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Measuring sustainability and decoupling

A survey of methodology and practice

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Preface

This report concludes on behalf of the IoES the study *Economic Instruments for Decoupling Environmental Pressure and Economic Growth* sponsored by the Nordic Council of Ministers. Jon Thor Sturluson, Ph.D. was the principal researcher and the study was conducted in the period spring 2003 to spring 2005.

Tryggvi Thor Herbertsson, Director
IoES, University of Iceland, December 2005

Summary

Economic growth and the state of the environment are closely interlinked and must be considered as interconnected. Continued economic growth is by no means a guaranteed result of laissez-faire, market economy policies. Market agents need special incentives and must be subject to regulation if we are to maintain the quality of natural resources required for continued growth.

Thousands of distinct definitions of sustainability, sustainable development and related concepts exist and several approaches or frameworks have been proposed for the purpose of measuring and monitoring progress towards sustainable development. Primarily the three quite different frameworks: the capital method, the ecological footprint approach and the *Driving force – Pressure – State – Impact – Response* (DPSIR) conceptual framework.

A distinction is often made between *weak* and *strong* sustainability. The distinction lies not in the definition of what sustainability is, but rather in whether it is feasible or not. The distinctive factor is substitutability between natural capital and man-made capital. Weak sustainability is attained if the aggregate capital stock (including both man-made and natural capital) is non-decreasing, while strong sustainability requires a non-decreasing stock of natural capital. Economists generally define sustainability in terms of a non-decreasing level of aggregate consumption over time, or non-decreasing productivity of the aggregate capital stock over time, and thereby focus on weak sustainability. Ecologists tend to support strong sustainability or resilience as a policy objective. An ecosystem is considered resilient if its fitness is resistant to exogenous disturbances, so that it maintains its basic qualities despite considerable perturbation. With the lack of theoretical consensus, more pragmatic approaches, such as the DPSIR are usually applied in the design of sustainability measures.

None of the sustainability indicator systems considered here is universally accepted, but many have significant potential for further development. Aside from chronic measurement problems, which all indicator projects share, the main shortcoming of the genuine savings indicator lies in the inherent difficulties of assigning monetary value to natural assets. The ecological footprint indicator also has valuation problems and is often criticized for not distinguishing between the environmental impacts of different uses of land, only of how much of it is effectively used by an activity. A similar criticism can be raised in the case of headline indicators, such as the Wellbeing Index and the Environmental Sustainability Index.

Decoupling roughly stands for “breaking the link between ‘environmental bads’ and ‘economic goods’”. Decoupling should not be thought of as an approximation of sustainability. While it often gives a reasonably good measure for potential or progress towards sustainability, it is neither a sufficient nor a necessary condition for sustainability.

Decoupling indicators, unlike many other statistical efforts related to the environment, are not meant to be all-inclusive or to summarize the general state of the environment. Their purpose is rather to measure countries’ progress towards mitigating or alleviating particular environmental pressures from the relevant driving forces. In can, however, can be difficult to measure dynamic concepts like decoupling with a single measure. The absolute level of a particular pressure variable is often more important than its relation to GDP or some other measure of a driving force. Decoupling indicators are also not applicable in the case of renewable resources and are problematic to interpret when considering international cooperation. That being said, there is still a good case for the use of decoupling indicators as a valuable tool in environmental and economic policy – but not as a basis for choice of policy instruments and not as a measure of sustainability per se.

Decoupling indicators are primarily attractive for their simplicity. For detailed policy analysis in which sustainability is the objective, other methods are needed. While headline indicators and decoupling indicators can be helpful in measuring the overall situation and short-term trends with respect to sustainability, the most promising approach for serious analysis of alternative policy options is the integration of environmental indicators into systems of national accounts, such as the National Accounting Matrix extended with Environmental Accounts (NAMEA) approach. On the basis of a consistent accounting system of both economic and biophysical variables, various modeling exercises are made much easier.

1. Introduction

Sustainable development is a fundamental concept concerning every human on earth. Many think it is the single most important topic in modern politics.

It has become evident that advanced abilities to harness nature have in many ways endangered numerous species and entire ecological systems. Improved living standards are primarily attained through technological progress, accumulation of knowledge, more efficient production methods, and depletion of natural resources. Economic growth, especially in less developed countries, can improve environmental conditions by introducing current technologies used for harnessing natural resources. Nevertheless, this comes all too often at the expense of environmental degradation.

Predictions of the end of economic growth, either voluntarily or through the inevitable collapse of the ecosystem[1], have proven too pessimistic, to say the least. The popular view, at least among economists, is that continued growth is viable even though we are most likely not on such a sustainable path at the moment, and coordinated effort is needed to lead development onto a sustainable path.[2]

Economic growth and the state of the environment are closely interlinked and must be considered as interconnected. Continued economic growth is by no means a guaranteed result of laissez-faire, market economy policies. Market agents need special incentives and must be subject to regulation if we are to maintain the quality of natural resources required for continued growth. The natural environment is the most pervasive source of externalities there is, and the presence of externalities calls for intervention by government at all levels – locally, nationally and internationally.

Nevertheless, even if this relatively optimistic view of the world is true, that a sustainable path of perpetual growth is feasible, we still face the problem of identifying it and measuring our progress on the transition path towards it.

An important milestone for sustainable development was the publication of the Brundtland Report in 1987, where the first publicized definition of the concept came forth:

> Sustainable development seeks to meet the needs of the present without compromising the ability of future generations to meet their own needs. [3]

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[1] (Meadows et al. 1972; Meadows et al. 1992)
[2] (Tietenberg 2000), 548.
[3] (World Commission on Environment and Development 1987)

This famous definition is simultaneously easy to grasp and elusive to interpret. One interpretation is that sustainable development involves the right of people to attempt to fulfill their goals under the constraint of not impeding future generations' opportunities to fulfill theirs. The elusive part, however, is the word *needs*, as there can be a stark difference between *desires* and *needs*.

It is popular today to refer to sustainability as a concept based on three pillars: an economic pillar, an environmental pillar and a social pillar. Undoubtedly, sustainability is term over some sort of a balance between the developments of these pillars. In this text we limit the discussion mostly to the areas of economic development and risks of environmental degradation.[4]

Several approaches or frameworks have been proposed for the purpose of measuring and monitoring progress towards sustainable development. Here we will primarily discuss three quite different frameworks that are used as the basis for statistical work on the interaction between the environment and the economy.

Within the *capital approach* various aspects of the environment are interpreted as (natural) assets which, like economic or man-made assets, can be either consumed or used as inputs in the production of consumption goods. By adopting this interpretation, natural assets can be treated as any other assets, and well-developed analytical tools from economics can be readily applied. This framework does not, in principle, limit analysis to the use value of the environment, as non-use value mirrors the value of pure public goods, which are frequently incorporated into economic models.[5] The main caveat of the capital approach is that it requires a monetary valuation of all non-trivial natural assets as well as a measure for how easily one natural asset can be substituted for other assets, be they natural, social or economic capital. Both valuation of natural assets and their elasticity of substitution with respect to other assets are hard to come by. The measurement problem is immense, and any estimate is bound to be highly subjective and debatable.

The major hurdle in finding a general measure of sustainable development is the problem of aggregation. In the capital approach money is used as a general measure of asset value or change in value. An alternative is the *ecological footprint approach*, where the common denominator of natural resources is not money but hectares of land. According to Wackernagel and Rees (1996), the definition of an ecological footprint is:

[4] Adding the social dimension to the discussion is conceptually easy in some cases (see the capital approach for example) but extremely difficult in others (see the ecological footprint method below). In all cases it adds considerably to the practical complexity of these issues and is therefore left out for now.

[5] A pure public good is both non-rival (i.e., one's consumption of it does not reduce the value of the good for others to enjoy) and non-excludable (i.e., it is difficult or impossible to limit access to it). National defense is the archetypical example of a pure public good.

> the aggregate area of land and water in various ecological categories that is claimed by participants in the economy to produce all the resources they consume and to absorb all the wastes they generate on a continuing basis, using prevailing technology.

The ecological footprint records a country's or a region's supply and use of natural resources measured in the form of a standardized acreage of arable land. The aggregate net balance is then a measure of the sustainability of natural resource use. The ecological footprint approach is not exempt from valuation problems any more than the capital approach, as measuring the impact of various forms of resource depletion and pollution in terms of square kilometers of land can be just as hard as putting a price tag on natural resources. Decomposition of these effects, in terms of area, production sector, environmental issues, etc., is, of course, possible. However, with increased disaggregation the whole exercise of standardizing various natural resource stocks or flows becomes less and less relevant.

Neither of these approaches, used to capture the overall sustainability of economic development, with respect to the environment, escapes the fundamental controversy over to what extent natural resources can be substituted for man-made capital. While some natural resources are, without a doubt, replaceable as far as human development is concerned, most are arguably irreplaceable. A few resources, most notably the atmosphere, are undoubtedly irreplaceable as they are essential for human existence. Any path of economic development undermining such natural resources is clearly unsustainable. Their quality must be maintained at a reasonably high level so that the risk of deterioration in the present and the future is absolutely minimal.

For monitoring the state of these essential natural resources and its links with economic development, the main concern is to identify which economic factors influence the respective natural resource and vice versa – which aspects of the economy are affected by environmental degradation. The *Driving force – Pressure – State – Impact – Response* (DPSIR) conceptual framework is a convenient building block for such analysis and is used as a background for several sets of indicators measuring various forms of sustainability. While not as well-defined an analytical method as the two previously mentioned approaches, it has proven to be a valuable complement as it both directly and indirectly emphasizes non-substitutable natural resources. Decoupling indicators, which are not direct measures of sustainability but measure progress towards sustainability, are based on the DPSIR framework. Decoupling is neither a sufficient nor necessary condition for sustainability, but is a handy tool for gauging progress in the short and medium term.

Despite some conceptual problems considered below, the use of decoupling as a concept is promising, and the work that has been done on decoupling indicators is an important step forward, primarily because of their simplicity and practicality. It is clear, however, that the scope for clarifying relationships between environmental pressures and economic driving-forces is considerable, and such efforts are in high demand. There is growing interest in the prospects of decoupling from policymakers' point of view, as they have a hard time disentangling environmental policies from their economic and social impacts. Opportunities for improved environmental quality without compromising economic growth are, and always will be, welcomed by politicians.

> Indeed, by 2005, [Denmark] expects to reduce its dependency on fossil fuels by 33% and to reduce chemical emissions by 20%. New sources of energy have created 15,000 new jobs and power is now Denmark's third largest export. With proof that sustainable development can be cost effective, the biggest cost of decoupling economic growth from environmental degradation is not economic but political.[6]

These issues are explored in more detail below, starting with Section 2 where we discuss basic terminology essential to the following discussion, mainly sustainability and decoupling. In Section 3 several representative sustainability assessment frameworks are described and discussed. Section 4 then deals with the measurement of decoupling and decoupling indicators: what they are and how decoupling indicators can be generalized as a well-known regression model. A convenient improvement to the current method of calculating such indices is also suggested. The paper concludes with some final remarks in Section 5. Suggestions for research in this field, particularly with large-scale economic models with environmental links are found in an appendix.

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[6] Svend Auken, Minister of Environment and Energy for Denmark, OECD Observer, May 14, 2001 (http://www.oecdobserver.org/).

2. The concept of sustainability

> "Sustainability risks being about everything and therefore, in the end, about nothing" (The Economist 2002)

To be able to measure and monitor sustainability and decoupling, we need to establish a clear meaning of these concepts, beginning with sustainability. We then go on discussing the concept of decoupling and measures of decoupling.

Thousands of distinct definitions of sustainability, sustainable development and related concepts exist (Pezzey 1992, 1997). In their textbook, Perman et al. (2003) discuss six representative definitions of what should be called a sustainable state. This is when:

1. utility or consumption is non-declining through time
2. resources are managed so that production opportunities for the future are maintained
3. natural capital stocks are non-declining through time
4. resources are managed so that levels of resource services are maintained
5. minimum conditions for ecosystem resilience through time are satisfied

This list is far from exhaustive but is representative of popular definitions from different academic fields. The first three are typical for economists, and numbers 4 and 5 are from ecologists. These five definitions are not necessarily mutually exclusive, but all have their strengths and weaknesses in terms of applicability.

The meaning of sustainability varies between disciplines and individual researchers. Ecologists often refer to sustainability as a comprehensive criterion that should guide global development. This perspective suggests that alternative measures of human wellbeing are needed, measures that look beyond the material benefits alone. Such a measure promotes efficiency, but in a broader sense than an economist would normally see it. Economists, on the other hand, typically consider sustainability to be an issue of intertemporal substitution and hold? that sustainability is achieved if the current generation maintains or improves the quality of life for the good of future generations.

A distinction is often made between *weak* and *strong* sustainability. The distinction lies not in the definition of what sustainability is, but rather in whether it is feasible or not. The distinctive factor is substitutability between natural capital and man-made capital. Weak sustainability is attained if the aggregate capital stock (including both man-made and natural capital) is non-decreasing, while strong sustainability requires a non-decreasing stock of natural capital.

2.1 The economist's view

The dismal science is much more optimistic towards sustainability than its famous nickname suggests. Representative is Solow's (1986) critique of the 'End of Growth' paradigm (Meadows et al. 1972). True enough, by definition, non-renewable resources exist in finite quantity. Still, he claims that focusing on conservation of resources for future generations is a 'damagingly narrow way to pose the question'. In his view, the obligation towards future generations should not be in the form of a fair share of the various depletable resources available to day, but rather in terms of overall production possibilities or certain standards of living.

Most economists define sustainability in terms of a time path of utility. Utility is a relative measure of preference between different alternatives, whether preference is derived from pleasure, happiness or other motives. While in most cases it is not an absolute cardinal measure, it can be used to compare standards of living between different allocations and across time. A common approximation is to let consumption represent utility, and therefore economists generally define sustainability in terms of a non-decreasing level of consumption over time, or non-decreasing productivity of the aggregate capital stock over time.

Most importantly, economists tend to think of sustainability in terms of maintaining the quality of services derived from the environment but not necessarily the preservation of individual aspects of the environment in its own right. Oil is a good example. An economist would typically not be concerned with preserving oil reserves per se, but rather that services that at present rely on oil will be provided in undiminished quality in the foreseeable future by any means necessary.

Using fairly standard assumptions about technology, Stiglitz (1974) has demonstrated that sustained growth in consumption per capita is feasible, even though production depends on exhaustible resources in limited supply. Three effects contribute to this result: a) technological progress, b) substitution from natural resources to physical capital and c) increasing returns to scale.

In economics, the concept of capital is used to describe a collection of tangible assets, such as machinery, equipment, housing and facilities. The important characteristic of capital is that it is does not (at least in its typical use) provide value but rather the services it can facilitate. Furthermore, capital usually wears away with use, so that it has to be replenished through investment in order to maintain a certain flow of services.

Other important stocks possess similar characteristics, such as the accumulated skills and knowledge that can be transformed into labor services, collectively referred to as human capital, and behavioral norms and communications skills as social capital. We can also think of states of nature in the same way, as natural capital that is both used as input in manufacturing and consumed or directly consumed as natural goods (hiking, trekking, etc.). Just as with other types of capital, natural capital provides certain flows of services providing welfare in one way or another.

Emphasizing capital has the benefit of emphasizing the potential for consumption in the future rather than current consumption. In fact, the current level of consumption is a rather conspicuous measure of long-term welfare. Interpreting environmental phenomena as a form of capital – natural capital – also has the following benefits:

a) It fits well with a well-thought-out methodology for economic capital and is therefore relatively easy, conceptually, to work with.
b) For the same reason it is more easily integrated with existing analytical tools.
c) The capital approach is easier to grasp than many other methods, since the concept of an asset is familiar to almost everyone.
d) It also sets a practical guide to the selection of indicators, as we are primarily interested in those affecting the stock of natural assets and not others. Without a clear and well-formed framework, such as this, one risks overextending the number of indicators, thereby diluting their interpretation.

Based on the capital approach, Hartwick (1977) set forth a straightforward rule as a necessary condition for sustainability. Roughly speaking, the Hartwick rule states that at minimum the net value or rent of depleted resources should be saved in the form of man-made capital so that future generations can potentially consume as much as the current one. Recent research on this topic has revealed that the Hartwick rule only applies in fairly restrictive circumstances (Asheim et al. 2003).

Stavins et al. (2003) propose a notion of sustainability intended to synthesize different views while being normative and thereby applicable to policy analysis. Their concept of sustainability combines two components: dynamic efficiency and intergenerational equity. Dynamic efficiency should be achieved by maximizing an inter-temporal utility function like the following:

$$Max_{c(\,)} W(t) = \int_t^{\infty} U\left(c(\tau)\right) e^{-\rho(\tau - t)} d\tau \,, \tag{1}$$

where W(t) stands for total welfare in a broad sense for generations born at time *t* and all future generations; U(c(t)) is a general idealized utility function of a vector of consumption variables, both direct consumption and enjoyment of non-market goods and services; and r is the rate of social time preference. The consumption path fulfills the condition of intergenerational equity only if total welfare in non-decreasing in time:

$$\frac{dW(t)}{dt} \geq 0 . \tag{2}$$

The economy is considered sustainable if and only if conditions (1) and (2) are fulfilled.

Acknowledging that this definition is extremely broad (but not vague), Stavins et al. suggest that in practice this notion could be treated similarly to Pareto efficiency. For a policy to be a Pareto improvement, some agents must be better off if it is implemented, while none is worse off. While not particularly practical, Pareto efficiency is the basis for cost-benefit analysis in the weaker form of the Hicks-Kaldor criterion (Kaldor 1939; Hicks 1940). The Hicks-Kaldor criterion roughly states that a policy should be implemented if those gaining from the policy are able to compensate those suffering from its implementation, without any such transfers actually taking place. It is easy to show that fulfillment of the Hicks-Kaldor criterion is a necessary (but not a sufficient) condition for Pareto optimality.

In this sense *potential* sustainability can be achieved through dynamic efficiency and realized by imposing the potential for generational equity. However, to actually implement generational equity across the entire time path from now to eternity is not in the power of any living human being. Stavins et al. reach the following conclusion: “In theory, it may be argued that sustainability is ultimately the most desirable policy goal, but in practice it may be more reasonable to aim for potential sustainability in the form of dynamic efficiency.”

Even though this approach avoids certain practical problems, three fundamental hurdles remain. First, what is the appropriate functional form for total welfare? For instance, are time separability and constant time preference reasonable assumptions? Second, what is an appropriate time preference parameter?[7] Are future generations of lesser importance than current ones? And third, what is the appropriate broad measure of consumption? These are all fundamental questions that need reasonable answers if a sustainability definition of this kind is to be useful for monitoring and policymaking. Even so, it is unlikely that a consensus can be formed around a single definition.

[7] The father of the intertemporal consumption model, John Ramsey (1928), thought, for instance, that the only just social time preference parameter was zero. The standard practice, however, is to use real risk-free interest rates or the long-run economic growth rate.

2.2 The ecologist's view

A distinction is often made between *weak* and *strong* sustainability. The distinction lies not in the definition of what sustainability is, but rather in whether it is feasible or not. The distinctive factor is substitutability between natural capital and man-made capital. Weak sustainability is attained if the aggregate capital stock (including both man-made and natural capital) is non-decreasing, while strong sustainability requires a non-decreasing stock of natural capital.

While most economists, including the previously mentioned Solow, Stiglitz and Hartwick, subscribe to the weak sustainability definition, ecologists tend to support strong sustainability as a policy objective. The debate over which is more relevant is rooted in both ethics and physics. It is, for instance, an ethical question how persistently we should protect endangered species. In most cases the loss of an animal or plant species will not put steady growth of consumption at risk. Many believe, however, that such an event is catastrophic and reduces the quality of life for future generations. Whether we can sustain certain life-support systems, such as air and water, with human-made capital alone is, on the other hand, a technical question. The limits of technology are constantly expanding, and no one can predict to what extent natural capital can be replaced by other types of capital hundreds of years from now.

Ecologists usually prefer to approach the sustainability issue from the perspective that man is part of an ecological system, not only a consumer of it, and the continued vitality and resilience of this system is what is most important rather than human welfare. An ecosystem is considered resilient if its fitness is resistant to exogenous disturbances, so that it maintains its basic qualities despite considerable perturbation. Common and Perrings (1997) argue that resilience is a necessary condition for ecological sustainability, which is in turn a prerequisite for sustainability of both the economy and the environment. This view contrasts with the economic view as dynamic efficiency or the Hartwick rule are neither necessary nor sufficient conditions for resilience. Even though it is difficult to measure, ex ante, many of the environmental indicators discussed below can be thought of as proxy measures of resilience.

Ecologists also tend to be more avid advocates for caution than economists, and to a larger extent prefer to give nature the benefit of the doubt, so to say. This emphasis on caution and resilience develops logically into a preference for the status quo, in terms of the environment, and emphasizes preservation of natural resources. Preferring the status quo over an uncertain alternative can also be a sound strategy when it comes to complicated ecological systems based on evolutionary game theory (Maynard Smith 1982). A long-lasting ecosystem state can be interpreted as a collection of evolutionary stable strategies which have withstood small perturbations in the behavior of its members. A drastic change in human behavior might, however, upset such equilibrium with unknown consequences.

2.3 The pragmatist's view

With the lack of theoretical consensus, a much simpler alternative approachs has proven popular in designing monitoring schemes involving both the environment and the economy; namely, to consider particular measures of environmental quality, one at a time, in relation to specific economic factors affecting them or affected by them. The prime examples of such frameworks are the Pressure – State – Response (PSR) conceptual model, adopted by the Organization for Economic Co-operation and Development (OECD 1994) and the Driving force – State – Response (DSR) framework developed by the UN Commission on Sustainable Development (UN 1997). More recently, various European organizations and national institutions have adopted the related Driving Force – Pressure – State – Impact – Response (DPSIR) framework (European Environment Agency (EEA) 1998).

The basic idea behind DPSIR is that environmental management can be represented by a five-step feedback process.

1. *Driving forces* are underlying causes of environmental degradation or resource depletion, such as the demand for energy, transport and housing. Gross domestic product (GDP) and population are also regularly considered as driving forces.
2. *Pressures* on the environment are directly caused by driving forces and include pollution, deforestation, and emissions of greenhouse gasses.
3. *State* refers to the state of the environment, usually measured as the stock of a particular resource or a measure of an environmental good's quality. The state is directly affected by environmental pressures. As the name suggests, state indicators are normally state or stock variables.
4. *Impact* stands for the various impacts from a changed state of the environment, such as financial impacts and health impacts, changes or flow in the state of the environment, such as loss in biodiversity or unspoiled wildernesses.
5. *Responses* are anthropogenic reactions to those impacts, such as policy measures and other public or private actions mitigating the relevant environmental impact.

The DPSIR framework can be helpful in drawing up a causal relationship between the environment and economic activity. Economic growth and various subcomponents of general economic activity can be seen as *dri-*

ving forces of environmental quality. An important example of such a subcomponent is the use of fossil fuels in power generation. The use of fossil fuels involves emissions of carbon dioxide (CO_2) and environmental *pressure* contributing to global warming. The concentration levels of CO_2 and other greenhouse gasses in the atmosphere represents *state* measures of environmental quality. The *impact* can be the average surface temperature in excess of long-run averages and the frequency of extreme weather phenomena or economic and social costs derived from these changes. The final link in the chain is the *response* decision makers choose to alleviate or reduce harmful impacts, such as carbon taxes and carbon emission permit quotas. The responses could in principle be targeted at any of the three: the driving force, the pressure or the state.

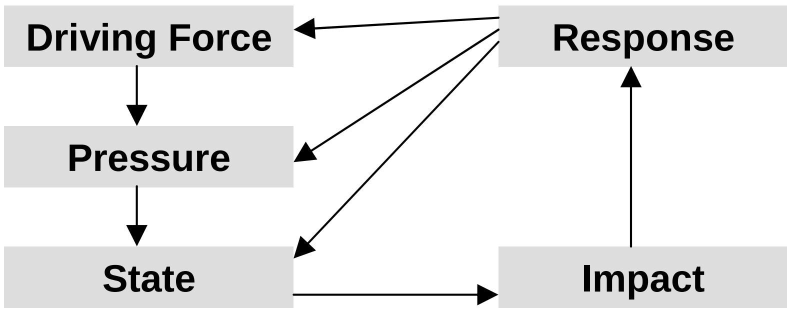

Figure 1: Conceptual relations in the DPSIR framework

The DPSIR framework was developed primarily to serve as a guide for selecting and organizing sustainability indicators, but it has also been applied as a first approximation in policy analysis, for instance, by building a decision support system (DSS) on top of an indicator system adopting the DPSIR framework (Fassio et al. 2004). But since there is no formal theoretical underpinning for DPSIR, considerable discrepancy can be found in its applications to policy analysis.

While the framework is not directly linked to any one definition of sustainability, it is more akin to strong rather then weak sustainability, because of the emphasis on one environmental issue at a time and offers no guidance as to how different issues should be weighed together to create an aggregate measure of sustainability. In the case of critical natural capital[8], a strong form of sustainability (Ekins 2003) is undoubtedly more relevant than the weak-form indicators, based on the DPSIR framework, and may coincide with measures of sustainability, based on a different school of thought, such resilience.

[8] See Ekins et al. (2003) and other papers from a special issue of Ecological Economics on Critical Natural Capital.

2.4 Decoupling

The concept of *decoupling* is related to that of sustainability but is much more narrowly defined. For instance, it only deals with the interaction of economic and environmental development, leaving social issues aside. The Organization for Economic Cooperation and Development (OECD) has started using the notion in its extensive environmental surveying projects, including the peer review process. According to OECD (2002) decoupling roughly stands for “breaking the link between ‘environmental bads’ and ‘economic goods’”. In particular, the relative change in a specific environmental *pressure* variable with respect to the change of a relevant *driving-force* variable over the same period. In other words, it describes the relative change in the two first components of the DPSIR framework.

Decoupling should not be thought of as an approximation of sustainability. While it often gives a reasonably good measure for potential or progress towards sustainability, it is neither a sufficient nor a necessary condition for sustainability. The former assertion is straightforward as a reduction in environmental pressure from a certain driving force need not be sufficient to restore a natural resource that has previously been overexploited. The second assertion is, however, less obvious. It may seem logical to view decoupling as a prerequisite for sustainability. The state of an environmental system may however be considered sustainable despite a lack of decoupling if either of the response measures focus on the state itself, or the dynamics between the pressure and the state are particularly non-linear.

By looking at environmental pressure variables instead of environmental state or impact variables (just to name the other alternatives from the DPSIR framework), decoupling emphasizes the contemporaneous or short-run effects of economic activity on the environment rather than its long-run impacts. Therein lies the main advantage of using decoupling as a policy objective as measure of decoupling can give strong indications of how well a country or region is managing to alleviate environmental pressures from the underlying driving forces, most notably economic growth.

3. Measuring sustainability

Measuring sustainability is fundamental if sustainability is to be achieved. But as there are at least as many ways to measure sustainability as there are definitions of the concept, this is no easy task. In fact, it is much more complex and controversial than the principal theories it is based upon as measurement and valuation problems abound. Still, it is an inescapable chore as guidance is so desperately needed for making necessary policy choices to counteract serious environmental problems.

1. Efforts to measure sustainability can be roughly divided into the following groups:
2. Extended national accounts, such as the UN System of Environmental and Economic Accounts.
3. Indicators based on the capital approach. In essence simplified application of national account methods.
4. Biophysical accounts, principally the ecological footprint.
5. Headline indicators based on aggregated indices and subindices.

3.1 Environmental accounting

Both environmental economists and environmental activists agree that the UN System of National Accounts (SNA) does not provide adequate measures of economic progress, income or welfare when the environment is taken into account. The main issues that are usually raised in this context are: a) the absence of consideration for depletion of natural resources, b) the lack of adjustments for the deterioration of environmental quality, and c) the controversy of treating costs associated with environmental protection and restoration as income instead of costs.

Despite various ambitious and elaborate incarnations, none of the alternative general welfare measures that have been proposed in response to this critique have gained widespread acceptance. Many, and even some of the economists involved in these attempts, have come to the conclusion that the probability that any generally accepted framework that could replace the SNA will be developed is very small or even zero. The main reason for this pessimism is linked to the difficulty of estimating the value of non-market natural assets and substitution between various types of capital. Finding good estimates for depreciation is always difficult, also for physical capital. For that reason gross domestic product (GDP), which is measured gross of depreciation, is preferred across the board to the theoretically more sound net domestic product.

Nevertheless, while scientists and activists have become increasingly disheartened in their search for a robust measure of sustainable income, interest in sustainability indicators has increased dramatically. The scope of environmental accounting in relation to standard national accounts is discussed below in Section 4.

3.2 Sustainability indicators

Sustainability indicators, as the plurality suggests, are not a single measure of sustainability, but rater a collection of data intended to facilitate judgments, either through analysis or direct observation, about sustainability. Indicator sets are not necessarily based on a well-specified single definition of sustainability but are mainly considered as accessible information for policy makers and other stakeholders to make their own judgments about progress towards sustainability.

The practice of constructing sustainability indicators and conducting sustainability assessments, as promoted by the World Commission on Environment and Development (The Brundtland Commission), has grown rapidly since the 1992 Earth Summit in Rio de Janeiro. A wide spectrum of organizations – Governments, Municipalities, Non-governmental organizations and private firms – has been involved. As a response to an apparent lack of consensus with respect to the choice of proper measures, a group of leading practitioners developed general guidelines for sustainability assessments, including the choice and application of indicators – the Bellagio Principles – which have been used in many subsequent regional studies of the kind.

In a slightly abridged form, the 10 Bellagio Principles (Hardi and Zdan 1997) state that assessments of progress towards sustainable development should:

1. be guided by a *clear vision* of sustainable development and goals defining that vision.
2. include a *review of the whole system*, its state, direction and rate of change, as well as its parts (social, ecological and economic sub-systems).
3. consider *essential elements of human existence*, such as equity and disparity within the current population and between present and future generations, ecological conditions on which life depends and economic development.
4. have *adequate scope*, including a time horizon long enough to capture both human and ecosystem time scales and a sufficiently large spatial dimension to include both local and long-distance impacts.

5. have a *practical focus,* thereby limiting the number of key issues to be analyzed, and a limited number of indicators and indicator combinations should be standardized and comparable to targets and thresholds when possible.
6. make all *methods, data and explicit judgments accessible to all*.
7. be designed to *address the needs* of the intended audience.
8. be based on *broad participation*, for instance, by key grass-roots, professional and social groups together with policy makers.
9. be an ongoing process *providing repeated measurements*; be iterative, adaptive and responsive to change.
10. be facilitated by a *sufficient institutional capacity* for data collection, maintenance and documentation.

While these principles are individually uncontroversial and should be respected as much as possible by those working on sustainability indicators, it is highly questionable if they can ever be fulfilled as a whole. The OECD is among various international organizations as well as national institutions that have put strong emphasis on environmental and sustainability indicators. The guidelines behind their selection of indicators (OECD 1994) is, for instance, considerably more practical. These guidelines can be separated into three parts. The first relates to policy relevance: a) Indicators should be easy to interpret, b) they should show trends over time, c) they should be responsive to underlying conditions that can be affected by decision makers, and d) a reference value should be established, against which conditions can be measured. The second part requires analytical soundness, in that indicators should have a sound scientific base. The third part deals with the practical side of measurability, namely: a) that indicators should be calculated from data that is already available or can be made available at reasonable cost, b) also that any data used should be well documented and of respectable quality, and, finally, c) that indicators should be updated regularly.

Hamilton (2004) suggests that in addition to these, a) there should be an underlying framework prescribing how different indicators are interrelated, b) that there should be a numeraire permitting aggregation of the various data, c) that aggregated indicators should have a clear interpretation with respect to sustainability, and d) that each component indicator should be linked to a particular well-defined policy objective.

All of these are relevant criteria by which we can evaluate sustainability indicators. But it would be wrong to apply the same standards to all sustainability indicator projects as their purpose, scope and target audience varies. Booher and Innes (2000) emphasize that indicators should be developed with the participation of those who will use and learn from them and with their ultimate purpose in mind. This is also one of the previously mentioned Bellagio principles. In fact, three quite different types of indicators have surfaced in recent years, each with a specific audience in mind: (1) The general kind that describes *system performance*, targeted at the general public and policymakers mainly in order to ask questions like “Where are we going?” (2) *Policy and program measures*, to provide policymakers with feedback on specific programs and initiatives, and (3) *Rapid feedback indicators* to assist individual agents (e.g., consumers and businesses) to make better decisions in the short term. Only in the first case is there a high level of aggregation into a single indicator, and the need for a universal numeraire is thereby relevant.

In addition the following properties are desirable for indicators of the first type:

1. Compatibility between nations, sectors or firms (depending on the scope of the analysis). If compatibility is not sufficient, agencies might be tempted to focus on those indicators suiting their purpose. One part of this issue is the selection of a relevant denominator when constructing relative indices.
2. They should give a consistent measure over time. Here, the question of denominator is also important to allow for inter-temporal comparison.

Selection of “leading indicators” must be done in an objective manner, based on practice and analysis. Statistical and econometric techniques, such as factor analysis and principal component analysis, should be applied as much as possible, when selecting among indicators.

When comparing environmental indicators across countries, and even across time within a single county, a proper denominator is required. Popular denominators are:

- GDP. Environmental pressure variables are often listed in the context of the popularized measure of the scale of economic activity.
- Total population. In other cases it is the number of inhabitants that determines the scale of the problem.
- Populated land area. While general economic activity is normally the principal driving force behind most environmental pressures, its impact is often proportional to the populated area it affects. It is based on the assumption that a given amount of pollution in a small area is more of a problem than the same amount of pollution in a larger area.

The most desirable characteristic of the second type, however, is responsiveness to policy. When choosing between two or more indicators to represent a particular environmental issue, it may be good strategy to choose an indicator that is likely to be affected by future policy decisions. Still, indicators have limited application in practical policy analysis. Only if they can be linked with proper general-equilibrium or macro-economic models with sufficiently detailed structure are they likely to be of much use in policy design. This issue is discussed further in Section 4.

We choose to avoid a discussion of the third type, a debate more akin to politics than economics. One thing is certain; popularization of sustainability indicators may raise awareness over related issues.

3.3 Genuine savings indicator of weak sustainability

The genuine savings indicator first suggested by Pearce and Atkinson (1993) measures national savings net of depreciation of both physical capital and natural capital. It is derived on the basis of the capital approach, discussed in Sections 1 and 2. The following equation defines a standard version of the indicator:

$$GS_t = S_t - D_{Mt} - D_{Nt} \qquad (3)$$

Where G_{St} stands for the genuine savings indicator in year t, S_t is a standard national account definition of gross domestic savings; D_{Mt} is depreciation of physical (man-made) capital, and D_{Nt} stands for depletion of natural capital. The World Bank has published such an indicator annually since 1999. In the World Bank's version of the genuine savings indicator, expenditure on education and approximated investment in human capital, which is normally treated as consumption expenditure in national accounts, is added as a savings item, while the estimated damage from carbon dioxide emissions is subtracted. Depletion of natural resources is furthermore divided into three categories: energy, mineral and net forest depletion.

A positive genuine savings indicator suggests that a country's wealth is increasing, a prerequisite for (weak) sustainable development. A negative value indicates that the country is on an unsustainable path. The indicator is usually presented as a percentage of national GDP.

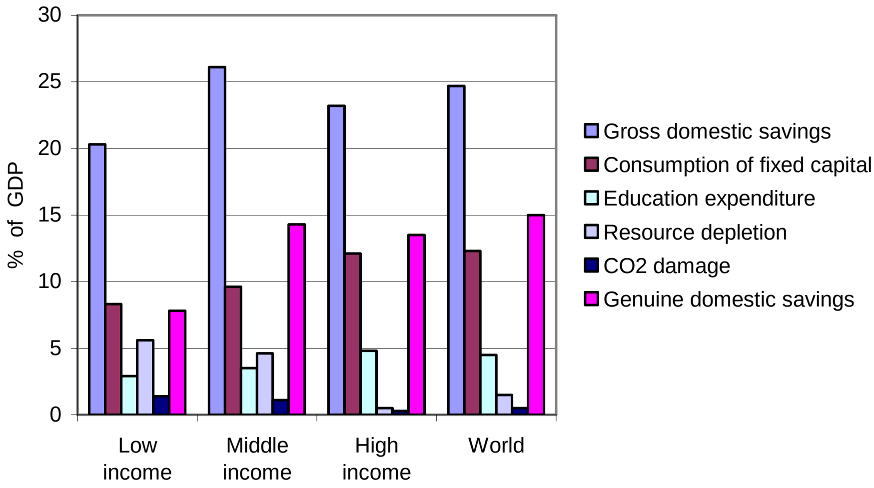

Figure 2: Aggregates of national genuine savings indicators for 1999 by income levels (source: World Bank, WDI 2001)

Figure 2 gives an example the aggregated outcome for the world and three income groups of countries. It illustrates the general tendency for low-income countries to perform worse than middle- or high-income countries. Rapid depletion of natural resources, low level of human capital investments and relatively high CO2 damage generally outweigh the typically lower depreciation of man-made capital. It is especially resource-intensive developing countries that appear to be unsustainable, in the weak sense, while most developed countries are weakly sustainable.

In their recent critical analysis Dietz and Neumayer (2004) argue that the genuine savings method has improved the standard of measuring weak sustainability and advanced the concept of sustainable development in general. Genuine savings also seem to perform well empirically when interpreted as potential for increased consumption in the future (Hamilton 2005).

While the genuine savings indicator is probably the best attempt made at measuring weak sustainability to date, it is not without its faults. Its main shortcomings are: unrealistic assumptions of how inter-temporally efficient the economy is, rather simplistic treatment of exogenous shocks and population growth, inadequate method for computing natural capital depreciation, and limited consideration for pollution and waste.

As with most other sustainability indicators, accounting of environmental degradation is related to the country of origin. Depreciation of minerals, for instance, is attributed to a mining country. An alternative viewpoint is to attribute depletion of natural capital to the country using the final goods. With a technique similar to input-output analysis, Proops and Atkinson (1998) have a developed genuine savings indicator emphasizing the country of use rather than the country of supply. In some cases, for instance Japan, which has high consumption levels but few non-renewable natural resources, the measured genuine savings are drastically different, depending on which method is used. Which method is more appropriate, the country-of-supply or the country-of-use method, depends on the context. The first emphasizes whether the country, as such, is sustainable, while the second one is more appropriate if we are interested in measuring each country's contribution to global sustainability.

3.4 Measuring strong sustainability

The preference for strong vs. weak sustainability is likely to depend primarily on the perception of potential substitutability between natural capital and man-made capital. If one believes that the scope for such substitution is limited, a more attractive method of accounting for sustainability is to measure nature's capacity to maintain economic activity.

The most popular method of doing so is by means of the ecological footprint.[9] The ecological footprint is defined as the aggregate area of land and water that is used up, one way or another, by economic agents to produce consumer goods and absorb waste using prevailing technology (Wackernagel and Rees 1996). In the World Wide Fund for Nature's regular reporting of the ecological footprint (WWF 2004), the footprint is subdivided into three main categories: a food, fiber and timber footprint; an energy footprint; and the footprint of built-up land. For each included country, the aggregate footprint is then compared to its biological capacity or supply of standardized units of arable land. The difference between the two is the ecological deficit (or surplus) – a measure of whether a country is sustainable or not.

Figure 3 shows the global footprint and ecological deficit for the world as a whole and groups of countries ordered by income levels. The figure shows a dramatic difference in how much natural resources developed countries use, per capita, compared with developing countries. The difference is most dramatic in the energy footprint. The ecological deficit is also greatest in the case of high income countries, or roughly 3 hectares per inhabitant, while the deficit is small for low-income countries, and middle-income countries can boast of an ecological surplus.

[9] Other methods of this type include the measurement of human appropriation of net primary production (Vitousek et al. 1986).

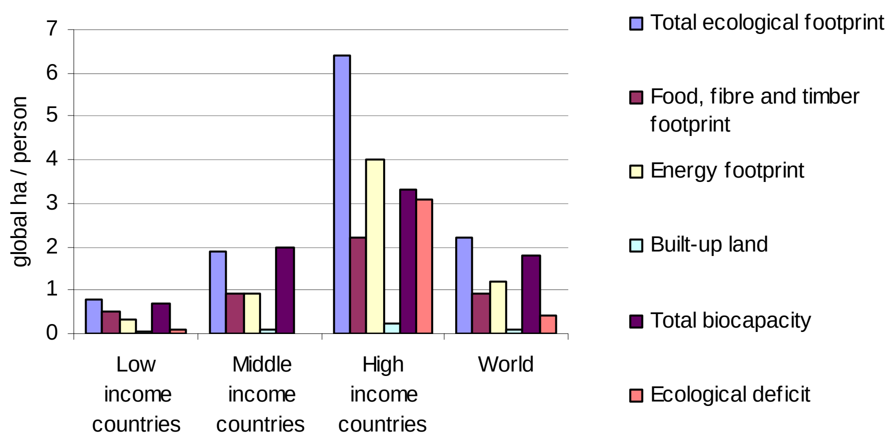

Figure 3: Biological footprint and biocapacity (Source: WWF 2004)

A global ecological footprint has been calculated back to 1961 when it is estimated to have been 0.49 times the global biocapacity, while it has steadily increased since then and became 1.21 in 2001. This implies that resource usage is not sustainable, and that the Earth's resources are being depleted at an alarming rate. The outlook is also rather bleak when Figure 6 is considered with respect to development. The eightfold difference between the ecological footprint per capita in the high-income countries and the low-income countries suggests that the global footprint will continue to increase with economic development.

The ecological footprint is not without shortcomings. Van den Bergh and Verbruggen (1999), for instance, argue that the Ecological Footprint is not the comprehensive and transparent planning tool it is often assumed to be; that is, it cannot serve as an indicator for assessing sustainability. According to them, its main problems are that it is too aggregate; its energy scenario is much too simplistic; no distinction is made between sustainable vs. unsustainable land use, and certain applications are actually biased against trade.

> The ecological footprint made by Nordic citizens is close to the average of high income countries. It ranges from 6.2 hectares per capita in Norway to 7 hectares in Finland and Sweden.[10] With the exception of Denmark, they all have an ecological surplus due to the large size of these countries, relative to the population.

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[10] The WWF does not publish ecological footprint estimates for Iceland.

3.5 Headline indicators

Several environmental indicators are not as well based on economic theory or ecological science as those previously mentioned, but are rather a collection of environmental, social and economic data considered important for sustainability. Here, we briefly discuss a few examples of this type of indicator.

The Wellbeing Index

Prescott-Allen (2001), with the cooperation and support of the World Conservation Union (IUCN) and the International Development Research Centre (IDRC), has created what is called the *Wellbeing index*, claimed to be the first global assessment of sustainability. It is a composite of several measures of human wellbeing, such as health, population and wealth, and environmental indicators, such as water quality, biological diversity, and energy use. The first group of indicators is compiled into a single Human Wellbeing Index (HWI) while the second group is summarized in the Ecosystem Wellbeing Index (EWI). A two-dimensional graph of the two indices is referred to as the Barometer of Sustainability. The third index, simply named the Wellbeing Index (WI), is the average of the first two.

The index is supposed to measure sustainability by giving the welfare of humans and the ecosystem as a whole equal weight. It is based on a three-step methodology for: (1) deciding which features should be measured, (2) choosing the most representative indicators for these features, and (3) aggregating these indicators into general measures of wellbeing. While individual indicators are normalized indices, the aggregate indicators are constructed as simple means of five intermediary indicators which, in turn, are constructed from simple averages of specific indicators available for the particular country.

The aggregate results published in 2001 for 180 countries are shown in Table 1. It shows the wellbeing index (WI), human wellbeing index (HWI) and ecological wellbeing index (EWI) for each country, together with the ranking of each country. An important observation is that the variability in EWI is considerable, even for countries with similar levels of HWI. This has been interpreted as a sign of potential for decoupling, as human welfare and ecological welfare are not necessarily substitutes. Still unanswered is to what extent such variations can be explained by fundamental natural causes or successful environmental policies.

An interesting insight is that the subindices of the HWI are much more correlated than the subindices of the EWI. While human wellbeing is to a large extent derived from high national income, the good or bad state of the ecosystem has a variety of causes. The way for most countries to raise their EWI is to restore and maintain habitats, expand protected areas, conserve agricultural diversity, and improve water quality. Industrialized countries also need to cut greenhouse gases.

Table 1: The Wellbeing Index, ranking of 180 countries (source: Prescott-Allen 2001)

Rank	Country	WI	HWI	EWI	Rank	Country	WI	H	E	Rank	Country	WI	HW	EWI
1	Sweden	64	79	49	61	Spain	46.5	73	20	121	Papua New Guinea	38	22	53
2	Finland	63	81	44	62	Samoa	46.5	43	50	122	Burkina Faso	38	17	58
3	Norway	63	82	43	63	Nepal	46	28	64	123	Angola	38	8	67
4	Iceland	62	80	43	64	Croatia	45	57	33	124	Madagascar	37	24	50
5	Austria	61	80	42	65	Russian Federation	45	48	42	125	Senegal	37	20	54
6	*Dominica*	*61*	*56*	*65*	66	Gabon	45	28	62	*126*	*Liberia*	*37*	*9*	*65*
7=	Canada	61	78	43	67	Bulgaria	44.5	58	31	127	Thailand	37	50	23
7=	Switzerland	61	78	43	68	Jamaica	44.5	54	35	128	Ukraine	37	47	26
9	Belize	57	50	64	69	Panama	44.5	52	37	129	Turkey	37	45	28
10	Guyana	57	51	63	70	Antigua & Barbuda	44.5	49	40	130	Algeria	37	29	44
11	Uruguay	57	61	52	71	Georgia	44.5	48	41	131	Bangladesh	37	27	46
12	Germany	57	77	36	72	Brunei Darussalam	44.5	47	42	132	Tanzania	36	18	54
13	Denmark	56	81	31	73	Venezuela	44.5	43	46	133	Nigeria	36	16	56
14	New Zealand	56	73	38	74	Macedonia, FYR	44	46	42	134	Chad	36	13	59
15	Suriname	55	52	58	75	Namibia	44	34	54	135	Congo, DR	36	7	65
16	Latvia	54	62	46	76	Togo	43.5	21	66	136	South Africa	35	43	27
17	Ireland	54	76	32	77	Congo, R	43.5	15	72	137	Azerbaijan	35	42	28
18	Australia	54	79	28	78	Bahamas	43	54	32	138	Iran	35	38	32
19	Peru	53	44	62	79	Chile	42.5	55	30	139	Myanmar	35	21	49
20	Slovenia	53	71	35	80	Trinidad & Tobago	42.5	53	32	140	Eritrea	35	10	60
21	*St Kitts & Nevis*	*53*	*52*	*53*	81	Colombia	42.5	43	42	*141*	*Bosnia & Herzegovina*	*35*	*24*	*45*
22	Lithuania	53	61	44	82	Cuba	42.5	40	45	*142*	*Maldives*	*35*	*22*	*47*
23	Cyprus	53	67	38	83	Vanuatu	42.5	35	50	143	Kenya	35	18	51
24	Japan	53	80	25	84	Malta	42	70	14	144	Rwanda	35	12	57
25	*St Lucia*	*52*	*53*	*51*	85	Israel	42	59	25	145	Sierra Leone	35	6	63
26	*Grenada*	*52*	*55*	*49*	86	Albania	42	38	46	146	Morocco	34	36	32
27	United States	52	73	31	87	Indonesia	42	36	48	147	Tajikistan	34	28	39
28	Italy	52	74	30	88	Malawi	42	22	62	148	Guatemala	34	23	44
29	France	52	75	29	89	Egypt	41	39	43	149	Niger	34	11	56
30=	Czech R	52	70	33	90	El Salvador	41	36	46	150	Mexico	33	45	21
30=	Greece	52	70	33	91	Central African R	41	16	66	151	Jordan	33	38	28
32	Portugal	52	72	31	92	Brazil	40.5	45	36	152	Uzbekistan	33	36	30
33	United Kingdom	52	73	30	93	Paraguay	40.5	35	46	*153*	*Korea, DPR*	*33*	*21*	*45*
34	Belgium	52	80	23	94	Lesotho	40.5	24	57	154	Yemen	33	15	51
35	Botswana	51	34	68	95	Guinea	40.5	15	66	155	Mozambique	33	11	55
36	Slovakia	51	61	40	96	Bhutan	40.5	14	67	156	Burundi	33	6	60
37	Luxembourg	51	77	24	97	Romania	40	50	30	157	Mali	33	21	44
38=	Armenia	50	45	55	98	Kyrgyzstan	40	38	42	*158*	*Somalia*	*33*	*3*	*62*
38=	Netherlands	50	78	22	99	Malaysia	39.5	46	33	*159*	*Qatar*	*32*	*40*	*24*
40	*Seychelles*	*50*	*50*	*49*	100	Yugoslavia	39.5	42	37	160	China	32	36	28
41	Ecuador	50	43	56	101	Cameroon	39.5	15	64	161	Comoros	32	20	44
42	Mongolia	50	39	60	102	Guinea-Bissau	39.5	13	66	*162*	*Bahrain*	*32*	*46*	*17*
43	Singapore	49	66	32	103	Honduras	39	33	45	*163*	*São Tomé & Principe*	*32*	*10*	*53*
44	Hungary	49	65	33	104	Swaziland	39	24	54	164	Libyan Arab J	31	38	24
45	Mauritius	49	54	44	105	Zimbabwe	39	23	55	165	Turkmenistan	31	32	30
46	*Solomon Is*	*49*	*37*	*61*	106	Djibouti	39	18	60	166	Haiti	31	19	43
47	Benin	49	27	71	107	Gambia	39	16	62	167	Pakistan	31	18	44
48	Costa Rica	49	56	41	108	Lao PDR	39	15	63	168	Ghana	30	22	38
49	Sri Lanka	49	40	57	109	Lebanon	38.5	40	37	169	Oman	30	31	28
50	Bolivia	49	34	63	110=	Nicaragua	38.5	28	49	170	Zambia	30	16	43
51	Estonia	48	62	34	110=	Viet Nam	38.5	28	49	171	Sudan	30	13	46
52	Fiji	48	50	46	112=	Cambodia	38.5	20	57	172	India	29	31	27
53	Belarus	48	46	50	112=	Côte d'Ivoire	38.5	20	57	173	United Arab Emirates	29	41	16
54	Poland	48	65	30	114	Equatorial Guinea	38.5	15	62	174	Mauritania	29	17	40
55	Argentina	48	55	40	115	Ethiopia	38.5	13	64	*175*	*Tonga*	*28*	*26*	*30*
56	Dominican R	48	49	46	116=	Philippines	38	44	32	176	Saudi Arabia	27	31	23
57	*St Vincent & Gren.*	*48*	*41*	*54*	116=	Tunisia	38	44	32	177	Uganda	27	10	44
58	Korea, R	47	67	27	118	Moldova	38	41	35	*178*	*Afghanistan*	*27*	*6*	*48*
59	Barbados	47	62	32	119	Kuwait	37.5	50	25	179	Syrian Arab R	27	28	25
60	Cape Verde	47	47	47	120	Kazakhstan	37.5	43	32	180	Iraq	25	19	31

All the Nordic countries receive relatively high WI scores. In fact Sweden, Finland, Norway and Iceland take the first four positions (in this order), and Denmark is number 13 out of 180. The five countries all have among the highest HWI scores and relatively good EWI, except Denmark, which lags somewhat behind, primarily because of its dependence on fossil fuels.

The Environmental Sustainability Index

A similar construct is the Environmental Sustainability Index (ESI), an aggregate environmental sustainability measure for 146 countries (Esty et al. 2005). It has been developed by the Yale Center for Environmental Law and Policy, at Yale University and the Center for International Earth Science Information Network at Columbia University, in cooperation with the World Economic Forum and the European Commission's Joint Research Centre.

The ESI consists of 21 indicators of environmental sustainability, compiled from 76 data sets. The issues tracked are classified into five categories:

- Environmental systems (the *state* of environmental systems, such as air, soil and water)
- Reducing environmental stresses (the *pressures* on these systems, in the form of pollution or exploitation levels)
- Reducing human vulnerability to environmental stresses (the *vulnerability* of humans to changes in the state of the environment)
- Social and institutional *capacity* to tackle environmental problems
- Global stewardship (the ability to *cooperate* internationally on global or regional environmental problems)

This breakdown is somewhat more elaborate than that of the EWI in terms of the environment. Economic and social issues are mostly excluded from the ESI, as the name suggests. ESI is not based on any specific theoretical definition of sustainability. Esty et al. (2005, page 12) rightly claim that “the cumulative picture created by these five components does not in any authoritative way define sustainability but, instead, represents a comprehensive gauge of a country’s present environmental quality and capacity to maintain or enhance conditions in the year ahead.”

The overall EWI index is calculated as unweighted means of the individual indicators. The score and ranking for the 146 countries included in the latest version of the ESI are displayed in Table 2. The scores are only to be interpreted as relative measures, and no explicit threshold for achieving sustainability is defined. Nevertheless, the ESI report for 2005 makes the claim that it is unlikely that any country deserves to be labeled as sustainable.

Four Nordic countries, Finland, Norway, Sweden and Iceland, are among the top five countries in the ESI ranking. Denmark, however, is in 26th place, drawn down by bad performance on the indicators for land use and reduction of ecosystem stress.

Table 2: The Environmental Sustainability Index, ranking of 146 countries (source: Esty et al. 2005)

Rank	Country	ESI	Rank	Country	ESI	Rank	Country	ESI
1	Finland	75.1	50	Cameroon	52.5	99	Azerbaijan	45.4
2	Norway	73.4	51	Ecuador	52.4	100	Kenya	45.3
3	Uruguay	71.8	52	Laos	52.4	101	India	45.2
4	Sweden	71.7	53	Cuba	52.3	102	Poland	45
5	Iceland	70.8	54	Hungary	52	103	Niger	45
6	Canada	64.4	55	Tunisia	51.8	104	Chad	45
7	Switzerland	63.7	56	Georgia	51.5	105	Morocco	44.8
8	Guyana	62.9	57	Uganda	51.3	106	Rwanda	44.8
9	Argentina	62.7	58	Moldova	51.2	107	Mozambique	44.8
10	Austria	62.7	59	Senegal	51.1	108	Ukraine	44.7
11	Brazil	62.2	60	Zambia	51.1	109	Jamaica	44.7
12	Gabon	61.7	61	Bosnia & Herze.	51	110	United Arab Em.	44.6
13	Australia	61	62	Israel	50.9	111	Togo	44.5
14	New Zealand	60.9	63	Tanzania	50.3	112	Belgium	44.4
15	Latvia	60.4	64	Madagascar	50.2	113	Dem. Rep. Congo	44.1
16	Peru	60.4	65	United Kingdom	50.2	114	Bangladesh	44.1
17	Paraguay	59.7	66	Nicaragua	50.2	115	Egypt	44
18	Costa Rica	59.6	67	Greece	50.1	116	Guatemala	44
19	Croatia	59.5	68	Cambodia	50.1	117	Syria	43.8
20	Bolivia	59.5	69	Italy	50.1	118	El Salvador	43.8
21	Ireland	59.2	70	Bulgaria	50	119	Dominican Rep.	43.7
22	Lithuania	58.9	71	Mongolia	50	120	Sierra Leone	43.4
23	Colombia	58.9	72	Gambia	50	121	Liberia	43.4
24	Albania	58.8	73	Thailand	49.7	122	South Korea	43
25	Central Arf. Rep.	58.7	74	Malawi	49.3	123	Angola	42.9
26	Denmark	58.2	75	Indonesia	48.8	124	Mauritania	42.6
27	Estonia	58.2	76	Spain	48.8	125	Philippines	42.3
28	Panama	57.7	77	Guinea-Bissau	48.6	126	Libya	42.3
29	Slovenia	57.5	78	Kazakhstan	48.6	127	Viet Nam	42.3
30	Japan	57.3	79	Sri Lanka	48.5	128	Zimbabwe	41.2
31	Germany	56.9	80	Kyrgyzstan	48.4	129	Lebanon	40.5
32	Namibia	56.7	81	Guinea	48.1	130	Burundi	40
33	Russia	56.1	82	Venezuela	48.1	131	Pakistan	39.9
34	Botswana	55.9	83	Oman	47.9	132	Iran	39.8
35	P. N. Guinea	55.2	84	Jordan	47.8	133	China	38.6
36	France	55.2	85	Nepal	47.7	134	Tajikistan	38.6
37	Portugal	54.2	86	Benin	47.5	135	Ethiopia	37.9
38	Malaysia	54	87	Honduras	47.4	136	Saudi Arabia	37.8
39	Congo	53.8	88	Côte d'Ivoire	47.3	137	Yemen	37.3
40	Netherlands	53.7	89	Serbia & Monteneg.	47.3	138	Kuwait	36.6
41	Mali	53.7	90	Macedonia	47.2	139	Trinidad & Tobago	36.3
42	Chile	53.6	91	Turkey	46.6	140	Sudan	35.9
43	Bhutan	53.5	92	Czech Rep.	46.6	141	Haiti	34.8
44	Armenia	53.2	93	South Africa	46.2	142	Uzbekistan	34.4
45	United States	52.9	94	Romania	46.2	143	Iraq	33.6
46	Myanmar	52.8	95	Mexico	46.2	144	Turkmenistan	33.1
47	Belarus	52.8	96	Algeria	46	145	Taiwan	32.7
48	Slovakia	52.8	97	Burkina Faso	45.7	146	North Korea	29.2
49	Ghana	52.8	98	Nigeria	45.4			

Visual models

The Consultative Group on Sustainable Development Indicators (CGSDI) has also developed indicators spanning the environmental, social and economic spectra of development. The CGSI collection is based on a broad definition of sustainable development and therefore includes a large number of indicators. Rather than organizing and aggregating the indicators as in the previous two examples, the CGESDI are now available in the form of visual models of highly aggregated sustainable development indices. These are the four-sided pyramid, the elliptical indicator cluster, the compass of sustainability and dashboard of sustainability.

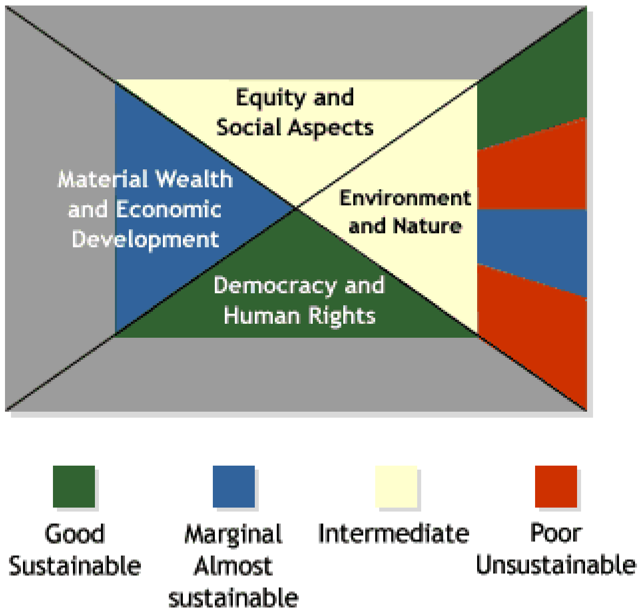

Figure 4: Example of the four-sided pyramid (Source: www.iisd.org)

The four-sided pyramid is a color-coded graphical representation of the state of sustainable development in a given region. The four sides of the pyramid represent in turn: Equity and Social Aspects, Environment and Nature, Democracy and Human Rights, and Material Wealth and Economic Development. Each of these four aspects of development is then further broken down into four representative indices as shown in Figure 4. The values of these indices are represented by four colors, ranging from red (worst), to white, then blue and finally green (best).

A slightly more advanced graphical representation, originally developed by members of the Balaton Group[11] and later improved upon by members of CGSDI, is the Compass of Sustainability.[12] This representa-

[11] http://www.unh.edu/ipssr/Balaton.html

[12] This methodology has been commercialized by AtKisson, Inc. who hold the copyright to the Compass Index of Sustainability.

tion is also based on pooling indicators into four aggregates, in this case into Human, Natural, Economic and Social factors, along with an overall sustainable development index (SDI). The representation is not restricted to color, but the index values are shown as well as graphs, showing development over time (as shown in Figure 5).

Last but not least is the Dashboard of Sustainability,[13] a more dynamic and interactive method of visualizing the state and development of sustainability all over the world, using modern internet technology. It is still based on an arbitrary aggregation method or clustering but allows the user to custom-make his own view, bringing forward particular indicators that are of value to him. It allows a casual comparison of the state of particular indicators in different countries and their relative policy performance shows distributions of indicators across any subset of countries and facilitates simple analysis of linkages between indicators.

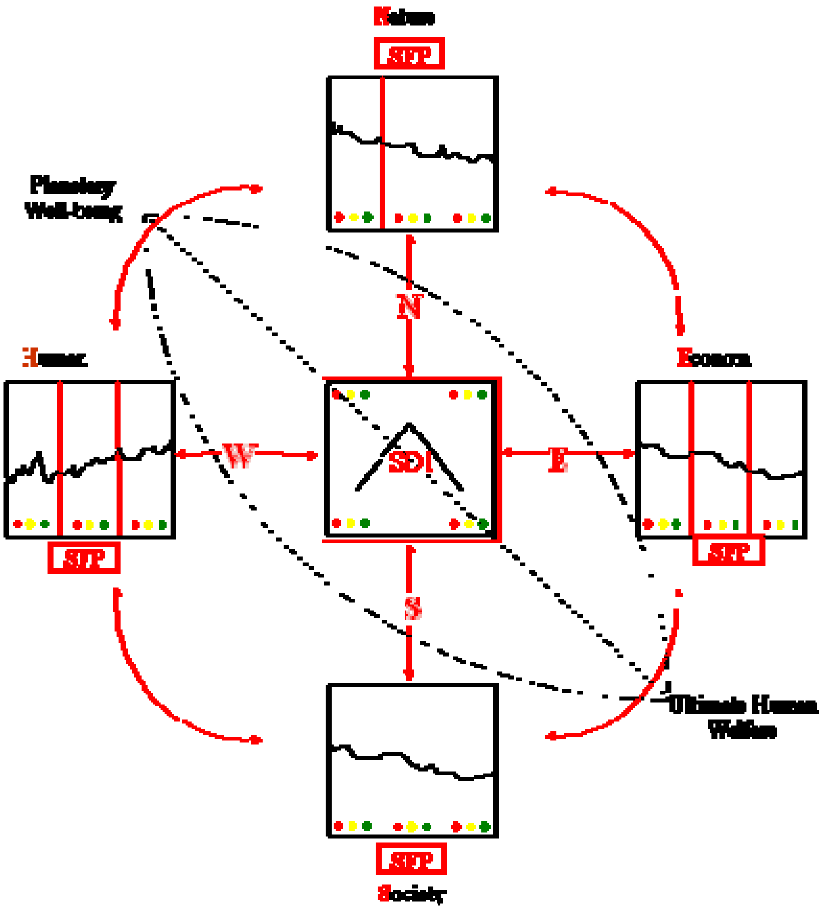

Figure 5: Example of the Compass of Sustainability (Source: http://www.iisd.org)

[13] http://www.iisd.org/cgsdi/dashboard.asp

3.6 Evaluation of sustainability indicators

So far we have discussed three types of global sustainability indicators. The first two, represented by the genuine savings and the ecological footprint, are directly linked to economic theory, on the one hand, and ecological science, on the other. Neither is universally accepted, but both are considered to have significant potential for further development. Aside from chronic measurement problems, which all indicator projects share, the main shortcoming of the genuine savings indicator lies in the inherent difficulties of assigning monetary value to natural assets. The ecological footprint indicator, which focuses on the sustainability of the planet's carrying capacity, but not sustained economic development, also has valuation problems and is often criticized for not distinguishing between the environmental impacts of different uses of land, only of how much of it is effectively used by an activity.

A similar criticism can be raised in the case of headline indicators, at least the Wellbeing Index (WI) and the Environmental Sustainability index (ESI). In both cases, the aggregate index is calculated with simple arithmetic means of standardized indices. To what extent individual environmental issues are represented is more complicated, however. Take, for instance, the role of global warming in the ESI indicator. The ESI weights the indices chosen equally, which cannot be representative of the importance of the underlying issues.[14]

The ESI has been heavily criticized (e.g., by Jha and Murthy (2003)) for arbitrary selection of indicators and lack of a clear relationship with a properly defined notion of sustainability. Incidentally a large proportion of this critique is equally applicable to other indicator initiatives. Most other indicator projects are not related clearly to a theoretically sound definition of sustainability even though the selection of indices to include is in all cases based, in part, on an accumulated base of theory and statistical practice.

[14] See Esty et al. (2005), Appendix H, for a brief overview of criticism of ESI and counterarguments.

4. Measuring decoupling

Sustainability indicators have developed fast in recent years, even though there still seems a long way to go before a reasonable estimate of global or regional sustainability sees the light. The existing indicators are not particularly reliable as aggregate measures of sustainability but can give good indications of how well individual countries are doing with respect to decoupling their economic development from environmental constraints. But for that purpose it is probably still better to use *de-coupling indicators*.

4.1 Decoupling indicators

Decoupling indicators (OECD 2002), unlike many other statistical efforts related to the environment, are not meant to be all-inclusive or to summarize the general state of the environment like the Wellbeing Index or the Environmental Sustainability Index. Their purpose is rather to measure countries' progress towards mitigating or alleviating particular environmental pressures from the relevant driving forces. This is done by measuring the ratio of proportional change (growth) in two variables at a time, one driving force variable and one pressure variable.

When growth in the driving force variable is faster than that of the pressure variable, it is referred to as *relative* decoupling. Only when the pressure variable is non-increasing can we talk about *absolute* decoupling. Such indicators have recently been integrated into the second round of the OECD peer reviews on environmental performance.[15]

A decoupling indicator, as a measure of decoupling, can be expressed as the ratio of relative change in a particular pressure variable and relative change in a relevant economic driving force variable, e.g., for the time period t_0 to t_1,

$$DR_{t_0,t_1} = \frac{EP_{t_1} / EP_{t_0}}{DF_{t_1} / DF_{t_0}} \qquad (4)$$

where DR_{t_0,t_1} stands for decoupling ratio, EP_t an environmental pressure variable level at time t and DF_t an economic driving-force variable level at time t. The choice of a relevant economic variable is always a judgment call and depends on the context. In many cases there is no single,

[15] The most recent reports are on the Netherlands and Poland.

best choice of a driving-force variable, in which case a few alternatives should be presented simultaneously.

To be able to represent "positive" outcomes with positive index values, a popular expression for the state of decoupling is the *decoupling factor*, which is simply one minus the decoupling ratio:

$$D_{t_0,t_1} = 1 - DR_{t_0,t_1} . \qquad (5)$$

It can be difficult to measure dynamic concepts like decoupling with a single measure. Complementing such indices by graphs comparing an environmental pressure variable and an economic driving force variable, as is done extensively in OECD (2002), is hardly satisfactory either. Several other problems associated with decoupling indicators should also be mentioned, some of which are carefully noted in OECD (2002).

First, in many cases, it is the absolute level of a particular pressure variable that is more important than its relation to GDP or some other measure of a driving force. After all, international treaties, such as the Kyoto Protocol on climate control and the Gothenburg Declaration on transboundary air pollution, aim at fixing absolute targets.

Second, decoupling indicators are less suitable for monitoring the use of renewable resources, such as fish stocks and forests, as they focus on environmental pressure (usually flow) variables but not the state of the respective environmental good. Emphasis on fish catch or lumber production rather than expected biomass or emissions instead of GHG concentration, can be misleading, as an increase in utilization is not necessarily unsustainable.

Third, they are not very useful when considering international cooperation. Joint implementation in reducing GHG emissions can, for instance, be considered as an adverse development for the country on the long side of such contracts, when the overall effect is quite positive. GHG leakage (export of emitting production rather than actual reduction in emissions) is also likely to be undetected by such indicators. Due to the complex relationships between the economy and the environment, one must be cautious when using such indicators for cross-country comparison. Caution is also advised when choosing the time horizon for such indices.

Fourth, decoupling indicators are of little use when complicated relationships between driving-force variables and environmental pressures are considered. A particular driving force can affect several different pressures simultaneously, and any given pressure can be affected by many driving forces simultaneously.

That being said, there is still a good case for the use of decoupling indicators as a valuable tool in environmental and economic policy – but not as a basis for choice of policy instruments and not as a measure of sustainability per se. The potential of decoupling indicators is for the purpose of assessing how successful individual countries are at reducing pressures on the environment. In that respect, decoupling indicators are potentially superior to headline indicators since they more directly measure whether environmental policies are adequate to deal with the problem on aggregate.

However, the potential is now, realized as development of sets of decoupling indicators are not as advanced as, for instance, the ESI framework, but that may change in the near future.

Examples of the OECD's (2002) decoupling indicators are shown in Figures 6 and 7. The first figure displays the environmental pressure of greenhouse gas emissions together with two typical driving force variables: GDP and population. The main figure displays the outcome for all OECD countries (except a few because of missing data) as well as separately for three OECD regions. From 1990 to 1999 emissions increased by about 4%, while, at the same time, GDP rose by 23%. On the whole this constitutes considerable decoupling of the weak form. Decoupling from population growth was not as profound in terms of population, and no decoupling occurred in many member states.

Figure 7 displays the decoupling factors, as defined by (5) for the period 1990 to 1999. With respect to GDP, all the OECD countries included showed relative decoupling, while six countries showed absolute decoupling (Czech Republic, Germany, Hungary, Poland, Slovak Republic and the United Kingdom). With respect to population growth, about half of the countries showed weak decoupling and the rest no decoupling at all.

Of the 12 key decoupling indicators originally published by the OECD (2002) under the rubrics of: climate change, air pollution, water quality, waste management and material use, the five Nordic countries achieved relative decoupling in the period 1990–1998. The main exceptions are Denmark, Iceland and Norway's absence of decoupling greenhouse gas emissions from population growth.[16] All the Nordic countries, as well as the OECD-Europe as a whole, achieved absolute decoupling of SOx in relation to GDP growth since 1980 and beyond. In addition, absolute decoupling has occurred in Iceland in terms of the discharge of nitrogen and phosphorus in relation to population growth.

[16] Weak decoupling is achieved, however, when GDP is considered to be the driving force.

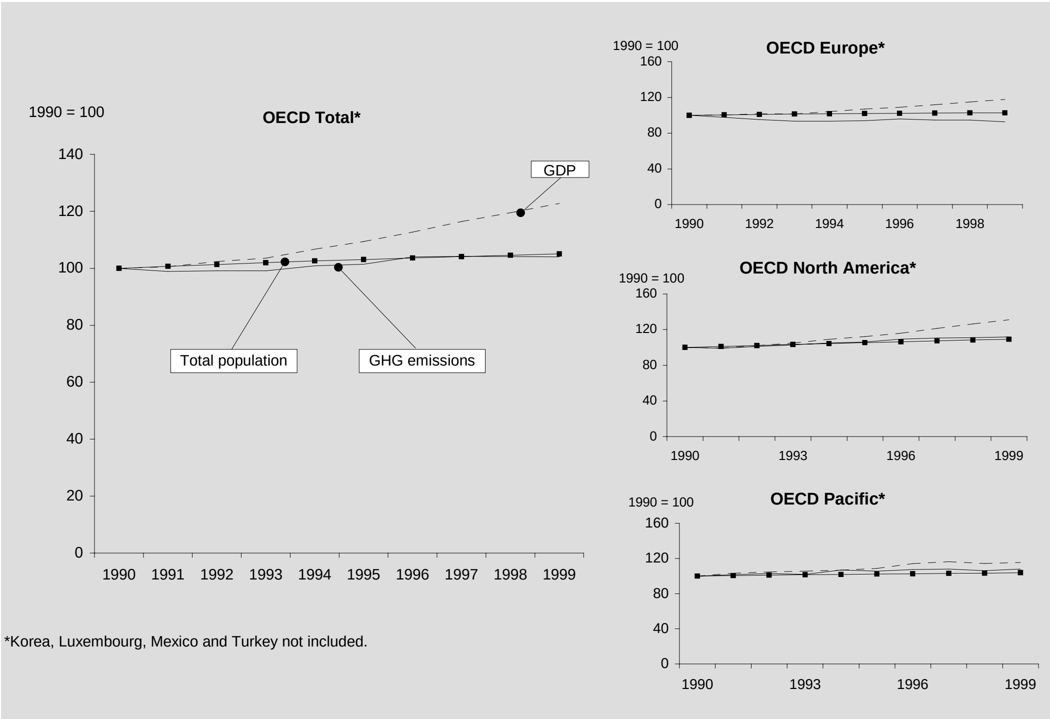

Figure 6: Total GHG emissions per unit of GDP and per capita (source OECD 2002)

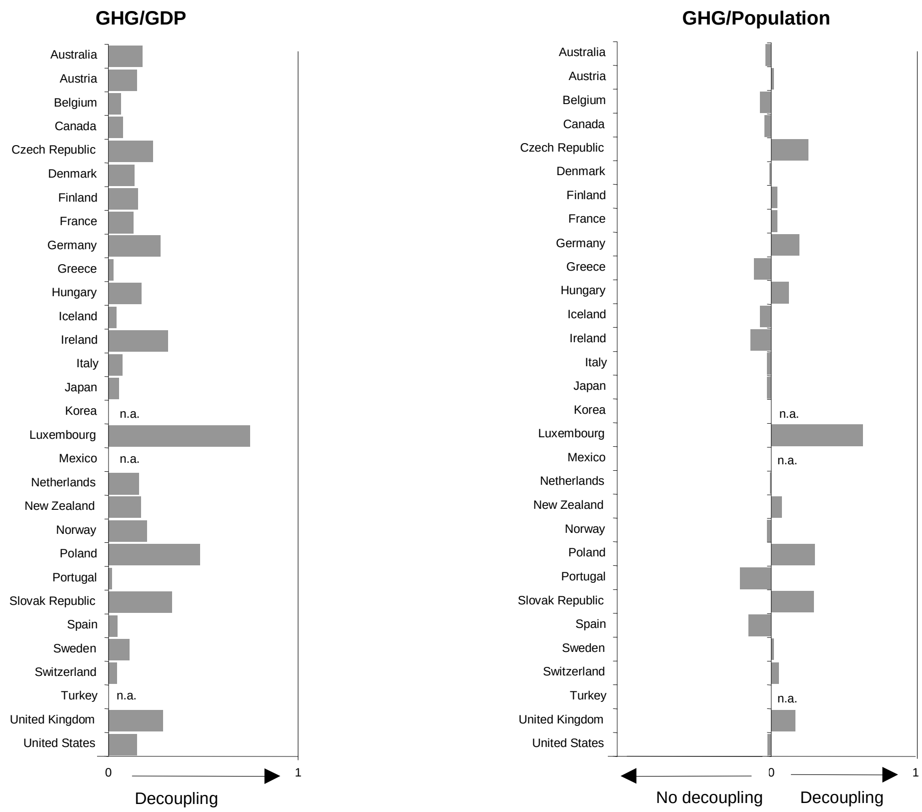

Figure 7: Decoupling factors for total GHG emissions with respect to GDP and populati-on (Source: OECD 2002)

4.2 A modified decoupling indicator

Decoupling indicators as well as sustainability indicators have been criticized for oversimplifying the causal relationship between driving forces and environmental pressures. In this section we start out by showing how a decoupling indicator is equivalent to a two-variable regression model with only two observations, which, by definition, gives perfect fit. Consider for instance the following simple regression in log-linear form:

$$p_t = \alpha + \beta d_t + \varepsilon_t \tag{6}$$

where p_t is the natural logarithm of an arbitrary environmental pressure variable, d_t is the natural logarithm of a related driving force, ε_t is a zero mean residual, and a and b are parameters. Taking the first order difference of (6) yields:

$$p_t - p_{t-1} = \beta\left(d_t - d_{t-1}\right) + \eta_t \tag{7}$$

or more conveniently put:

$$\dot{p}_t = \beta \dot{d}_t + \eta_t \tag{8}$$

where $\dot{p}_t$ is a the first order difference of the natural logarithm of p_t and p_{t-1}, a close approximation of the percentage change in p from $t-1$ to t, and $\eta_t = \varepsilon_t - \varepsilon_{t-1}$ is also a zero mean residual variable. Now assume that we only have two observations, which means that, in difference form, we have a single observation. It then follows trivially that the ordinary least squares (OLS) estimator for b is

$$\hat{\beta} = \frac{\dot{p}_t}{\dot{d}_t}. \tag{9}$$

But as long as the denominator is positive, that is, the driving-force variable is increasing (a standard prerequisite when calculating decoupling ratios), this is a monotonic transformation of the decoupling ratio defined in (4). Ignoring the logarithmic approximation, the only difference is that gross percentage changes are used in (4), while net percentage changes are used in (9). A modified decoupling factor based on

$$D'_{t_0,t_1} = 1 - \hat{\beta} \tag{10}$$

therefore shares the fundamental property of the originally defined decoupling factor (5), namely, that it is negative when no decoupling takes place and positive when decoupling takes place. Interestingly, the modified measure has an additional property that is particularly appealing. It exceeds unity if and only if absolute (or strong) decoupling takes place. When the decoupling is only relative (or weak) the decoupling factor takes a value between zero and one.

As a result, it is easier to identify which countries in an international comparison have achieved absolute decoupling, and which have only attained relative decoupling in a particular period. This distinction is not so easily spotted in the original definition.

4.3 Finding the source of decoupling

The claim that decoupling indicators, while valuable as system performance indicators, are not particularly useful when analyzing detailed policy questions deserves more concise argumentation.

The argument is best made with an illustration. Figure 8 gives a scatter plot of CO_2 emissions from fuel combustion in Sweden from 1960 to 2000 in relation to GDP. Both variables are transformed to the logarithic form, so that we can interpret any fitted slope in the figure as a modified decoupling indicator as defined in (9), which then could be transformed into a decoupling factor by (10). The immediate observation is that the choice of starting- and endpoints is crucial for the outcome. A decoupling factor calculated for the first 20 years would be negative, suggesting no decoupling. For the last 20 years, absolute decoupling is apparent, while for the whole 40 years only relative decoupling is realized (as the slope is smaller than one).[17]

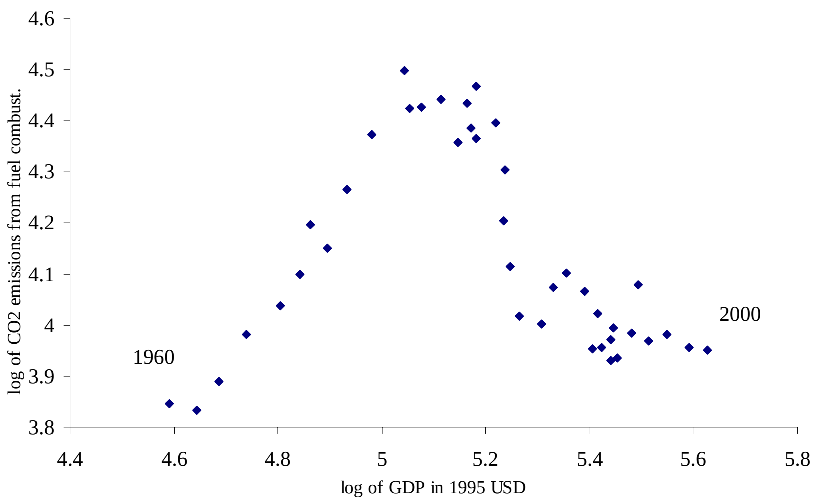

Figure 8: CO_2 emissions from fuel combustion in Sweden, 1960–1990 (Source: IEA)

[17] The fitted lines are not displayed in the figure to avoid clutter. It should not be difficult to imagine trend lines as described in the text.

This raises the question, why restrict analysis to a model with so few variables as a more detailed econometric model could potentially perform better? The estimate for b – the elasticity of a environmental pressure variable with respect to a particular driving force – might be more stable over time if other exogenous factors were taken into account as well. In the current example it is tempting to estimate a third-order polynomial in the driving force variable, instead of a linear function, effectively transforming the indicator into a typical environmental Kuznets curve (Grossman and Krueger 1995). But such a regression would be seriously misspecified, ignoring the significant technological shift in energy generation in Sweden that occurred in the period between 1972 and 1985.[18,19]

While such historically significant technological shifts are hard to overlook in the case of Sweden, it is not reasonable to assume that all variables of this kind, in hundreds of countries around the globe, could be sufficiently well identified by a single team of researchers.

It can be shown that (see OECD 2002, page 8) that decoupling indicators can be extended to allow for decomposition of driving forces and thereby separate the net driving force into various components, namely:

1. Scale effects, due to reduction in overall economic activity
2. Technological effects, due to shifts in application of technologies
3. Composition effects, due to changes in the relative share of particular industries in GDP
4. Substitution effects, as relative prices affect consumption patterns

Applying such decomposition on key environmental pressures, such as emissions of carbon dioxide, is likely to be more illustrative of the decoupling progress than a Kuznets curve regression, at least judging by the example taken here.

4.4 Linking indicators with economic models

Decoupling indicators are primarily attractive for their simplicity. For detailed policy analysis in which sustainability is the objective, other methods are needed. While headline indicators and decoupling indicators can be helpful in measuring the overall situation and short-term trends with respect to sustainability, the best tool for serious analysis of alternative policy options is the integration of environmental indicators into systems of national accounts, such as the National Accounting Matrix

[18] Namely, the installment of 11 nuclear power reactors.

[19] The most important difficulty with the environmental Kuznets curve, as Pearson (1994), Ekins (1997), Moomaw and Uruh (1997) and Chua (1999) have argued, is that the hypothesis relates emissions of pollutants only to per capita income, leaving no role for policy independent of income. The contribution of technical progress and substitution from relatively high-emitting activities is thus ignored.

extended with Environmental Accounts (NAMEA) approach (Haan and Keuning 1996). On the basis of a consistent accounting system of both economic and biophysical variables, various modeling exercises are made much easier.

The question of decoupling is, in essence, a dynamic and multi-dimensional one, calling for policy analysis through dynamic simulations rather than comparative statistics (Anderson and Cavendish 2001).

High standards in policy making call for high standards in statistics as well as modeling. Comprehensive models that take into account causal relations between relevant environmental indicators and economic variables are the primary vehicles for such analysis. Various types of models have been considered for this purpose; they can be broadly divided into two categories: general-equilibrium models, primarily designed for policy analysis, based on alternative long-term equilibria, and macroeconomic models, which have mainly forecasting purposes. See the appendix for further discussion on this issue and suggestions for further research.

Another promising use of large-scale models together with integrated economic and environmental datasets is using an optimal (economic) growth model to derive optimal extraction paths for a critical exhaustible natural resource (for instance suggested by Stiglitz 1974). As long as a reasonably good estimate can be found in each case, the true rate of extraction in relation to the theoretically optimal one is perhaps the best measure of whether the use of that resource contributes to overall sustainability or weak sustainability. Alternatively dynamic models can be used to simulate sustainable growth paths and the associated *Sustainable National Income* (SNI) (de Boer and Hueting 2004).

5. Conclusions

It is disappointing how weak the ability to measure sustainability remains, despite continuing efforts for more than a decade. The reason is partly the lack of reliable measures for tracking progress and monitoring implemented policy, but the primary reasons are measurement problems, difficulties with valuing heterogeneous assets and the substitutability between natural capital and man-made capital.

Given these problems, it is very unlikely that a single indicator could replace GDP as a proxy for overall national wellbeing, even if such an indicator could have any real functional value as a policy tool. Attempts to create systematic sets of indicators, both internationally and at the national level, are nevertheless far from being useless. Various sets of indicators have managed to raise awareness of the still elusive concept of sustainable development and brought attention to important gaps in current measurement of environmental pressures and the state of nature.

The main purpose of sustainability indicators is to make the concept of environmental sustainability more applicable, by linking them with real-world data. Using an analogy from navigation, a perfect set of indicators should tell us (Hardi and Zdan 1997):

1) where we are
2) where we are heading (current direction)
3) what to expect about the future
4) where we should be going

The first two objectives seem feasible, based on the speedy development of current indicator assessment methods. Even though the level and method of abstraction and aggregation will always be open for debate. However, expecting sets of indicators to tell us what is around the bend is clearly more farfetched and unlikely to materialize in the near future.

Policy analysis needs a different set of indicators, where simplicity and clarity in the form of aggregation should be sacrificed. Even within a relatively homogenous group of nations like the Nordic countries, significant differences in the composition of environmental pressures are evident. Hence, each country may need to develop its own policy analysis strategy, to seek out which environmental indicators are closely related to economic activity and bridge the gap between environmental statistics and economic policy modeling.

Integration of environmental indicators into systems of standard indicators of economic performance, such as simultaneous efforts to reduce pollution and employment subsidies in the very same industries, is also likely to reduce the risk of inconsistent policies. The likely benefits of current efforts in creating sustainability and decoupling indicators are exactly these, to improve the quality and consistency of policy making.

Tracking the state of the environment and its relation to economic activity is an important project, but it is terribly difficult. Decoupling indicators, together with other methods discussed above, are valuable in the analysis of the present state of decoupling and past trends. Even much criticized aggregate sustainability indicators may well prove to be valuable reference points. Still, even if successfully compiled, aggregate indicators are no replacement for detailed integrated models of alternative policy instruments.

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Sammanfattning

Ekonomisk tillväxt och miljöförhållanden är nära kopplade till varandra och måste betraktas som sammankopplade. Forsatt ekonomisk tillväxt är inte alls någon självklar följd av laissez-faire marknadsekonomiska lösningar. Marknadsaktör behöver speciella incitament och måste hålla sig till regler så att vi kan behålla kvaliteten i våra naturresurser som anses vara nödvändiga för fortsatt ekonomisk tillväxt.

Det finns tusental av åtskilliga definitioner av hållbarhet, hållbar utveckling och relaterade begrepp. Dessutom finns det ett antal tillvägagångssätt eller ramverk som har föreslagits för att kunna mäta och utvärdera framsteg mot hållbar utveckling.

Man skiljer ofta mellan *svag* och *stark* hållbarhet. Skillnaden avgörs inte av definitionen av vad hållbarhet är, snarare i om hållbarheten är eftersträvansvärd elle ej. Den skiljande faktorn är om man kan skilja mellan naturkapital och fysiskt kapital. Svag hållbarhet uppnås om det samlade kapitalet (inklusive både fysiskt kapital och naturkapital) inte minskar, medan stark hållbarhet kräver icke minskande naturkapital. Ekonomer brukar definiera hållbarhet i termer av icke minskande samlad konsumption över tid eller icke minskande produktivitet av samlad kapital över tid. Därmed fokuserar man på svag hållbarhet. Ekologer tenderar att tala för stark hållbarhet eller resiliens som den önskvärda politiken. Ett ekosystem betraktas som resilient om det står sig mot exogena störningar, således att det behåller sin grundkvalitet trots betydande störningar. På grund av brist på teoretisk konsensus har mer pragmatiska tillvägagångssätt, som t ex *Driving force – Pressure – State – Impact – Response* modellen (DPSIR) använts när man har format mätinstrument för hållbarhet. Ingen av hållbarhetsindikatorerna som behandlas här är accepterade universellt, men många av dem har betydande potential för vidare utveckling. Förutom återkommande mätproblem, som alla indikatorsprojekt har gemensamt, ligger "genuine savings" metodens huvudbrister i svårigheterna med att tillämpa monitärt värde på naturtillgångar. Ecological footprint indikatorn har också mätproblem och utsätts ofta för kritik för att inte skilja mellan miljökonsekvenser av olik markanvändning och hur stor andel av den är effektivt använt för aktiviteter. Liknande kritik kan också riktas mot huvudindikatorerna, som t ex "Wellbeing Index" och "Environmental Sustainability Index".

Avkoppling betyder i stort sätt att avkoppla länken mellan negative miljö effekter och positiv ekonomisk utväckling'". Avkopplig skulle man inte betrakta som uppskattning av hållbarhet. Även om det ofta förmår att ge en någorlunda bra mätning av potentialet för framsteg mot

hållbarhet, är det varken tillräcklig eller nödvändig förutsättning för hållbarhet.

Avkoppling indikatorer, olikt annan miljöstatistisk, är inte avsedda att vara heltäckande eller att summera eller inkludera den generella miljösituationen. Deras syfte är snarare att mäta länders framsteg i att lindra tryck på miljön från relevanta pådrivare. Det kan ändå vara svårt att mäta dynamiska begrepp som att t ex avkoppling med en enstaka mätning. Den absoluta nivån av en viss tryck variabel är ofta viktigare än sambandet med BNP eller andra indikatorer av pådrivare. Avkoppling indikatorer är inte användbara när det gäller förnybara resurser och är problematiska att förklara med tanke på internationellt samarbete. Det kan ändå sägas att det finns god anledning till att använda avkoppling indikatorer som värdefullt verktyg i miljöpolitik och ekonomisk politik – men inte som grund för val av policyåtgärder och inte som indikator på hållbarhet per se.

Avkoppling indicators är primärt attraktiva på grund av deras klarhet. För en detaljerad policy analys där hållbarhet är kärnan, är andra metoder nödvändiga.

6. Appendix – Assessing decoupling potential, using economic models with structural environmental links – the case of the Nordic Countries

A1. Introduction

Various indicators of sustainability, and the more narrowly defined concept of decoupling, can give policymakers a rough indication of the development of respective environmental problems in relation to basic underlying factors. As such, they can be valuable when prioritizing resources for further analysis but should have limited weight when it comes to actual decision making.[20]

The success or failure of attempts to decouple environmental pressure from economic growth should not be analyzed on the basis of decoupling indicators (or sustainability indicators) alone. Careful and thorough analysis based on a consistent framework providing a link between state-of-the-art models of long-run economic behavior and a consistent system of environmental indicators is needed.

Such models have been developing for several decades and more rapidly in recent years due to numerous studies of the economic cost of fulfilling the targets set by the Kyoto protocol. With the development of hybrid accounts, such as the system called National Accounting Matrix including Environmental Accounts (NAMEA), the groundwork for extensive modeling of the interaction between the economy and the environment is much easier than before.[21]

A particularly useful and much applied framework is that of computable general equilibrium models (CGE), which are particularly suitable for analyzing counterfactual scenarios' equilibrium behavior in the long run. Such models have been built in all the Nordic countries and applied to environmental policy issues, in particular concerning the climate and air pollution.[22] Even though such models differ in many respects, it is still

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[20] See in more detail in Sturluson (2005) //check final reference //

[21] See Hann and Keuning (1996) for a definition of NAMEA and Hass (2004) for a description of Nordic NAMEA.

[22] See Bye et al. (2002) for an overview.

valuable to compare how they project decoupling of global warming and acidification pressures and economic growth in respective countries.

The research project suggested here involves defining scenarios where characteristic economic instruments, CO_2 taxes and marketable permits, are utilized.[23] These compatible scenarios will then be applied to five existing Nordic models and compared with the respective benchmark scenarios as well as between countries. Decoupling effects for each country are to be decomposed into

1) Scale effects, due to reduction in overall economic activity
2) Technological effects, due to shifts in the application of technologies
3) Composition effects, due to changes in the relative share of particular industries in GDP
4) Substitution effects, as relative prices affect consumption patterns

The most important indicators are to be considered in relation to conventional economic indicators, such as GDP an EV[24] are CO_2, SO_2 and NO_x emissions. All three are related as they stem from fossil fuel consumption, and policies aimed at reducing emissions of one of these gasses, CO_2 for instance, affect emissions of them all. These linkages can have important implications for the choice of policy measures .

The reason for the limited focus on global warming and air pollution stems from that fact that hybrid accounts are best developed in these areas, and economic models linked with other environmental pressures are not generally available as of yet. Clear results from this study would without doubt support further development of more complete integrated economic and environmental models for the use of policy making.

A2. Large-scale economic models with environmental links

When analyzing the potential of sustainable development or the relative economic cost of achieving specified environmental goals through different means, we are asking for a combination of two things: A material flow accounting (MFA) system and an economic model. MFA measures the use of natural resources used as inputs or otherwise reduced in association with production. An economic model can predict how the use of products and production itself is likely to change in response to changes in prices, and thereby, with the use of MFA, predict the use of various

[23] While carbon taxes are emphasized here, the distinction between such price incentives are often very similar to the effects of quantity incentives, such as in a cap-and-trade scheme.

[24] Equivalent variation, EV, is the most common welfare measure used in applied general equilibrium models. In short it measures consumers' ex ante valuation of the policy in question in monetary terms. That is, how much money they would have to receive in order to be indifferent between such a transfer and the policy change.

natural resources and pollution as a consequence of economic development. Computable general equilibrium (CGE) models are particularly suitable for this purpose.

In recent years a growing interest in the integration of MFA and CGE has been apparent. An early contribution to this trend is a form theoretical extension of a Walrasian general equilibrium model, the so-called Walras-Cassel model (Ayres and Kneese, 1969). The extension is in the form of an additional production sector that produces non-market environmental goods. The use of such models has not been noticeable except recently. The Walras-Cassel model is still an important theoretical foundation for several ambitious projects in the past 10 years. Such efforts are, in most cases, focused on particular natural resources, even though many are still quite extensive and complicated.

In this study we focus on climate change and regional air pollution, and therefore small-scale MFAs suffice. In any case, extensive and integrated MFA systems do not exist for all the Nordic countries, and global climate change is, by far, the most prominant environmental concern at present.

Numerous CGE studies have analyzed the economic impacts of global warming, predominantly the economic costs of mitigating carbon emissions through taxes or quotas. In an overwhelming majority of such studies the economic cost of achieving the Kyoto targets and similar emission targets beyond 2012 are relatively low, i.e., less than a percentage of annual GDP. The results, however, differ considerably, depending on whether the policy measure can raise revenue, which, in turn, can be used to reduce other distortionary taxes, particularly on labor. The welfare effects of a revenue neutral carbon tax policy can be divided into three components (Goulder et al. 1997, Parry et al. 1999). The first is the direct welfare effect of reduced CO_2 emissions minus the direct economic cost (deadweight loss) of the tax on consumers and firms. The second component is the revenue recycling effect created by a reduction in distortionary taxes to compensate for the increased revenue from carbon taxes. This third component, dubbed the tax interaction effect, captures the cost of lost revenue due to increased product prices.

It can be difficult, however, to compare such results between different models. Models can differ in many respects. On the one hand, differences may reflect the characteristics of each country, such as the industrial structure or the mix of energy sources, but, on the other hand, they can just as easily stem from different modeling assumptions that are not directly aligned with a balanced behavioral assessment of the country in question. See Bye et al. (2002) for more discussion about difficulties in comparing results from different models.

The five models suggested for this study are the following:

- *MSG6:* Statistics Norway, which has a long tradition of CGE analysis with its MSG model. The model is used for long-term analysis, such as structural changes in public finance, trade and environmental policies. A special version of the model has a sufficiently detailed system of environmental indicators for this project. Contact: Brita Bye, Statistics Norway.
- *ADAM/EMMA* is an extension of the original ADAM model developed and maintained by Denmark Statistics and Risö National Laboratories, which connects emissions of CO_2, SO_2 and NO_x models. Further extensions to these models allow modeling of even more detailed environmental and economic interactions. Contact: Frits Møller Andersen, Risö.
- *EV:* The Government Institute for Economic Research, VATT, in Finland, which also has high competence in CGE modeling and has recently been focusing on the integration of top-down and bottom-up approaches. An effort that should a priori yield more realistic technological effects. Contact: Juha Honkatukia, VATT.
- *EMEC:* The National Institute for Economic Research (Konjukturinstitutet, KI), in Sweden, has developed a CGE model for analysis of climate policies, which is called EMEC . Contact: Charlotte Nilsson, KI
- *VIKING:* The Institute of Economic Studies (IoES) has its own CGE model which has already been implemented for the study of fiscal instruments in climate policy. Contact: Tryggvi Herbertsson, IoES.

The concerns raised by Bye et al. (2002) apply here as well. These models differ in many respects. Two of them are full fledged dynamic models, while the rest are static. One, the Danish ADAM/EMMA, is not even a CGE model, but a macroeconomic model, with many characteristics of the CGE models. The reason we put up with this incompatibility is that two important criteria give these models an edge over other models in the respective country. These two criteria are: a) The extent of linkages with MFAs that have already been developed and tested, and b) ongoing use of these models for policy modeling. As a result, there is a slight bias towards models that are maintained by public institutions. The exception here is Iceland, with the Viking model being the only long-run model that is maintained at present.

Before going further into the difficulties of comparing these models and the task of eliciting the decoupling potential in each country, we take a brief look at each model in turn.

The Norwegian MSG model

The Norwegian MSG model has come of age and is presently available in its sixth incarnation: MSG-6. Still it is slightly inaccurate to talk about this MSG as a single model since various versions of it have been used for different purposes in recent years. For instance, there exist both static and dynamic versions of the model. No comprehensive manual exists of the complete model, but fairly good descriptions can be found in various papers with policy applications (e.g., Bye 2002, Bye and Aavitsland 2003 and Fæhn and Holmøy 2000, 2003, Holmøy and Strøm 2004).

Compared with most CGE models, its structure is highly disaggregated. It consists of 32 private production sectors, 7 government sectors and 60 consumption goods. Production technology is described with flexible production functions where labor, three types of physical capital, two types of energy, and material inputs from other sectors are the inputs. Special attention is given to transport services, due to their importance in environmental policy. The structure of the production is shown in Figure A1.

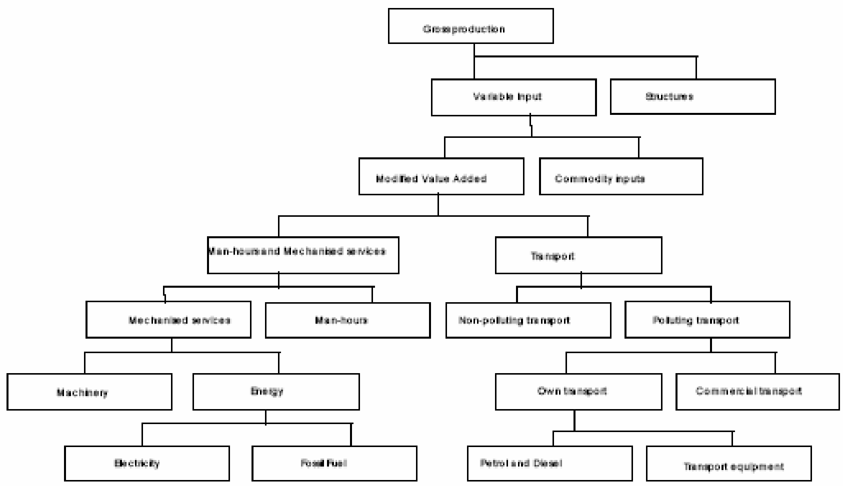

Figure A1: The structure of production in MSG-6

Each industry is modeled as a group of firms, and the market structure can differ between industries. The general rule is for firms to have decreasing returns to scale and some level of market power in the domestic market. This implies pure profits for firms and non-negligible investment costs.

MSG is a model of heterogeneous industries. Producers enjoy some market power at home, a feature supported by empirical analyses of the Norwegian economy. Producer behavior at home is therefore characterized by monopoly competition. On the world market, however, prices are fixed, suggesting that producers are confronted with free competition and act as price takers in the export markets. In each sector, real capital formation is determined in a way ensuring that the expected return on capital equals an exogenously given return on capital.

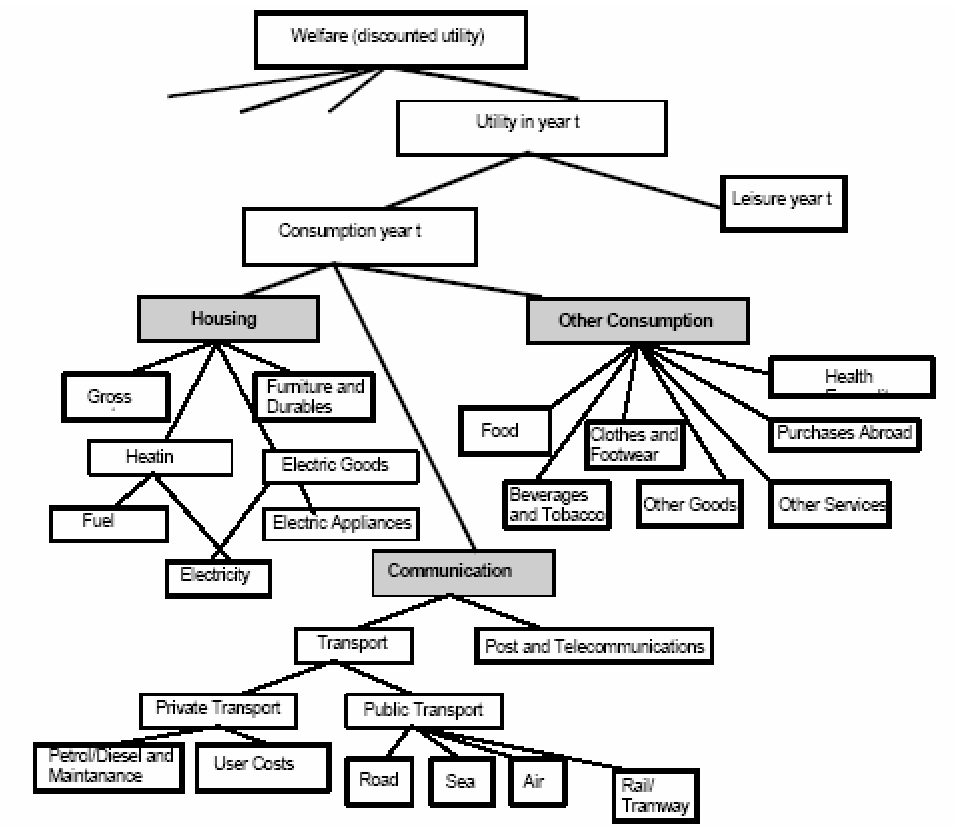

Figure A2: The structure of households' utility function in MSG-6

Consumer behavior is specified by an inter-temporal, nested CES utility function. The system produces both demand relationships and implied labor supply functions. The uncompensated wage elasticity of aggregate labor supply is set equal to 0.1. The structure of the nested utility function is shown in Figure A2.

The various parameters of the model, such as those describing development of factor productivity and substitutability between different inputs and goods, are determined on the basis of econometric analysis and calibration. The level of public goods provision is exogenously specified, while certain tax parameters are endogenously determined in order for the budget to balance.

The model is consistent with the small, open-economy paradigm, which means that prices for goods in foreign markets are assumed to be exogenous, and all agents have access to world capital markets at an exogenously determined interest rate.

A detailed emission model is incorporated in MSG, making it an effective tool for assessing the economic costs of global warming mitigating policies. Nine pollutants disaggregated by source and sector have been specified in the model.

The Finnish EV model

Representing Finland in this model comparison exercise is the EV-model: an Economic-engineering model for Finland developed at the Government Institute for Economic Research. The model departs from the other models in this survey by its combination of a traditional CGE model and an engineering model of the energy sector. It thus combines "top-down" and "bottom-up" approaches.

The structure of the model's production side is described in Figure A3. Output in a typical production sector is separable into a capital-labor-energy composite (KLE) and intermediary materials (outputs of other sectors). KLE is further made up of an energy component and a capital-labor component, and so forth.

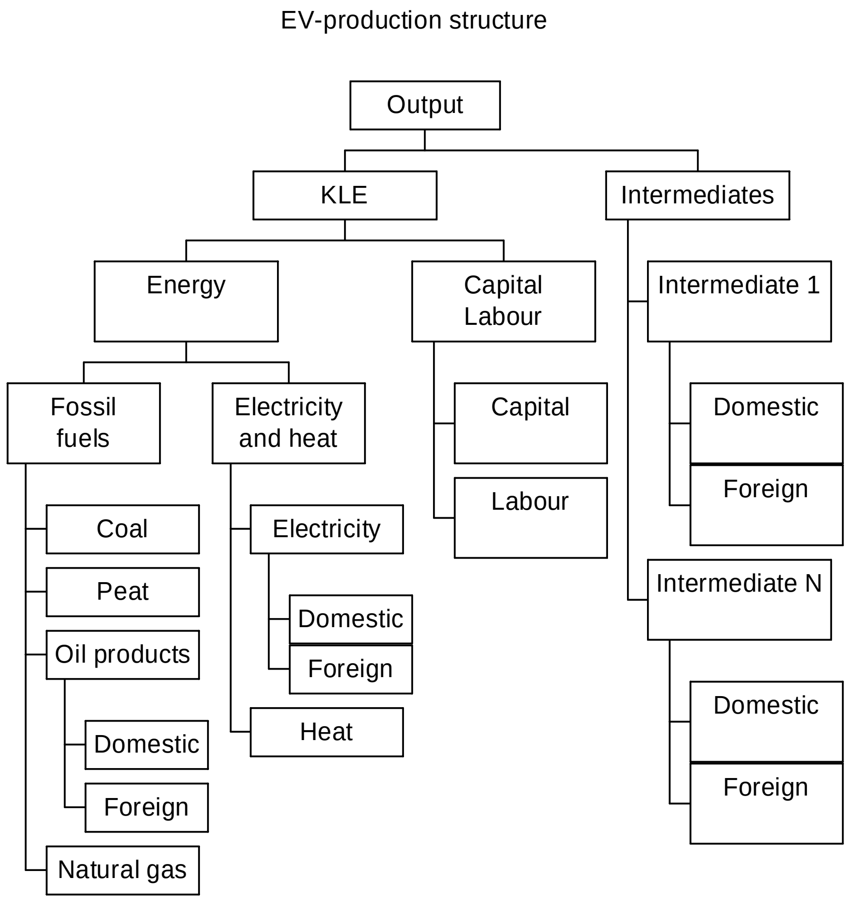

Figure A3: The EV-model's production structure

Several sectors receive special attention, based on Finland's particular industrial culture. The energy component is made up of the following fuels: wood fuels, peat, coal products, natural gas, coke, oil products (foreign and domestic), and nuclear. Fuels are used for consumption and production of other products, most importantly electricity and space heating. Several distinct processes for generating electricity and heat are defined in the model. These differ primarily in their use of fuel, but also in the way cogeneration enters the picture (combined heat and power, CHP). A total of 17 processes are considered and calibrated based on detailed engineering data

Forest industries are divided into mechanical and chemical forest industries because of how much they differ in their energy use and production processes. The mechanical forest industry is, for instance, interesting as it is fairly energy-intensive, while also providing bio-fuels as a byproduct.[25] Chemical forest industries, mainly pulp and paper, are also very energy-intensive. The energy source varies, however, depending on the product. This is reflected in the model as production of each of the major products: newsprint paper, SC-paper, LWC-paper, fine paper and other papers, are modeled separately. The selection of product mixed is determined in the model, based on cost minimization with respect to demand and the availability of domestic fuels.

The metal industry is divided into three categories: steel production, stainless steel production, and production of other metals. Steel production is further separated into two production process categories: Basic oxygen furnace steel and electric arc furnace steel, as these two processes are completely different with respect to energy use, and thereby environmental impact.

Instead of the conventional approach in CGE models to calibrate a prespecified functional form, such as the nested-CES form, the production side is solved using linear, and nonlinear programming.

The consumer’s side is based on the representative consumer approach and is highly aggregated (only one group of consumers). More heterogeneity may be added later, thus allowing for analysis of distributional effects. The functional form is the nested-CES one, with specified substitutability between consumption and leisure on the first level and consumption goods and energy goods on the second level. Farther down, substitutability between domestic and foreign consumption goods is based on the Armington assumption.

Investment goods are produced from other goods in fixed proportions (Leontieff-technologies), and depending on the application and time frame, the model can apply the ORANI-assumptions using partially fixed capital. In the case of sectors with bottom-up specifications, a capacity level determines the level of a fixed capital stock. This distinction means that bottom-up sectors can realize intramarginal profits, which are not realized in the homogenous top-down sectors.

The public sector is only modeled in detail concerning tax structure, particularly energy taxes. Neither the production of public services nor consumers' utility derived from them is considered in specifics. Thus, the

[25] The level of which is assumed to be constant in the model.

model is only intended for analysis of changes in tax policy which do not result in significant changes in the output of public services.

To close the model, a fixed trade surplus or deficit is assumed.

Model parameters are based on engineering data, input-output table calibration and exogenous estimates for elasticities of substitution. These are mostly taken from the GTAP database, but, where applicable, parameters from Finnish studies are used. It should be noted that the EV model is less prone to err on the grounds of generalizations about parameter values as most crucial modeling features specifically related to climate policies are modeled with a bottom-up approach.

The EV model is only linked with an MFA of CO_2 emissions.

The Swedish EMEC model

EMEC is a dynamic CGE model, in which long-run economic growth – the main driving force behind emissions of green house gasses – is determined by the supply of capital and labor, on the one hand, and exogenously specified technical progress, on the other. Firms maximize profits and consumers their utility from consumption and leisure and are responsive to price changes. Hence the model is capable of capturing the effects of market-based environmental policies, such as CO2 taxes and permits markets.

EMEC consists of 17 production sectors, a single government sector and 20 commodities. Production is represented by a nested CES function with capital, labor, energy and output from other sectors as inputs. Labor supply is exogenous, while agents have free access to capital in the world market at an exogenously specified interest rate. Firms can choose between three types of labor (unskilled, skilled and specialists) and six different energy sources (oil, coal, natural gas, heavy fuel oil, biofuels, electricity, and district heating). All production sectors are characterized by perfect competition and constant returns to scale.

The EMEC model has relatively extensive MFA links.

The Icelandic Viking model

The Icelandic Viking model is very similar to the Swedish EMEC model, even though it is smaller in scale. It includes 20 sectors of production, thereof four energy sectors and four transportation sectors. These goods are mapped into 9 consumption goods. CO_2 emissions are modeled as joint outputs in each sector, but other environmental indicators have not yet been implemented.

Production is defined by nested CES functions, see Figure A4. The production structure is mostly top-down in nature, with one exception. A hydrogen sector, which is inactive in the benchmark scenario, is allowed to replace gasoline and diesel oil for private and public road transport should it become competitive under alternative relative prices.

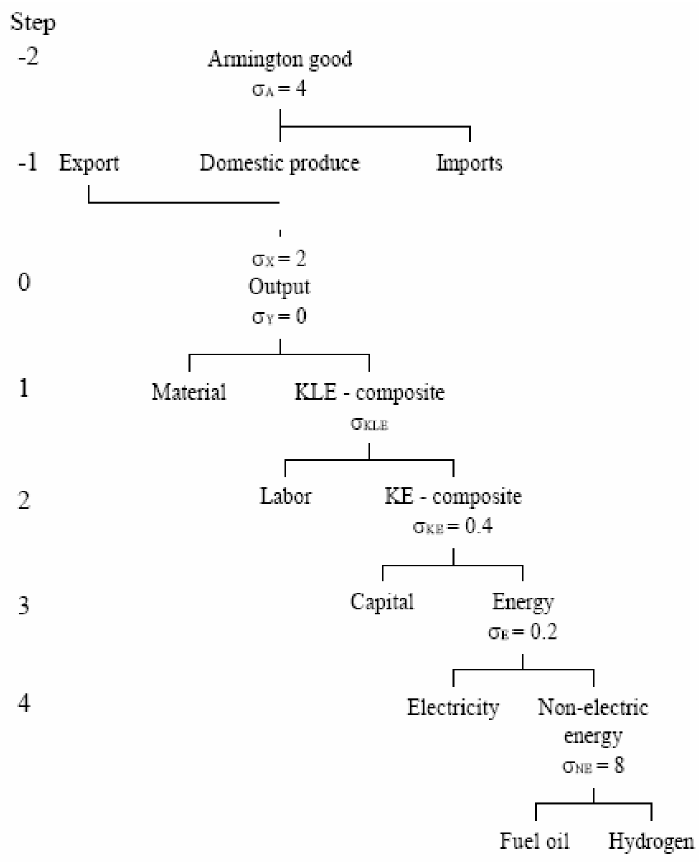

Figure A4: The Viking model's production structure

The model also differs from the Swedish and Norwegian models in that capital markets are not assumed to be completely open, and capital is sector-specific to a certain degree (depending on the time frame).

The structure on the consumer side is described in Figure 5. What is important is that demand for savings is determined at the top level, and labor supply on the second level. The elasticity of substitution between leisure and consumption is chosen so that the uncompensated wage elasticity of labor supply is 0.1. See Hall et al. (1998) and Sturluson (1999) for details.

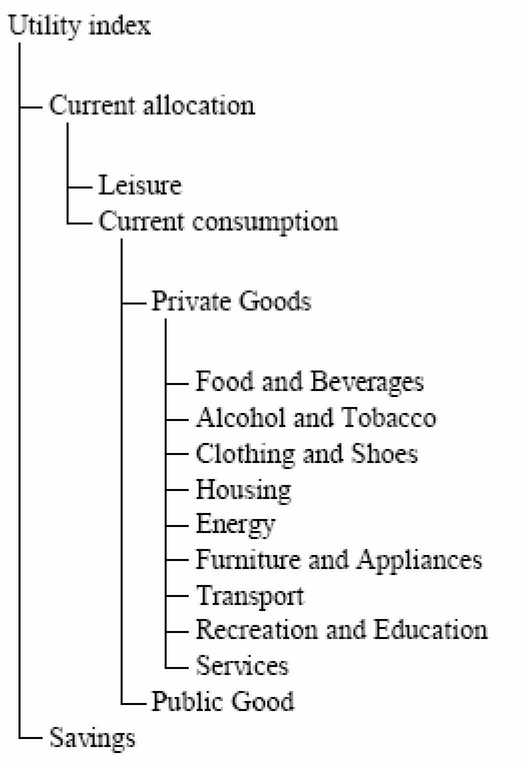

Figure 5: Household allocation structure of the Viking model

The Danish ADAM/EMMA model

The Danish ADAM model is quite different from the other four models discussed so far, as it is not a CGE model but a macroeconometric model, based on the Keynesian tradition. Still, it is a very comprehensive model with many production sectors, households and government agents and has, in many respects, long-run properties similar to CGE models. It is, nevertheless, a fundamentally different type of model, and this property may hinder comparison. The case for focusing on ADAM instead of Danish CGE models is that ADAM has been used extensively for environmental analysis with the implementation of the satellite model EMMA and has a relatively rich spectrum of environmental variables interconnected with an economic model. For further reference, see Andersen (1997, 2001) and Statistics Denmark (1995).

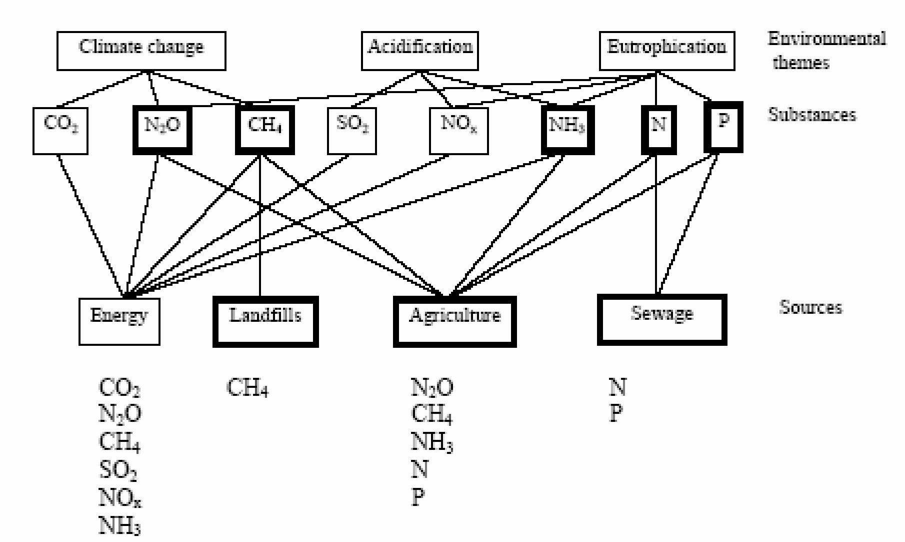

Figure A6: Environmental themes in the EMMA satellite model to ADAM

A3. Model comparison

In all of these models, with the exception of the Danish ADAM model, all resources are fully utilized, which is a standard assumption in economic models intended to describe long-run relationships. Hence, by construction, they are not suitable for analyzing short-run phenomena like unemployment and inflation.

All the models have a top-down specification with the exception of the Finnish EV model, which as a bottom-up structure. The first type only uses broad and exogenous assumptions about technical progress, while the second type endogenizes innovation (adaptation of technology). This constitutes a potential problem of incompatibility.

Two models (Finland and Iceland) are static, while two are dynamic (Denmark and Sweden), and one can be both (the Norwegian MSG model). This is not a serious issue, as we are primarily interested in comparing the properties of certain long-run relationships, which are easily captured in a static model. The added benefit of a dynamic model is an understanding of the adjustment path between an initial position and such an equilibrium.

The models are not consistent with respect to the wage elasticity of labor supply. The Norwegian and Icelandic models assume an increase in labor supply following a decrease in the net wage rate, while the Swedish model, for instance, does not.

What they all have in common, though, is that they have all been used before in assessing the economic impacts of fulfilling the obligations of the Kyoto protocol. This entails that in all cases there exist well-defined benchmark scenarios, sometimes referred to as business-as-usual scenarios. We will utilize this property and focus our attention on small deviations from the benchmark scenarios to create indicators for each economy.

A4. Outline of the project

What makes this study different from a survey of CO_2 abatement cost modeling is that instead of only relying on published results for each model, we call for specific scenarios to be run for each model. This is done in order to provide more consistency between results and facilitate comparison of decoupling potential in each country. Still there are differences in modeling specifics and assumptions that will be impossible or to time-consuming to control for. The amount of coordination suggested here is meant to be a balance between the ideal setup for comparison and budgetary concerns. In the setup we would essentially have the same structural model for each and every country, perfectly consistent assumptions and a proper treatment of the interaction between all the models and the rest of the world. Such a task would be extremely expensive and time-consuming.

Benchmark scenarios

As previously built and analyzed models are used in the study, for the most part, and where not otherwise stated, the predominant benchmark assumptions that have been used for official estimates of abatement costs will be used. A few selected assumptions, considered central to the results, are harmonized to facilitate the comparison. Here, it is suggested that the following benchmark assumptions will be harmonized:

- Projected rate of rest-of-world economic growth, by sectors
- Projection of world market prices for oil, natural gas and other major commodities
- Projections of electricity prices in the common Nordic electricity market
- Projections of CO_2 quota prices
- World market interest rates
- Projected rate of improved emissions efficiency

Paths for oil extraction, fish catches and foresting, which usually are treated as exogenous paths, should be based on previously established reference levels that have been used in the respective models. The first step in the exercise is finding common parameters and paths, and possibly extending the above list is the first step.

Time frame

The models included in the analysis differ with respect to the time frame they are meant to analyze. With only one exception the models included in the study are designed for long-run analysis only, while the Danish ADAM model is mainly considered for medium-term analysis. Its long-run properties, however, are quite robust, compared with standard macro-models. The Finnish, Icelandic and Swedish models are static by nature, while the other two are dynamic, in one way or another. Static models are not any less suitable for long-run analysis but can at best offer a highly simplified adjustment path that the economy takes towards the long-run equilibrium. The time it takes for dynamic models to reach a long-run equilibrium can differ, e.g., depending on how mobile capital is between sectors. As a result the time perspective of the comparison can be problematic. In order to select the most appropriate perspective, it is advised to collect simulation results from three years: 2010, 2020, and 2030. Hopefully long-run equilibrium will be reached in 2030 and, perhaps, as soon as 2020 in the dynamic models. The relatively short horizon of 2010 is also interesting as it relates to the conditions of the Kyoto protocol, which specifies emission targets for the period 2008 to 2012.

Scenarios

For each model we calculate 18 scenarios, along three dimensions. The first dimension is as follows.

Three basic scenarios, two of which should already be available:

1. A benchmark (business-as-usual) scenario, based on publicly used and partially harmonized assumptions (see above).
2. An official target scenario,[26] taking into account planned mitigation programs and market mechanisms aimed at achieving emission targets.
3. A standardized scenario, based on scenario 2 but where the levels of CO_2 taxes are endogenized in order to minimize the aggregate welfare loss of the region as a whole.[27]

The second dimension consists of two levels of CO_2 taxes (scale the existing structure including rebates and exceptions): the solution of the basic scenario and a scenario where CO_2 taxes are 10% higher. By this we can approximate the potential of decoupling at the margin and calculate indices on a sectoral basis.

[26] In case no single official scenario is available, we opt for a central scenario already analysed and published for the model in question. The main objective here is to control for how deviations from original assumptions may affect the results.

[27] Since this scenario requires repeated runs and manually arranged interaction between the models, we will only go this far if time and resources allow.

The third dimension is created to decompose decoupling effects into: Scale effects, technological effects, composition effects and substitution effects. The four combined effects are represented by the difference between scenarios 1 and 2 along the first dimension – first, by a scenario in which total factor productivity is assumed to be equalized in all sectors, while returning the same output as the official target scenario. This allows identification of the composition effect. Second, a scenario based on the assumption that no technological progress takes place (energy efficiency for instance is constant) can be used to further isolate the technological effect. Third, a scenario fixing, in addition, all prices, apart from the after-tax price of goods and materials under the CO_2 tax, to isolate the substitution effect from the remainder.

This seemingly complex approach is preferred over direct decomposition as in Bruvoll, Fæhn and Ström (2003) and Bruvoll and Larsen (2004) since the results of the latter method are hard to compare between the different models.

Reporting and analysis

Activity levels and prices for each sector, measures of GDP, EV and the emissions of the following: CO_2, NO_X, SO_2 and VOC, by sector and consumption goods and for each of the above-mentioned scenarios is the basis of the comparative analysis.

A5. Limitations

A few desirable aspects of the model comparison need to be excluded for practical purposes. An important issue that is not addressed in this proposal is the possibility of emission 'leakages', or transfer of emissions from the country where a CO_2 tax or any other environmental policy is executed to a second country where producers are not affected by the policy. Several cross-country studies have addressed this issue, including Martin et al. (1992), Pezzey (1992), Jacoby et al (1997), Brown et al. (1999). Bruvoll and Fæhr (2004) offer a recent study of the phenomena for Norway. Estimates of leakage effects differ between studies, both based on the intensity of abatement policies and modeling framework. As important as this subject is, it would require a separate study to do it justice.

A related drawback is how imperfectly this study would handle the interaction of trade effects following changes in environmental policy. While a full-fledged integrated model of all the five countries and the rest of the world would be the ideal setup, the current suggestion is likely to provide sufficiently robust insights without overextending the scope of the project.