Interactions Among Economic Development, Openness to Trade and Environmental Sustainability With a Case Study on Korea

Savas Alpay[1]

Department of Economics, TOBB Economy and Technology University, Ankara, Turkey

Abstract

In this study, we try to provide answers for the following three questions: (1) whether economic development (as proxied by GDP per capita) is a significant determinant of environmental sustainability, (2) whether this interaction shows different characteristics at different stages of the economic development; in particular, whether the ESI-GDP interaction in Korea is different from those of the other developing countries and developed countries, and (3) whether trade liberalization leads to higher environmental sustainability. We demonstrate that an increase in GDP per capita will have the higher impact on the environmental sustainability index (ESI) in Korea as compared to both developing countries and developed countries. Regarding the impact of trade liberalization policies on environmental sustainability, our data does not provide statistically significant results; the impact of higher openness on the environmental sustainability index (ESI) is mixed (for some countries positive and for some negative), but not significant. In brief, the results of our analysis may be seen positively by the policy makers in developing countries as they do not need to give up policies toward higher economic growth to protect their environment; development and sustainability can be complementary if suitable policies on development and environment are implemented jointly.

1. Introduction

The Stockholm Conference on Environment and Development in 1972 had been an important international meeting where concerns about global environment were outspoken and the importance of formulating policies to overcome environmental problems started to be recognized. In 1980's and 1990's, with rapidly emerging concerns about global threats such as ozone-layer depletion and global warming, environmental issues made their way into public policy agenda in many developed countries.

In particular, two areas of research have attracted the attention of economists and policy makers. Firstly, the relationship between environmental quality and economic growth has been empirically modelled through emissions-income relationship by many authors. Grossman and Krueger (1991, 1993, 1995) have shown an inverted U-type relationship between per capita income and emissions of SO_2 and suspended particulates. This inverted-U type relationship between income and emissions is commonly known as Environmental Kuznets Curve Hypothesis (EKC) in the

[1]E-mail: salpay@etu.edu.tr

literature. EKC hypothesis has been tested by many others: Shafik and Bandyopadhyay (1992), Selden and Song (1994), Cropper and Griffith (1994), Kaufmann, Davidsdottir, Garnham, and Pauly (1998), and Agras and Chapman (1999) can be seen among others. Shafik and Bandyopadhyay (1992) have analyzed total and annual deforestation, where Cropper and Griffith (1994) have studied "rate" of deforestation. Selden and Song (1994) have looked at various air pollutants (suspended particulate matter (SPM), SO_2, NO_x and CO) and found similar results; however, the turning points, i.e. threshold levels, were substantially different across these studies. Holtz-Eakin and Selden (1995) have found that CO_2 emissions did not show the same EKC pattern. Instead, CO_2 emissions monotonically increases with income. Hettige et al. (1999) have explored the income-environmental quality relation for industrial water pollution. They have shown that water pollution stabilizes with economic development, but have not detected an eventual decline.

Secondly, several methodological approaches have been employed to examine trade and environment linkage. These approaches have been summarized by the literature surveys by Dean (1992), Ulph (1994), van Beers and van den Bergh (1996) and Alpay (2001). Among the interactions between trade and environment, the impact of trade liberalization on environmental quality has usually been studied together with the interactions between economic growth and environment mentioned above (one can see Grosmann and Krueger 1991, 1993, Kaufmann et al. 1998, and Agras and Chapman 1999).

All these studies try to establish a direct linkage between income and pollution and/or between trade and pollution. They seem to overlook the more basic and fundamental interaction among these variables: the impact of income growth and trade liberalization on environmental awareness and policy making. Theoretically, if one considers environmental quality as a normal good, one would expect that demand for better environment, and therefore public pressure for stricter environmental regulations will rise with increases in per capita income. In this paper, we will use a recently developed measure for environmental sustainability known as Environmental Sustainability Index (ESI), and examine the interactions between ESI and income empirically (ESI includes dimensions related to environmental awareness and policy making). In particular we focus on three questions: (1) whether economic development (as proxied by GDP per capita) is a significant determinant of environmental sustainability, (2) whether this interaction shows different characteristics at different stages of the economic development; in particular, whether the ESI-GDP interaction in Korea is different from those of the developing countries and developed countries, and (3) whether trade liberalization leads to higher environmental sustainability.

Given this very important data set on the sustainability of the environment, we will first identify the conditions of Korea as reported in the data set with respect to overall environmental sustainability index as well as the five core components of the ESI. As the data is provided in a disaggregated format we will be able to provide interesting and important details not only regarding the current level of core components such as the state of environmental systems, stresses on this system, social and institutional capacity but also regarding their subcomponents such as air and water quality, pesticide use, soil degradation, deforestation, basic human sustenance, science and technology capacity, civil and political liberties, international commitment etc.

In section 2, we briefly present an introduction to the Environmental Sustainability Index (ESI). In section 3, we present comparative analysis of ESI index across the group of countries mentioned above. Section 4 introduces our model and data sources, and the section 5 summarizes main findings.

2. Environmental Sustainability Index

Environmental Sustainability Index (ESI) (2001) is the result of collaboration among the World Economic Forum's Global Leaders for Tomorrow (GLT) Environment Task Force, the Yale Center for Environmental Law and Policy (YCELP), and the Columbia University Center for International Earth Science Information Network (CIESIN).

Environmental sustainability index is constructed by focusing on the following five dimensions: (1) *the state of the environmental systems*, such as air, soil, ecosystems and water; (2) *the stresses on those systems*, in the form of pollution and exploitation levels; (3) *the human vulnerability* to environmental change in the form of loss of food resources or exposure to environmental diseases; (4) *the social and institutional capacity* to cope with environmental challenges; and (5*) the ability to respond to the demands of global stewardship* by cooperating in collective efforts to conserve international environmental resources such as the atmosphere. Then, environmental sustainability can be defined as the ability to produce high levels of performance on each of these dimensions in a lasting manner. These five items are referred to as the core components of environmental sustainability.

There is no scientific knowledge that will specify precisely what levels of performance are high enough to be truly sustainable, especially at a worldwide scale. Nor it is possible to identify in advance whether any given level of performance is capable of being carried out in a lasting manner. Therefore the index has been built in a way that is primarily comparative. The difficult task of establishing the thresholds of sustainability remains to be tackled; this is not easy as it is complicated by the dynamic nature of such economic factors as changes in technology over time.

The reasoning behind the choice of these five core components as building blocks of environmental sustainability as explained in the ESI Report (2001) is as follows:

Regarding Environmental Systems: "A country is environmentally sustainable to the extent that its vital environmental systems are maintained at healthy levels, and to the extent to which levels are improving rather than deteriorating."

Regarding Reducing Environmental Stresses: "A country is environmentally sustainable if the levels of anthropogenic stress are low enough to engender no demonstrable harm to its environmental systems."

Regarding Reducing Human Vulnerability: "A country is environmentally sustainable to the extent that people and social systems are not vulnerable (in the way of basic needs such as health and nutrition) to environmental disturbances; becoming less vulnerable is a sign that a society is on a track to greater sustainability."

Regarding Social and Institutional Capacity: “A country is environmentally sustainable to the extent that it has in place institutions and underlying social patterns of skills, attitudes and networks that foster effective responses to environmental challenges.”

Regarding Global Stewardship: “A country is environmentally sustainable if it cooperates with other countries to manage common environmental problems, and if it reduces negative extra-territorial environmental impacts on other countries to levels that cause no serious harm.”

These core components have been derived from a set of 22 environmental sustainability *indicators*, which were identified on the basis of a careful review of the environmental literature and substantiated by statistical analysis. Similarly, each of the indicators has been associated with a number of *variables* that are empirically measured. A total of 68 variables have been used in the derivation of the indicators. The variables are chosen by considering the theoretical logic and relevance of the indicator in question, data quality, and country coverage. In general variables with extensive country coverage are included, but in some cases, variables with narrow coverage are also incorporated if they measure critical aspects of environmental sustainability that would otherwise be lost. For example, air quality and water quality data were missing in many poor countries, but they were included anyway because of their central role in environmental sustainability. The list of the indicators and associated variables are as follows(first core components, then indicators, and under indicators, variables are listed):

Environmental Systems

- Air Quality
  - Urban SO2 concentration
  - Urban NO2 concentration
  - Urban TSP concentration
- Water Quantity
  - Internal renewable water per capita
  - Water inflow from other countries per capita
- Water Quality
  - Dissolved oxygen concentration
  - Phosphorus concentration
  - Suspended solids
  - Electrical conductivity
- Biodiversity
  - Percentage of mammals threatened
  - Percentage of breeding birds threatened
- Terrestrial Systems
  - Severity of human induced soil degradation
  - Land area affected by human activities as a % of total land area

Reducing Stresses

- Reducing Air Pollution
  - NOx emissions per populated land area
  - SO2 emissions per populated land area

VOCs emissions per populated land area
Coal consumption per populated land area
Vehicles per populated land area

- Reducing Water Stress
  - Fertilizer consumption per hectare of arable land
  - Pesticide use per hectare of crop land
  - Industrial organic pollutants per available fresh water
  - Percentage of country's territory under severe water stress
- Reducing Ecosystem Stress
  - Percentage change in forest cover
  - Percentage of country's territory in acidification exceedence
- Reducing Waste & Consumption Pressures
  - Consumption pressure per capita
  - Radioactive waste
- Reducing Population Pressure
  - Total fertility rate
  - % change in projected population between 2000 & 2050

Reducing Human Vulnerability

- Basic Human Sustenance
  - Daily per capita calorie supply as a % of total requirements
  - % of population with access to improved drinking-water supply
- Environmental Health
  - Child death rate from respiratory diseases
  - Death rate from intestinal infectious diseases
  - Under-5 mortality rate

Social and Institutional Capacity

- Science/Technology
  - R & D scientists and engineers per million population
  - Expenditure for R & D as a percentage of GNP
  - Scientific and technical articles per million population
- Capacity for Debate
  - IUCN member organizations per million population
  - Civil and political liberties
- Regulation and Management
  - Stringency and consistency of environmental regulations
  - Degree to which environmental regulations promote innovation
  - Percentage of land area under protected status
  - Number of sectoral EIA guidelines
- Private Sector Responsiveness
  - No. of ISO14001 certified companies per million dollars GDP
  - Dow Jones Sustainability Group Index membership
  - Average Innovest EcoValue'21 rating of firms
  - World Business Council for Sustainable Development members
  - Levels of environmental competitiveness
- Environmental Information
  - Availability of sustainable development info. at the national level
  - Environmental strategies and action plans
  - Number of ESI variables missing from selected data sets

- Eco-Efficiency
  - Energy efficiency (total energy consumption per unit GDP)
  - Renewable energy prod. as a % of total energy consumption
- Reducing Public Choice Distortions
  - Price of premium gasoline
  - Subsidies for energy or materials usage
  - Reducing corruption

Global Stewardship

- International Commitment
  - No. of memberships in environmental intergovernmental orgs.
  - Percentage of CITES reporting requirements met
  - Levels of participation in the Vienna Convention/Montreal Prot.
  - Compliance with environmental agreements
- Global-Scale Funding/Participation
  - Montreal Protocol Multilateral Fund participation
  - Global Environmental Facility participation
- Protecting International Commons
  - FSC accredited forest area as a % of total forest area
  - Ecological footprint “deficit”
  - CO_2 emissions (total times per capita)
  - Historic cumulative CO_2 emissions
  - CFC consumption (total times per capita)
  - SO_2 exports

The Environmental Sustainability Index (ESI) is calculated by taking the average values of the 22 indicators, which are computed from the variables.

3. Comparative Analysis

The Environmental Sustainability Index (ESI) has been developed for 142 countries, and it measures overall progress towards environmental sustainability The three highest ranking countries in the 2001 ESI are Finland, Norway, and Canada. A high ESI rank means that a country has achieved a higher level of environmental sustainability than most other countries; on the other hand, a low ESI score indicates that a country is facing substantial problems in achieving environmental sustainability. The ESI scores are based upon a set of 22 core indicators, each of which is derived from two to six variables for a total of 68 background variables. The ESI permits cross-national comparisons of environmental progress in a systematic and quantitative fashion. Among the many use of ESI, we can mention (i) identification of issues where national environmental results are above or below expectations; (ii) policy tracking to identify areas of success or failure; (iii) benchmarking of environmental performance; (iv) identification of best practices; and (v) investigation into interactions between environmental and economic performance.

As seen in Tables 1 and 2 in the appendix, the average ESI scores for the developing countries and the developed countries are 48.6 and 64.2, respectively. The ESI for Korea is 35.9, and thus the performance of Korea with respect to overall environmental sustainability is lower than the average performance of both developed and developing countries. This pattern is also mostly observed in the five core dimensions of the ESI with two exceptions. Korea outperforms developing countries with respect to *human vulnerability* and *social and institutional capacity* dimensions. The worst performance of Korea is on the reducing stresses dimension of ESI, and the best performance is associated with human vulnerability.

Given this overall picture, we can now look into details at the indicator levels, which are the building blocs of the core components. This is possible due to the richness of the ESI data set.. We need to emphasize strongly that the scores listed in the following paragraphs are just for the comparison purposes as all of them are calculated as index values. They are very useful in seeing the need for improvement in terms of sustainability and its core components listed above as compared to world averages. Other details are available in the ESI (2002) report in the country profiles section.

Korea ranks 135 among all countries with respect to overall ESI score. This indicates that with respect to environmental sustainability, the conditions in Korea are worse than almost all other countries, and thus appropriate policies have to be enacted in a timely manner. In regards to subcomponents of *environmental systems*, namely indicators of air quality[2], water quantity[3], water quality, biodiversity[4] and land[5], the performance of Korea is below average in her peer group[6]. The most notable problem is seen in the biodiversity indicator. A similar situation exists with respect to indicators in the *reducing stresses* dimension of ESI. The indicators in this group include reducing air pollution, reducing water stress, reducing ecosystem stress[7], reducing waste and consumption pressures. In this group, reducing air pollution is the leading problem. Korea's performance in the *reducing human vulnerability* dimension is almost same as the average performance in her peer group. The indicators included

---

[2]Air quality is a critical factor in determining the condition of an environmental system; the ESI incorporates measures of urban air quality using three concentration variables: sulphur dioxide (SO_2), nitrogen dioxide (NO_2) and total suspended particulates (TSP).

[3] Water quantity measures the availability of water for human uses such as drinking water, agriculture and industry, as well as for ecosystem preservation.

[4] This indicator is calculated by using percentage of mammals threatened and percentage of mbreeding birds threatened.

[5] This indicator is used to quantify the extent of human impact on the land. It is measured by combining layers of information on land cover, population density, stable "lights at night" and human infrastructure in a geographic information system.

[6] Peer groups are defined by GDP per capita. The ESI report divides the countries into 5 equal groups sorted by GDP per capita.

[7] This indicator is calculated by considering two variables that express stress on ecosystem health: percent of forest cover change and percent of a country with acidification exceedance.

in this dimension are basic human sustenance[8] and environmental health[9]. With respect to social and institutional capacity dimension, science and technology indicator is above average, but the other indicators namely, capacity for debate[10], private sector responsiveness, eco-efficiency[11] and environmental governance[12], are well below the average. The final core component of ESI, *global stewardship*, includes indicators such as participation in international cooperative efforts, reducing greenhouse gas emissions and reducing transboundary environmental pressures indicators. The performance of Korea in regards to these indicators is also lower than her peers. In brief, the assessment of 22 indicators, which make up the core components of ESI, for Korea, shows that the environmental sustainability in Korea needs to be improved from many different angles. A comprehensive pro-environmental policy package should be developed.

4. Model and Estimation

Our main goal in this paper is to identify the interactions between environmental sustainability, economic development and openness to international markets. Our data set comes from the original report on The Environmental Sustainability Index (ESI) (2002), which is described above briefly.

Our simple model is as follows:

(1) $$ESI == F(ED, OT)$$

where ESI refers to Environmental Sustainability Index, ED represents economic development and it is proxied by GDP per capita; OT is openness to international markets, and it is proxied by trade intensity variable (which is measured by the ratio of sum of exports and imports to GDP).

[8] Basic human sustenance indicator is measured by using two variables: the proportion of undernourished in the total population and percentage of population with access to improved drinking water supply.

[9] Environmental health indicator is measured by using child death rate from respiratory diseases, death rate from intestinal infectious diseases and under-5 mortality rate.

[10] This indicator measures these features. Variables include the existence of civil and political liberties, the presence of democratic institutions, the degree to which important environmental issues are debated by a society, and whether or not information is available to support decision-making.

[11] The variables used to calculate eco-efficiency are: energy efficiency (total energy consumption per unit GDP) and renewale energy production per unit of total energy consumption.

[12] Environmental governance indicator is measured by considering the following variables: quality of environmental regulations, existence of sectoral guidelines for environmental impact assessments, degree of transparency in environmental decision-making, and absence of corruption, extent of protected areas, and degree of certification of forest areas for sustainable management.

On the estimation side, we have used non-parametric kernel estimation method (Pagan and Ullah 1999) instead of classical linear regression method. We can mention two advantages of using the nonparametric kernel method. Firstly, the non-parametric method does not impose any a priori functional relationship between variables. It identifies the best possible model from the data itself. This is very useful in our case as a theoretical model explaining the dependence of Y on ED and OP is not very well established. Secondly, the nonparametric kernel estimation technique enables us to compute the impact of independent variables on the dependent variable for *each observation point* in the data set. As our goal is to compare the impact of economic development and openness to trade on the environmental sustainability across different levels of economic development, these advantages of nonparametric kernel estimation will be very useful. A brief introduction for the non-parametric kernel estimation method we have used is presented in appendix 2.

Our estimation results for the model in equation (1) indicate that the estimated coefficients of the openness to trade variable are not statistically significant for most of the observations. Thus, we have decided to drop openness to trade variable from the model and performed a new non-parametric regression between environmental sustainability index and GDP per capita. The estimated coefficients for GDP per capita turn out to be positive and significant. In particular, for Korea the value of the coefficient is equal to 0.000516. The average of the estimated coefficients for developing countires is 0.000416, and for the developed countries it is equal to 0.000383. The plot of gradients across GDP per capita is given in appendix 1 (Figure 1). It is clearly observed that the impact of GDP per capita on the sustainability is positive at all levels, and moreover this impact is higher at lower levels of income, and it is lower for higher levels of income.

5. Conclusions

Understanding the impact of economic development and trade liberalization policies on the environmental quality is becoming increasingly important as general environmental concerns are making their way into main public policy agenda. This is especially important nowadays as the environmental consequences of human activities exceeded certain limits and can not be considered as negligible. On the other hand, economic development and trade liberalization are among the top priority policies in most of the developing countries. Thus, it is worth studying environmental consequences of economic development and more openness to trade.

In this paper we investigated the implications of a newly developed extensive environmental sustainability index (ESI 2002) for Korea together with the interactions between economic development and environmental sustainability. The index has been based on 5 core dimensions, which are derived from 22 indicators; indicators are constructed by using 68 variables, overall. ESI (2002) presents the outcome of the index generation process both at the aggregated and disaggregated level for 142 countries. The disaggregated data set help us see the current conditions of each country with respect to environmental sustainability. According to ESI (2002) report, Korea is among the poorly performing countries with respect to environmental sustainability. The disaggregated data set clearly indicates that pro-environmental policies need to be developed in almost all areas covered in the ESI report. With the exception of reducing human vulnerability dimension, where Korea shows an average performance, a lot of countries outperform Korea with respect to the core dimensions of environmental sustainability index. The most critical conditions exist in regards to reducing stresses on environmental systems (such as reducing air pollution, water stress, eco-system stress, waste and consumption pressures).

Our estimation results show that per capita income has a very strong and positive relation with environmental sustainability index (ESI). Additionally, the income-ESI relationship show different characteristics across developing and developed countries. Marginal impact of income on the environmental sustainability index is shown to be higher in developing countries as compared to developed countries. Noting that the level of ESI is mostly higher in high-income countries than in middle and low-income ones, this may be used as an evidence for Environmental Kuznets Curve (EKC) hypothesis as well. The decline in marginal contribution of income to ESI with rising income indicates the possibility that higher income countries have already taken enough precautions for a better environment so that there is relatively limited room for additional improvement that may be generated with even higher income. This changing nature of the relationship between income and environmental sustainability may imply a changing interaction between emissions and income at different income levels. The stabilization of ESI levels in high income group can be seen as a support for the inverted U-type relationship between income and emissions, indicated in the EKC studies.

We also demonstrate that an increase in GDP per capita will have the higher impact on the environmental sustainability index (ESI) in Korea as compared to the averages of both developing countries and developed countries. This finding indicates that for Korea, there is a higher potential to improve the environmental conditions as her economy grows. Regarding the impact of trade liberalization policies on environmental sustainability, our data does not provide statistically significant results; the impact of higher openness on the environmental sustainability index (ESI) is mixed (for some countries positive and for some negative), but not significant.

Finally, the results of our analysis may be seen positively by the policy makers in the developing countries as they do not need to give up policies toward higher economic growth to protect their environment; development and sustainability can be complementary if suitable policies on development and environment are implemented jointly.

References

Agras, J. and Chapman, D., 1999, A Dynamic Approach to the Environmental Kuznets Curve Hypothesis, *Ecol. Econ.* 28, 267-277.

Alpay, S., 2001, “How Can Trade Liberalization Be Conducive to a Better Environment? A Survey of the Literature”, mimeo, Bilkent University.

Cropper, M. and Griffith, C. (1994), “The Interaction of Population Growth and Environmental Quality”, *American Economic Association Papers and Proceedings* 84(12), 250-254.

Dean, J., 1992, “Trade and The Environment: A Survey of the Literature” in “International Trade and the Environment”, (P. Low, ed.), Washington DC: World Bank.

Environmental Sustainability Index (2002), www.ciesin.org.

Fan, J. and I. Gibels, 1996, Local Polynomial Modeling and Its Applications, Chapman and Hall, London.

Grossman, G.M. and Krueger, A.B., 1991, Environmental Impacts of North American Free Trade Agreement, *NBER Working Paper Series*, No: 3914.

Grossman, G.M., and A.B. Krueger, 1993, “Environmental Impacts of North American Free Trade Agreement”, in “The US-Mexico Free Trade Agreement”, (P. Garber ed.), Cambridge, MA: MIT Press.

Grossman, G.M., and A.B. Krueger, 1995, “Economic Growth and the Environment”, *Quarterly Journal of Economics*, 110, 353-77

Hettige, H., Mani, M., Wheeler D., 1999, “Industrial Pollution in Economic Development: Kuznets Revisited”, in “Trade, Global Policy and the Environment”, World Bank Discussion Papers No. 402, (P. Fredriksson ed.) Washington DC, World Bank.

Holtz-Eakin, D.and T.M. Selden (1995), “Stoking the Fires? CO_2 Emissions and Economic Growth”, *Journal of Public Economics* 57, 85-101.

Kaufmann, R.K., Davidsdottir B., Garnham S., Pauly P., 1998, “The Determinants of Atmospheric SO_2 concentrations: reconsidering the environmental Kuznets curve”, *Ecological Economics*, 25, 209-230.

Pagan, A., and A.Ullah, 1999, *Nonparametric Econometrics,* Cambridge University Press, New York and Melbourne.

Racine, Jeff, 1999, N© BETA, Computer Software, University of South Florida.
Rothman, D.S., 1998, “Environmental Kuznets Curves-Real Progress or Passing the Buck? A case for Consumption-Based Approaches”, *Ecological Economics* 25, 177-194.

Selden, T.M. and D. Song, 1994, “Environmental Quality and Development: Is There a Kuznets Curve for Air Pollution Emissions?”, *Journal of Environmental Economics and Management* , 27, 147-162.

Shafik and Bandyopadhyay (1992), “Economic Growth and Environmental Quality: Time Series and Cross-Country Evidence”, World Bank Policy Research Working Paper, WPS 904, Washington DC: World Bank.

Shafik N., 1994, “Economic Development and Environmental Quality: An Econometric Analysis”, *Oxford Economic Papers*, 46, 757-773.

Summers, R. and A. Heston (1991), “The Penn World Table (Mark 5): An Expanded Set of International Comparisons, 1950-1988”, *Quarterly Journal of Economics* 106(2), 327-368.

Suri, V., Chapman, D., 1998, Economic Growth, Trade and Energy: Implications for the Environmental Kuznets Curve, *Ecol. Econ*. 25, 195-208.

Ulph, A., 1994, “Environmental Policy and International Trade-A Survey of Recent Economic Analysis”, University of Southampton Discussion Paper in Economics and Econometrics, 9423.

Van Beers, C. and J.C.J.M. van den Bergh, 1996, “An overview of Methodological Approaches in the Analysis of Trade and Environment,” *Journal of World Trade* 30(1), 143-167.

World Bank, 1992, “World Tables 1992”, Baltimore: Johns Hopkins University Press.

World Resources Institute, 1992, “World Resources 1992-93”, New York: Oxford University Press.

Appendix 1.

Table 1. Developed Countries

COUNTRY	ESI*	ENVIR. SYSTEM	REDUC. STRESS	HUMAN VULNER.	SOC.INST CAPACITY	GLOBAL STEW.
SLOVENIA	58.8	54.5	45.6	85.0	64.9	56.0
PORTUGAL	57.1	53.3	61.6	78.9	56.2	40.9
GREECE	50.9	43.7	49.6	81.9	48.4	45.4
NEW ZEALAND	59.9	49.0	40.5	82.2	77.3	60.1
SPAIN	54.1	41.0	55.1	80.6	64.0	37.3
ISRAEL	50.4	39.2	35.2	80.4	63.7	50.2
AUSTRALIA	60.3	66.1	43.6	84.9	70.6	38.9
CANADA	70.6	90.4	47.0	85.0	75.2	39.5
ITALY	47.2	33.0	35.6	82.7	58.1	46.3
IRELAND	54.8	57.2	28.0	83.9	69.6	48.6
FRANCE	55.5	50.7	34.6	82.2	68.8	54.7
UNITED KINGDOM	46.1	38.5	12.3	84.8	78.7	40.5
BELGIUM	39.1	25.9	9.4	80.8	65.4	57.2
NETHERLANDS	55.4	44.7	21.1	85.1	81.7	60.6
FINLAND	73.9	78.7	57.7	84.9	86.1	54.9
GERMANY	52.5	45.3	25.1	80.9	75.6	49.6
AUSTRIA	64.2	64.6	40.1	85.1	74.3	66.7
SWEDEN	72.6	72.1	51.2	85.0	86.6	67.1
ICELAND	63.9	73.1	33.3	83.6	79.0	53.1
JAPAN	48.6	32.7	28.9	82.1	75.1	38.0
UNITED STATES	53.2	60.1	30.8	80.4	74.2	24.2
DENMARK	56.2	43.9	29.2	82.0	81.5	54.4
NORWAY	73.0	77.6	57.6	84.8	85.5	52.3
SWITZERLAND	66.5	52.4	36.1	84.3	91.5	64.5
Average	**57.7**	**53.6**	**37.8**	**82.9**	**73.0**	**50.0**

* These terms are defined in section 2.

	ESI	ENVIR. SYSTEM	REDUC. STRESS	HUMAN VULNER.	SOC.INST CAPACITY	GLOBAL STEW.
KOREA	**35.9**	**21.7**	**15.6**	**81.7**	**58.6**	**35.1**

Table 2. Developing Countries

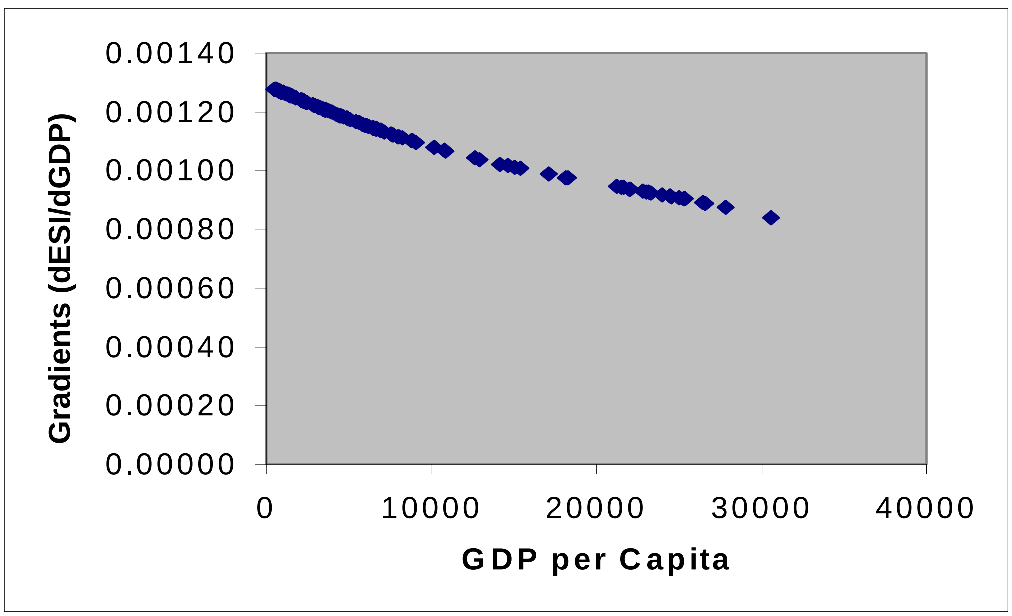
COUNTRY	ESI	ENVIR. SYSTEM	REDUC. STRESS	HUMAN VULNER	SOC. INST.	GLOBAL STEW.
CONGO, DEM. REP. OF	54.3	75.8	51.1	25.1	38.3	67.4
ETHIOPIA	41.8	43.6	55.0	2.4	39.7	66.6
BURUNDI	41.6	45.1	45.6	6.4	40.9	64.9
MYANMAR	46.2	44.7	67.6	32.6	27.5	55.1
SLOVAK REPUBLIC	61.6	59.3	55.3	84.3	56.0	66.5
MALAWI	47.3	50.4	49.8	7.4	48.5	71.8
GUINEA-BISSAU	38.8	37.3	57.1	5.1	34.7	53.9
NIGER	39.4	53.3	40.4	5.1	30.6	66.2
NEPAL	45.2	37.8	48.9	31.5	41.8	66.5
BURKINA FASO	45.0	44.7	55.4	10.3	38.8	68.3
TAJIKISTAN	42.4	42.5	61.3	21.6	31.4	45.6
MOZAMBIQUE	51.1	54.9	68.2	5.4	46.9	65.0
CAMBODIA	45.6	47.0	60.9	8.2	41.6	58.3
CHAD	45.7	59.2	51.7	3.8	39.5	66.9
RWANDA	40.6	43.6	52.7	6.1	39.0	53.0
MALI	47.1	60.5	51.2	9.3	36.9	67.6
LAO PEOPLE'S DEM.REP	56.2	57.6	56.4	35.3	57.3	65.6
MADAGASCAR	38.8	21.5	55.7	7.9	44.9	63.1
TANZANIA	48.1	54.9	59.0	9.9	40.7	63.5
NIGERIA	36.7	39.7	45.2	18.2	29.5	45.2
CENTRAL AFRICAN REP.	54.1	68.6	61.5	9.4	44.9	68.7
TOGO	44.3	47.1	53.9	18.3	34.4	61.0
UGANDA	48.7	49.0	46.0	15.4	50.5	74.2
ZAMBIA	49.5	49.8	49.5	6.9	63.6	63.5
KYRGYZ REPUBLIC	51.3	43.5	67.2	52.3	44.7	47.2
GAMBIA, THE	44.7	40.3	58.6	37.3	32.7	54.8
VIETNAM	45.7	42.7	51.2	50.5	33.2	60.0
BANGLADESH	46.9	40.9	65.4	40.3	29.8	59.7
KENYA	46.3	51.9	62.9	10.2	35.7	58.3
BENIN	45.7	43.0	50.1	21.0	38.0	73.0
MOLDOVA	54.5	55.0	68.9	77.3	34.6	45.2
MONGOLIA	54.2	70.5	58.3	32.8	42.5	52.7
INDIA	41.6	27.4	55.3	43.8	40.8	44.3
GHANA	50.2	52.3	59.9	32.3	38.6	62.2
NICARAGUA	51.8	60.5	55.4	45.6	37.4	59.6
PAKISTAN	42.1	37.6	47.7	41.5	31.8	59.2
GUINEA	45.3	49.7	60.4	8.1	40.0	55.5
INDONESIA	45.1	32.6	60.8	57.5	37.3	45.4
HAITI	34.8	18.1	56.4	7.9	35.5	58.3
ARMENIA	54.8	50.4	69.2	51.0	42.6	59.4
SENEGAL	47.6	51.9	56.8	30.6	35.5	57.6
ANGOLA	42.4	62.6	56.2	1.9	32.8	51.8
BHUTAN	56.3	49.4	62.0	31.4	58.4	70.9
ZIMBABWE	53.2	56.5	63.7	39.2	44.4	53.9
AZERBAIJAN	41.8	44.2	61.2	47.6	27.9	27.8
CAMEROON	45.9	47.1	60.5	15.1	36.2	60.4
UZBEKISTAN	41.3	49.2	54.6	60.3	21.0	32.7
CHINA,P.R.: MAINLAND	38.5	31.5	55.9	61.9	33.7	18.4

PAPUA NEW GUINEA	51.8	66.9	56.7	18.0	39.7	63.3
COTE D IVOIRE	43.4	45.4	52.0	22.4	33.9	57.9
SRI LANKA	51.3	37.8	58.4	56.3	48.4	63.7
UKRAINE	35.0	42.7	43.0	73.6	20.9	14.9
HONDURAS	53.1	57.2	56.1	61.3	41.6	55.2
PHILIPPINES	41.6	19.6	56.1	56.4	42.1	49.3
ALBANIA	57.9	62.2	62.8	59.8	47.2	59.0
BOSNIA AND HERCEGOVINIA	51.3	45.8	64.2	63.7	44.9	40.4
BOLIVIA	59.4	71.1	61.4	43.5	49.3	62.5
BULGARIA	49.3	35.9	59.4	79.1	37.5	53.0
KAZAKHSTAN	46.5	50.6	64.3	70.6	27.8	27.6
BELARUS	52.8	53.0	70.3	79.3	30.7	40.2
PARAGUAY	57.8	63.8	52.4	60.7	53.3	61.8
GUATEMALA	49.6	54.0	51.3	52.3	39.1	55.7
MACEDONIA, FYR	47.2	43.0	37.2	73.8	46.3	53.9
THAILAND	51.6	50.0	63.7	58.9	45.0	39.6
ECUADOR	54.3	65.3	57.2	61.2	36.9	54.8
ROMANIA	50.0	48.1	62.3	62.7	35.4	48.7
RUSSIA	49.1	72.2	60.0	79.7	26.8	14.3
NAMIBIA	57.4	75.0	48.1	38.5	54.3	58.1
DOMINICAN REPUBLIC	48.4	36.9	65.1	51.5	42.3	47.5
EL SALVADOR	48.7	50.1	49.2	48.8	40.5	59.5
PERU	56.5	69.3	64.8	51.1	45.9	41.2
LATVIA	63.0	62.9	68.9	74.8	53.7	59.2
COLOMBIA	59.1	69.8	59.0	71.7	42.6	58.5
JAMAICA	40.1	21.4	47.6	61.4	46.6	38.2
LITHUANIA	57.2	59.7	64.9	64.8	50.9	44.9
SOUTH AFRICA	48.7	44.8	53.8	57.7	52.1	35.0
BOTSWANA	61.8	77.2	53.1	51.0	60.6	56.7
MALAYSIA	49.5	58.9	43.2	73.0	44.2	37.0
PANAMA	60.0	57.1	60.9	66.2	62.4	55.3
ESTONIA	60.0	57.7	67.4	76.3	61.1	36.7
COSTA RICA	63.2	51.5	45.3	79.1	81.2	64.5
GABON	54.9	81.2	62.9	25.6	32.4	49.8
VENEZUELA	53.0	77.2	60.8	57.8	31.1	30.7
MEXICO	45.9	31.1	54.7	67.2	42.2	48.7
POLAND	46.7	38.6	42.1	78.5	53.6	34.3
HUNGARY	62.7	53.7	60.0	84.3	62.3	65.0
TRINIDAD AND TOBAGO	40.1	49.7	47.2	71.4	31.6	13.1
CROATIA	62.5	53.4	65.9	76.6	69.5	48.5
BRAZIL	59.6	66.3	63.2	66.0	51.9	50.0
CHILE	55.1	50.3	57.4	79.9	57.5	36.4
CZECH REPUBLIC	50.2	52.7	32.0	79.7	56.1	46.0
URUGUAY	66.0	65.4	60.5	81.1	68.1	60.7
ALGERIA	49.4	50.3	60.2	64.2	32.0	49.8
EGYPT	48.8	53.8	48.4	62.1	34.3	57.0
IRAN, I.R. OF	44.5	41.0	58.2	70.7	26.9	41.4
JORDAN	51.7	42.7	51.2	70.9	50.4	56.1
KUWAIT	23.9	19.1	10.2	76.5	36.5	14.4
LEBANON	43.8	35.5	35.4	74.8	46.7	45.4
LIBYA	39.3	53.7	31.2	62.2	33.0	26.8

MAURITANIA	38.9	55.4	46.6	9.7	26.7	47.7
MOROCCO	49.1	33.2	59.2	60.4	43.9	60.7
OMAN	40.2	46.0	38.3	41.0	40.2	33.6
SAUDI ARABIA	34.2	35.0	28.8	76.2	33.6	18.2
SUDAN	44.7	53.1	57.1	29.5	23.2	60.2
SYRIAN ARAB REPUBLIC	43.6	48.3	47.4	68.1	26.5	44.0
TUNISIA	50.8	48.4	56.9	68.8	35.3	58.5
TURKEY	50.8	54.8	59.7	66.8	39.2	38.1
UNITED ARAB EMIRATES	25.7	27.3	12.6	75.0	36.8	9.3
SIERRA LEONE	36.5	42.1	43.4	2.2	35.5	61.2
ARGENTINA	61.5	72.4	60.5	75.2	51.6	49.6
Average	**48.6**	**50.1**	**54.7**	**46.2**	**41.7**	**51.4**

Source for Tables 1 and 2: ESI Report (2002).

Figure 1. Gradients* versus GDP per Capita.



*The gradients represent the impact of a change in GDP per capita on the environmental sustainability index.

Appendix 2.

Non-parametric Kernel Estimation

Consider the stochastic process $\{y_t, x_t\}$, $t = 1,2,...,n$; where y_t is a scalar and $x_t = (x_{t1}, x_{t2},..., x_{tq})$ is $(1 \times q)$ vector which may contain the lagged values of y_t. The regression model is $y_t = m(x_t) + u_t$, where $m(x_t) = E(y_t \mid x_t)$ is the true but unknown regression function, and u_t is the error term such that $E(u_t \mid x_t) = 0$.

If $m(x_t)$ is a correctly specified family of parametric regression, then one can construct the ordinary least squares (OLS) estimator of $m(x_t)$. For example, if $m(x_t) = \alpha + x_t \beta = X_t \delta$, where $\delta = (\alpha \quad \beta')'$ and $X_t = (1 \quad x_t)$, is linear we can obtain the OLS estimator of δ by minimizing $\sum u_t^2 = \sum (y_t - X_t \delta)^2$ as

(2.1) $$\hat{\delta} = (X'X)^{-1} X'y .$$

However, it is well known that if the specified regression $X_t \delta$ is incorrect then the OLS estimates $\hat{\delta}$, and hence $\hat{m}_t = X_t \hat{\delta}$ are inconsistent and biased, and they may generate misleading results.

An alternative approach is to use the consistent nonparametric regression estimation of the unknown $m(x)$ by the local linear least squares (LLLS) method. For obtaining the LLLS estimator we first write first-order Taylor series expansion of $m(x_t)$ around x so that

(2.2.) $$y_t = m(x_t) + u_t = m(x) + (x_t - x) m^{(1)}(x) + v_t$$
$$= \alpha(x) + x_t \beta(x) + v_t = X_t \delta(x) + v_t ,$$

where $\alpha(x) = m(x) - x\beta(x)$, $\delta(x) = [\alpha(x)\beta(x)']'$, and $\beta(x) = m^{(1)}(x)$, and $m^{(1)}$ shows the first derivative. Then, solving the problem:

(2.3) $$\min \sum_{t=1}^{n} v_t^2 K_{tx} = \min \sum_{t=1}^{n} (y_t - X_t \delta(x))^2 K_{tx}$$

with respect to $\delta(x)$, we get the LLLS estimator as:

(2.4) $$\tilde{\delta}(x) = (X' K(x) X)^{-1} X' K(x) y$$

where *K(x)* is a diagonal matrix of the kernel (weight) $K_{tx} = K((x_t - x)/h)$ and *h* is the window width. The LLLS estimators of $\alpha(x)$, $\beta(x)$ and $m(x)$ are calculated as $\tilde{\alpha}(x) = [1 \quad 0]\tilde{\delta}(x)$, $\tilde{\beta}(x) = [0 \quad 1]\tilde{\delta}(x)$ and $\tilde{m}(x) = \tilde{\alpha}(x) + x\tilde{\beta}(x)$. These LLLS estimators are consistent; for further details on properties, see Fan and Gijbels (1996) and Pagan and Ullah (1999).

The LLLS estimators of $\delta(x)$ and $m(x)$ are also called the nonparametric kernel estimators, which are essentially the local linear fits to the data corresponding to the x_i's which are in the interval of length *h* around *x*, the point at which δ is calculated.

In this sense the LLLS estimator provides the varying estimates of δ with changing values of x. It depends on the kernel function K and the window width h. The function K is chosen to be a decreasing function of the distances of the regressor x_t from the point x, and the window width h determines how rapidly the weights decrease as the distance of x_t from x increases. In our empirical analysis we have considered an optimal parabolic kernel and the cross validated window width; for further details, one can see Pagan and Ullah (1999, ch.3) and Racine (1999).