (1998), The Effectiveness and Efficiency of Environmental Policy in China, in Michael B. McElroy, Chris P. Nielsen, Peter Lydon (eds.), *Energizing China, Reconciling Environmental Protection and Economic Growth*, Harvard University Press, p. 432.

[42] B. Hansen, W.R. Turrell and S. Oesterhus (2001) Decreasing Overflow From The Nordic Seas Into The Atlantic Ocean through the Faroe Bank Channel since 1950, *Nature* 411, pp. 927-930.

[43] W S Broecker (1997) "Thermohaline Circulation, the Achilles Heel of our Climate System: Will Man-Made CO2 Upset the Current Balance? Science, Vol 278, pp. 1582-1588

[44] OECD (2002) *Sustainable Development: A Framework for Peer Reviews and Related Indicators*, OECD, Paris, SG/SD(2002)3

[45] European Commission, (2001) *Communication from the Commission: A Sustainable Europe for a Better World: A European Union Strategy for Sustainable Development*, European Commission, Brussels, 15 May (COM (2001) 264 final).

[46] It is quite possible for a developed country to conclude that, at the national level, CO2 emissions are declining, but GDP continues to expand. A policy maker might conclude on this basis that decoupling is occurring. Yet such a conclusion ignores the point that other factors influence the relationship between economic growth and environmental quality. These factors include the scale of economic activity, its composition, changing techniques of production and the impact internationally of national consumption patterns expressed through trade.

[47] European Commission (ibid, p.5)

[48] See T. Rutherford (1992), *The Welfare Effects of Fossil Carbon Reductions: Results from a Recursively Dynamic Trade Model*, Economics Department, Working Paper No 112, OECD, Paris, and A. W. Wyckoff and J. M. Roop (1994), "The Embodiment of Carbon in Imports of Manufactured Products: Implications for International Agreements on Greenhouse Gas Emissions", *Energy Policy,* March 1994, pp. 187-194.

[49] For the earliest incarnation of this work see in particular, A Wyckoff and Roop (1994) The Embodiment of Carbon in Imports of Manufactured Products: Implications for International Agreements on Greenhouse Gas Emissions. *Energy Policy,* March 1994, pp. 187-194.

[50] The following section is drawn from N Ahmad (2003), *A Framework For Estimating Carbon Dioxide Emissions Embodied In International Trade Of Goods* OECD, Paris. The paper is available at http://www.oecd.org/doc/M00042000/M00042108.doc.

[51] United Nations (2001) *World Population Prospects The 2000 Revision*, United Nations, New York, p. 5. The full report (with updates) can also be accessed via http://www.un.org/esa/population/unpop.htm.