Measuring Environmental Risk

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Abstract: Environmental issues and risk have become central in socioeconomic research and policy planning in order to ensure sustainable development. As environmental risk is difficult to assess and measure, different indexes have been developed to evaluate specific aspects of such risk. Environmental risk typically involves problems generated by the consumption of energy (fuels), water shortages, disasters, global warming, poverty, and population growth. Environmental indexes are typically disaggregated and deal with separate aspects of environmental risk. Some useful overall indexes exist, such as the Environmental Sustainability Index (ESI). This paper reviews the existing data and indexes for environmental risk.

***Keywords*:** Environmental risk, Environmental sustainability, Environmental indexes and indicators.

1. Introduction

Environmental risk is an important concept for countries in evaluating their potential for economic and social sustainability. The definition of environmental risk is broad. For example, environmental risk is defined as a catastrophe, pesticide risk or the relative sustainability of the environment to social and economic activities. Some definitions of environmental risk include a small number of indicators, while others incorporate a large number of components.

The scientific community has attempted to measure environmental risk through the form of indexes, which is the focus of this paper. Furthermore, the paper will pay special attention to indexes that are relevant to economics and the social sciences. The content of an index will vary according to the definitions of environmental risk and the context in which the index is established.

Indexes that are consistent over time are not easily available, generally being cross-sectional and/or available on an annual basis. In the literature, the main purpose in constructing these indexes is to produce policy reports on sustainability.

Many indexes have been developed by governmental, non-governmental and inter-governmental agencies, as well as by private consulting firms. These indexes tend to be specific to regions, countries and issues. Many different, and sometimes inconsistent, measures of the environment are available, but only a few enterprises have attempted to create an aggregate index measuring overall environmental sustainability or risk over time and across countries.

2. Environmental Sustainability and Risks

Defining environmental risk for the social sciences and economics is a serious challenge. The primary difficulty arises from choosing the appropriate elements of environmental risk that are relevant for social and economic purposes.

The environmental issues relevant to economics are directly associated with sustainability. Environmental sustainability is defined in the Environmental Sustainability Index (ESI, 2001) report as "the ability to produce high levels of performance on ... these dimensions [environmental systems, reducing environmental stresses, reducing human vulnerability, social and institutional capacity and global stewardship] in a lasting manner".

Environmental risk and environmental sustainability will be used interchangeably in this paper. An identified risk to the environment for a region or country affects sustainability, such that, the lower is the risk to the environment, the greater is its sustainability. It is difficult to determine what a "desirable path to sustainability" actually represents in scientific terms. Sustainability may be relative to other regions or countries. Risk may be more easily evaluated for some issues, such as natural resources, where near depletion might have "high risk".

The Environmental Risk Analysis Program at Cornell University defines Environmental Risk as clustered in five areas, namely consumption of

energy (fuels), water shortages, disasters, global warming, poverty, and population growth. Furthermore, they define that resources are used in a sustainable manner "when they are used at a rate and in ways such that they are not depleted or permanently damaged" (this information is available at http://environmentalrisk.cornell.edu). The goal of indicators is to quantify observed phenomena to understand diverse and complex situations. Indexes are usually the result of aggregated data, and indexes can be aggregated into more general indexes.

3. Sustainability Indexes

3.1 Environmental Sustainability Index (ESI)

The ESI is a project jointly led by the Environment Task Force of the Global Leaders for Tomorrow, World Economic Forum (WEF), the Yale Center for Environmental Law and Policy, Yale University, and the Center for International Earth Science Information Network (CIESIN), Columbia University. ESI integrates a large amount of information through various dimensions of sustainability. The index measures each country's progress towards environmental sustainability.

The ESI (1) identifies issues where national performance is above or below expectations; (2) sets priorities among policy areas within countries and regions; (3) tracks environmental trends; (4) assesses quantitatively the success of policies and programs; and (5) investigates the extent of the interaction of environmental and economic performance and other factors influencing environmental sustainability.

Based on a large cross-sectional database, the ESI ranks 142 countries according to five core components, each subdivided into 20 indicators formed on the basis of the 68 underlying variables, and has been published annually since 2001. The ESI is a weighted average of the indicator scores, with greater weight on the social and institutional components. The sources of the data are from the UN, university departments, NGOs, commercial firms and national laboratories.

Broad environmental issues are covered by the index, such as the control of pollution and natural resource management, over a large number of countries. Moreover, the survey underlines the poor state of environmental metrics. Some environmental issues, however, have been surveyed precisely, such as climate change, ozone depletion and deforestation.

The choice of variables was made according to country coverage, quality and timeliness of data. The ESI is based on a relative comparison between countries, such that a high score for a given country is due to a high average of the individual indicators relative to other countries. ESI ranks Finland, Norway and Sweden as the three top countries. The report mentions that no countries are on a perfectly sustainable path, and that all countries perform badly in at least some sub-categories. The breadth of coverage of environmental issues leads to similar ESI scores for different countries and environments. Diverse examples can be found in the results presented by the ESI main report (for example, the scores for Libya and Belgium are 39.3 and 39.1, ranking them 124 and 125, respectively, of 142 countries). Cluster analysis is also conducted to identify similarities among countries, given the diverse dimensions of environmental sustainability (human vulnerability, systems and stresses).

3.2 Environmental Performance Index (EPI)

The EPI has been developed in parallel to the ESI by the same institutions, and ranks countries according to air and water quality, land protection, and climate change prevention. This index was created to support performance-based benchmarking and to evaluate the results obtained in the ESI. The EPI, which is still experimental at this stage, is derived from aggregated data sets into four core indicators that measure air and water quality, greenhouse gas emissions, and land protection. Such indicators provide measures of both current performance and rates of change. The performance over time is tracked from 1990 to the present, with the exact dates vary according to data availability. The index is confronted with data problems to fulfill its initiative, as the time series data for environmental measurement can be rather poor.

3.3 Wellbeing Index

Prescott-Allen's "Wellbeing of Nations" was published under the International Development Research Centre (IDRC) in cooperation with the IUCN, the World Conservation Union, the International Institute for Environment and Development, the Food and Agriculture Organisation of the UN, Map Maker LTD, UNEP, and the World Conservation Monitoring Centre. The book focuses on a cross section of 180 countries, measures the quality of life and the environment, and combines human wellbeing indicators with issues of environmental sustainability. The book computes two main indexes, namely a Human Wellbeing Index, which measures the quality of life, and an Ecosystem Wellbeing Index, which measures the quality of the environment. These are combined to form a Wellbeing Index. Finally, the Wellbeing/Stress Index, that measures human wellbeing relative to the amount of environmental stress, is generated. *The Wellbeing of Nations* is concerned with people and ecosystems, with equal weights, and proposes that sustainable development is a combination of human and ecosystem wellbeing.

3.4 Dashboard of Sustainability

The UN Commission on Sustainable Development (UNCSD) and the Consultative Group on Sustainable Development Indicators (CGSDI) have produced sustainability indicators based on the UNCSD indicator framework. It gathers 60 indicators for 100 countries. The CGSDI is an international team of experts, which is coordinated by the International Institute for Sustainable Development (IISD). The CGSDI use visual models of highly aggregated sustainable development indexes, using a cluster approach. These models display the data for a qualitative analysis based on a four-sided pyramid, elliptical indicator cluster, compass of sustainability and a dashboard of sustainability. For the visual models, they also use indicators and data constructed by other agencies.

These measures encompass environmental and social issues, as well as economics and institutions. The resulting indicators are displayed through diverse visual models, with the most important prototype being called the "dashboard of sustainability". This dashboard is a non-commercial software that represents complex relationships among economic, social and environmental issues. It is aimed at policy makers and academic researchers, and enables the creation of composite indicators. In order to display the relationships, graphic presentation and aggregation algorithms have been developed.

The dashboard is experimental. From this project, the CGSDI and UNCSD have also produced an aggregate index called the Policy Performance Index (PPI), which has a wider variety of components, such as economic output, social care and welfare, nature and environment, institutions, and governance.

3.5 Genuine Progress Indicator (GPI)

Created in 1995, this annual index measures more accurately the progress for the USA, and uses the same accounting framework as GDP. The GPI adds the economic contributions of household and volunteer work and subtracts factors such as crime, pollution and family breakdown. Although including a broader notion of human wellbeing, the GPI is still limited and does not account fully for important ecological issues affecting social and economic life.

4. Risk and Disasters

4.1.1 Living with Risk

The UN International Strategy for Disaster Reduction (UNISDR) produced the report "Living with Risk", which focuses on disaster risk reduction. The document is intended for practitioners in disaster management, and environmental and sustainable development, and provides policy guidance. The report is a qualitative analysis of information on disaster risk reduction initiatives.

4.1.2 A Disaster Database

The Centre for Research on the Epidemiology of Disasters (CRED) at the Catholic University of Leuven, Belgium, has created an Emergency Events Database (EMDAT) with the initial support of the World Health Organisation and the Belgian Government. The database is used primarily for national and international humanitarian action purposes by assisting decision makers to prepare for potential disasters. It also provides data for an assessment of the relative vulnerability of countries and regions, and enables decision makers to set priorities. The data set distinguishes between whether a certain type of disaster, such as floods or earthquakes, are more significant in terms of its human impact (injured, killed, refugee, homeless and displaced persons) within a country, or whether one country is more vulnerable than another in terms of specific issues. The disaster issues are grouped by causes of disaster under four headings, namely natural, technological, famine and conflict.

These relative effects for some specific disasters can be examined over time as the EMDAT has recorded the occurrence and effects of more than 12,800 disasters worldwide from 1900 to the present on an annual basis. The conflict database is from 1991 to the present. Various sources of data have been used to compile the database, such as UN agencies, non-governmental organisations, insurance companies, research institutes and press agencies.

4.2 Environmental Risk Analysis Program

Diverse environmental projects are undertaken under the Environmental Risk Analysis Program at Cornell University. A major component of the project involves an analysis of the impact of pesticides, their inherent risks, and the creation of an associated pesticide risk indicator.

The research centre at Cornell University also identifies the greatest threat to the environment as being clustered around six specific areas, namely population growth, global warming (fossil fuels and nuclear energy), over-consumption of materials (and sustainability), water shortages, poverty, and wars. Each of these components has international organisations, NGOs or research centres as their respective source of information, and where analysis is conducted on these specific issues.

4.3 Dow Jones Sustainability Indexes

In the private sector, there exist incentives to measure the importance of environmental and social issues within private firms. The Dow Jones Sustainability Indexes (DJSI), for example, were launched in 1999 and track the financial performance of the leading sustainability-driven firms around the world.

The aim is to provide asset managers with a benchmark to manage a sustainability portfolio and for financial products that are linked to economic, environmental and social criteria. These indexes quantify the importance of promoting sustainability in the private sector. The DJSI are derived from, and are integrated with, the Dow Jones Global Indexes as the same methodology is used. Members of DJSI are diverse companies from various countries and various economic sectors, ranging from basic materials to utilities. The DJSI is divided into two set of indexes, namely the DJSI World and DJSI STOXX, and is used by asset managers in 14 countries, with 50 licenses having been sold to date.

4.3.1 DJSI World

The Dow Jones Sustainability World Indexes (DJSI World) consist of over 300 (the top 10%) leading sustainability companies in 59 industrial sectors for 34 countries. The market capitalisation of the DJSI World in August 2003 exceeded USD5 trillion. These indexes are based on the Laspeyres' formula, and are calculated as price and total returns indexes in USD and EURO, yielding a total of 24 indexes. DJSI World is reviewed annually for potential component changes, which affects the sustainability performance (such as bankruptcies, mergers or takeovers). Moreover, the composite DJSI World is further divided into specialised subset indexes by excluding companies that generate revenue from alcohol, tobacco, gambling, armaments or firearms.

4.3.2 DJSI STOXX

The Dow Jones STOXX Sustainability Indexes (DJSI STOXX) consist of a pan-European and Euro-zone indexes, DJSI STOXX and DJSI EURO STOXX, respectively. These indexes were published for the first time on 15 October 2001. As for DJSI World, both of these indexes are composite, and are further subdivided into specialised indexes by excluding some firms generating revenue in the five categories mentioned above. The Dow Jones STOXX Sustainability Indexes, which include 179 components, track the financial performance of the top 20% of the companies in terms of sustainability in the Dow Jones STOXX 600. Each of the DJSI STOXX indexes are calculated as price and total return indexes, both in USD and EURO, yielding a total of 16 indexes. The DJSI STOXX indexes are reviewed on both an annual and quarterly basis to ensure consistency in the representation of the top 20% leading sustainability firms.

4.3.3 Corporate Sustainability and Assessment

"Corporate Sustainability is a business approach to create long-term shareholder value by embracing opportunities and managing risks deriving from economic, environmental and social developments" (DJSI, 2003a). Identification and selection of companies depend on the quality of a firm's strategy and management, as well as its performance in dealing with integrating long-term economic, environmental and social aspects. These aspects can be now quantified. The corporate sustainability concept refers to a quantification of corporate sustainability performance. Leading sustainability companies are identified by the Corporate Sustainability Assessment of SAM Research, which requires companies to complete questionnaires. The SAM group also uses company and third-party documents, and personal contacts to deem a company acceptable for the DJSI. Further external verification is undertaken by consulting firms. The choice of SAM's analysts relies on specific sustainability trends such as climate change, water, food, accountability and health.

4.4 Ecological Indicators

4.4.1 Living Planet Index/Ecological Footprint

The WWF, Redefining Progress and UNEP produced the *Living Planet Report 2002* (WWF, 2002). This report periodically updates the state of the world's ecosystem (Living Planet Index) and the pressures placed on them by the consumption of renewable natural resources (Ecological Footprint (EF)). The Living Planet Index spans the period 1970 to 2000, and is an average of three ecosystem-based indexes, namely a forest species population index, a marine species population index, and a freshwater species population index.

The EF focuses on environmental issues and is composed of six footprint indicators, namely built-up land, energy, fishing ground, forest, grazing land and cropland. As a unit of area, Ecological Footprint measures the land and sea needed to absorb carbon dioxide by converting the combined quantities of energy and renewable resources consumed by a nation, region or the world. Furthermore, the EF estimates an ecological balance, which accounts for the national footprint relative to its sea and productive land surface. If the footprint exceeds the national capacity, the country would be in deficit.

4.4.2 World Resources and EarthTrends

EarthTrends of the World Resources Institute is an online data source that focuses on environmental, social and economic trends (this information is available at http://earthtrends.wri.org). The data are gathered from different renowned data sources and agencies and cover a wide range of issues. EarthTrends provides information in ten main areas, with tables containing statistics for each topic, country profiles, selected variables, and environmental information at the regional, global and country levels. Research for policy and analytical purposes on the environment and sustainable development is also available on each

topic. The data are typically observed annually, and the availability of data for each country depends on the specific variables requested. At present, there are approximately 500 variables in the system.

The World Resources Institute, in collaboration with several international, governments and NGOs, produces diverse publications on a variety of environmental topics. For example, The World Resources Report refers to the conditions and trends in the global environmental and natural resources, and is published jointly by the United Nations Development Programme, the United Nations Environmental Programme and the World Bank. This report provides a qualitative and quantitative analysis regarding the global environment.

4.5 Other Initiatives

International Sustainability Indicators Network is a group of NGOs, consultants and governmental organisations working on sustainability analysis.

Another important initiative is UNEP's *Global Environmental Outlook*, which analyses the current state of the global and regional environment. This was initiated in response to the environmental reporting requirements of UNEP's Agenda 21, and to a governing council decision of UNEP. The *Global Environmental Outlook-3* overviews the main environmental developments over the past 30 years, and investigates how social, economic and other factors have affected the global environment. The analysis is conducted qualitatively and quantitatively based on environmental indicators.

5. Comparing Indexes

5.1 How are Indicators and Indexes Related?

An issue raised by the main report of ESI is the broad correlation between per capita income and the environmental sustainability index. This highlights the importance of the interaction between economic activities and diverse environmental issues. The relationship between economics and environmental outcomes is investigated through simple correlations between GDP per capita and ESI. Apart from GDP per capita, the ESI report examines the correlation of ESI and the Competitiveness Index of the World Economic Forum (2001), for which the correlation coefficient is 0.34. Furthermore, environmental sustainability should not be attributed solely to economics, but also to government policies, the private sector and individuals.

Moreover, ESI is significantly correlated with the Wellbeing Index and the CGSDI Overall Index (0.73 and 0.60, respectively). There is more substantial divergence among the ecosystem-driven indicators than their human counterparts as there is a greater consensus within the latter group. In addition, data are more readily available and in greater quantities with regard to human indicators. Ecosystem indicators frequently diverge from each other because eof the lack of availability of data and discrepancies in their analytical framework.

In *The Wellbeing of Nations* (Prescott-Allen, 2001), the Human Wellbeing Index (HWI) and the Ecosystem Wellbeing Index (EWI) have been compared with the Human Development Index (HDI) (UNDP, 2003) and the Ecological Footprint (Wackernagel et al., 2000), respectively. The HDI measures how close a nation is to deprivation, and is consistently higher than the HWI. The HWI includes 36 indicators such as freedom, violence and equity, covering 9 elements, whereas HDI shows the change in 4 indicators, namely life expectancy, income, literacy and school enrolment. As a consequence, the HDI rating may suffer from missing data and an over-emphasis on a few elements included in the index (Prescott-Allen, 2001).

On the other hand, EWI can be compared to the Ecological Footprint, which measures consumption pressures. The main difference between the two is that EWI attempts to measure the actual pressure from the consumption process, whereas EF measures the expected pressure.

5.2 Limitations of the Various Indexes

5.2.1 Time Series

The lack of time series environmental indexes prevents robust empirical analysis. Environmental time series indexes would enable an investigation of the relationships, as well as the simple correlations with other social and environmental indexes, to determine optimal environmental performance.

Both ESI and EPI track environmental trends, but any comparisons may be somewhat restrictive as ESI has been published annually for the last two years, the scores are not directly comparable as the methodology has evolved, and EPI is based on the difference between 1990 and 2002.

CGSDI attempted to make their PPI comparable, and to replace well known indicators such as GDP, for policy decision purposes. However, the information used is typically cross sectional. These research incentives are not based on time series data, which eliminates the possibility of a dynamic analysis. The more specialised indexes such as CRED's disaster database and DJSI are more frequently observed. Furthermore, EarthTrends compiles mainly annual time series data, as well as large cross sections of data.

5.2.2 Complexity

In general, the indexes include a wide variety of

measures of environmental elements to examine various aspects of environmental issues and human dimensions. This may limit empirical analysis when searching for relationships among diverse environmental and social elements. Such problems arise from the fact that an understanding of sustainability is increasingly complex and requires more accurate data. However, indexes are based on simple aggregation procedures, while specialised indexes are limited as they are concerned with only a limited aspect of the broad concept of sustainability.

GDP, for example, is a powerful measure, but is limited to the output of a market economy. Its narrow measure ignores several important aspects, such as the state of ecosystems, and environmental and social costs (arising from pollution and resource depletion). Despite the increasing information contained in reports and measures of environmental factors, of both an ecosystem and human nature, few studies have attempted to incorporate these environmental issues comprehensively into an index which might be as powerful and informative as GDP.

5.2.3 Measurement Errors

ESI uses several "proxies" in its construction (WEF, 2002a, p.6). When ESI is used in cross-sectional analysis, the results may suffer from endogeneity and measurement error problems. Data problems seem to be a major hindrance to the measurement of environmental risk and sustainability. The ESI report indicates that a number of crucial environmental factors had been omitted, while others were measured imprecisely. Measurements errors in the construction of the index are a serious problem when used in empirical analysis.

Acknowledgements

The second and third authors acknowledge the financial support of the Australian Research Council.

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