THE JOURNAL OF THE KOREAN ECONOMY, Vol. 6, No. 1 (Spring 2005), 67-89

# Interactions among Economic Development, Openness to Trade and Environmental Sustainability with a Case Study on South Korea*

Savas Alpay**

In this study, we try to provide answers for the following three questions: (i) whether economic development (as proxied by GDP per capita) is a significant determinant of environmental sustainability, (ii) whether this interaction shows different characteristics at different stages of the economic development; in particular, whether the ESI-GDP interaction in South Korea is different from those of the developing countries and developed countries, and (iii) whether trade liberalization leads to higher environmental sustainability. We demonstrate that an increase in GDP per capita will have higher impact on the environmental sustainability index (ESI) in South Korea as compared to both developing countries and developed countries. Regarding the impact of trade liberalization policies on environmental sustainability, our estimations do 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.

JEL Classification: Q56
Keywords: environment, environment sustainability, economic development, openness to trade, South Korea

* Received August 30, 2004. Accepted April 19, 2005.
** Department of Economics, TOBB Economy and Technology University, Ankara, Turkey.

## 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 literature. EKC hypothesis has been tested by many others: Shafik and Bandyopadhyay (1992), Selden and Song (1994), Cropper and Griffith (1994), Kaufmann *et al*. (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 increase 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 (2002). 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; 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). By doing so, we will be able to examine the EKC hypothesis in a very comprehensive data set, which incorporates many different indicators of environmental sustainability. The data set is also very rich in terms of the number of countries included.

We will analyze the EKC hypothesis in a way different from the earlier studies by concentrating on the interaction between economic development and environmental sustainability. Furthermore, earlier studies have been subject to a modelling criticism: It is unclear why the specific reduced-form equation (the quadratic or cubic specification of pollution with respect to income per capita) employed in their estimations exists. In our paper, we will use non-parametric kernel estimation technique. This technique does not impose any a priori functional restrictions in the empirical testing of EKC hypothesis, and avoids the modelling criticism raised in the literature.

In brief, we will try to answer the following questions: (i) whether economic development (as proxied by GDP per capita) is a significant determinant of environmental sustainability, (ii) whether this interaction shows different characteristics at different stages of the economic development; and (iii) whether trade liberalization leads to higher environmental sustainability.

Given the data set included in the ESI (2002) report on the sustainability of the environment, as a specific application, we will identify the conditions of South Korea 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. Finally, we will also determine whether the ESI-GDP interaction in South Korea is different from those of the developing countries and developed countries.

In section 2, we briefly present an introduction to the Environmental Sustainability Index (ESI). Section 3 introduces our model and estimation results, and section 5 summarizes main findings.

## 2. ENVIRONMENTAL SUSTAINABILITY INDEX

Environmental Sustainability Index (ESI) (2002) 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: (i) *the state of the environmental systems*, such as air, soil, ecosystems and water; (ii) *the stresses on those systems*, in the form of pollution and exploitation levels; (iii) *the human vulnerability* to environmental change in the form of loss of food resources or exposure to environmental diseases; (iv) *the social and institutional capacity* to cope with environmental challenges; and (v) *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.

These core components have been derived from a set of 20 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 variables is reported in the appendix.

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 2002 ESI are Finland, Norway, and Sweden. 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 20 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 table 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 South Korea is 35.9, and thus the performance of South 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. South Korea outperforms developing countries with respect to *human vulnerability* and *social and institutional capacity* dimensions. The worst performance of South 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.

South Korea ranks 135 among all countries with respect to overall ESI score. This indicates that with respect to environmental sustainability, the conditions in South 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,[1] water quantity,[2] water quality, biodiversity[3] and land,[4] the performance of South Korea is below average in her peer group.[5] 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,[6] reducing waste and consumption pressures. In this group, reducing air pollution is the leading problem. South Korea's performance in the *reducing human vulnerability* dimension is almost same as the average performance in her peer group. The indicators included in this dimension are basic human sustenance[7] and environmental health.[8] With respect to social and institutional capacity dimension, science and technology indicator is above average, but the other indicators namely, capacity for debate,[9] private

---

[1] 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 (SO2), nitrogen dioxide (NO2) and total suspended particulates (TSP).

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

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

[4] 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.

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

[6] 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.

[7] 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.

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

[9] This indicator measures these features. Variables include the existence of civil and political liberties, the presence of democratic institutions, the degree to which important

sector responsiveness, eco-efficiency[10] and environmental governance,[11] 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 South Korea in regards to these indicators is also lower than her peers. In brief, the assessment of 20 indicators, which make up the core components of ESI, shows that the environmental sustainability in South Korea needs to be improved from many different angles. A comprehensive pro-environmental policy package should be developed.

## 3. 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.

Empirical studies in the literature of Environmental Kuznets Curve hypothesis described in the introduction use the following generic model:

$$Y_{it} = G_{it}\ b_1 + G_{it}^2\ b_2 + G_{it}^3\ b_3 + X_{it}\ b_4 + E_{it}\ ,$$

---

environmental issues are debated by a society, and whether or not information is available to support decision-making.

10) 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.

11) 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.

where $Y_{it}$ is a measure of water or air pollution in station *i* in year *t*, $G_{it}$ is GDP per capita in year *t* in the country in which station *i* is located, $X_{it}$ is a vector of other covariates (like temperature, population density, location dummies such as residential, industrial and commercial) and $E_{it}$ is the error term. In such a model, the test of EKC hypothesis is done by checking the sign and the significance of the coefficients of GDP per capita terms. Earlier studies on the empirical test of EKC hypothesis have been subject to a modelling criticism: It is unclear why the specific reduced-form equation, shown above, exists. Our estimation methodology differs from the earlier studies and deals with this problem.

Our model is as follows:

$$\text{ESI} = f(\text{ED, OT}), \tag{1}$$

where ESI refers to Environmental Sustainability Index; ED represents economic development and it is proxied by GDP per capita; OT represents 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).

As opposed to classical regression aproach, equation (1) does not specify any linear or non-linear explicit relationship between the dependent and the independent variables. As we are missing a theoretical explanation on how environmental sustainability, the economic development and the openness to international markets should be related to each other, we try to avoid starting with a specific model. In such a case, a non-parametric approach which does not require a priori functional relationship seems desirable. Therefore, we choose to use non-parametric kernel estimation method (Pagan and Ullah, 1999) in the econometric analysis of equation (1). 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, as desired. It identifies the best possible model from the data itself. Secondly, the nonparametric kernel estimation technique enables us to compute the impact of independent variables on the dependent variable for *each observation point* (i.e., for each country in our case) 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. Before moving to our estimation results, a brief introduction for the non-parametric kernel estimation method will be useful.

### 3.1. 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 $\delta$ by minimizing $\sum u_t^2 = \sum (y_t - X_t\delta)^2$ as

$$\hat{\delta} = (X'X)^{-1} X'y. \qquad (2)$$

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

$$\begin{aligned} y_t &= m(x_t) + u_t \\ &= m(x) + (x_t - x)m^{(1)}(x) + v_t \\ &= \alpha(x) + x_t\beta(x) + v_t \\ &= X_t\delta(x) + v_t , \end{aligned} \quad (3)$$

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:

$$\min \sum_{t=1}^{n} v_t^2 K_{tx} = \min \sum_{t=1}^{n} (y_t - X_t\delta(x))^2 K_{tx} , \quad (4)$$

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

$$\hat{\delta}(x) = (X'K(x)X)^{-1} X'K(x)y , \quad (5)$$

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 $\hat{\alpha}(x) = [1 \quad 0]\hat{\delta}(x)$, $\hat{\beta}(x) = [0 \quad 1]\hat{\delta}(x)$ and $\hat{m}(x) = \hat{\alpha}(x) + x\hat{\beta}(x)$. 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 $\delta$ is calculated. In this sense the LLLS estimator provides the varying estimates of $\delta$ 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).

### 3.2. Estimation Results

Our estimation results for the model in equation (1) indicate that the estimated coefficients of the openness to trade variable are mostly positive but not statistically significant for most of the observations. Thus, we will only report the results corresponding to impact of economic development on environmental sustainability. The estimated coefficients for GDP per capita turn out to be positive and significant. In particular, for South Korea the value of the coefficient is equal to 0.000516. The average of the estimated coefficients for developing countries is 0.000416, and for the developed countries, it is equal to 0.000383. As our estimation technique presents gradients with their standard errors for *each* observation point, we can not list them here due to space constraints.[12] Instead, we will use plots to report our estimation results. The gradients represent the impact of a change in GDP per capita on the environmental sustainability index (ESI). The plot of gradients across GDP per capita is given in the appendix (Figure 1). It is clearly observed that the impact of GDP per capita on environmental sustainability is positive at all levels of economic development, but there is no a specific pattern. Table 1 reports the gradients for countries which have comparable GDP per capitas with South Korea.

---

[12] 135 gradients have been estimated. Table 1 presents a subset of these estimations. The author can easily provide these estimation results if requested.

**Table 1 Non-parametric Kernel Estimations**

| Country | GDP per Capita | Gradient [∂ESI / ∂(GDP per Capita)] |
|---|---|---|
| GABON | 3908 | 0.000513 |
| VENEZUELA | 4122.2 | 0.000447 |
| MEXICO | 4237.2 | 0.000495 |
| POLAND | 4254.8 | 0.000471 |
| HUNGARY | 4658.1 | 0.000165 |
| TRINIDAD AND TOBAGO | 4664.5 | 0.000464 |
| CROATIA | 4701.8 | 0.000498 |
| BRAZIL | 4854.3 | 0.000325 |
| CHILE | 5350.9 | 0.000465 |
| CZECH REPUBLIC | 5536.3 | 0.000362 |
| URUGUAY | 6812.2 | 0.000430 |
| KOREA | 6829.2 | 0.000516 |
| SIERRA LEONE | 7715.8 | 0.000329 |
| ARGENTINA | 8276.5 | 0.000367 |
| SLOVENIA | 9899.7 | 0.000320 |
| PORTUGAL | 11276.9 | 0.000492 |
| GREECE | 11618.7 | 0.000443 |
| Average | 6395.12 | 0.000418 |

## 4. 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 South Korea together with the interactions between economic development and environmental sustainability. The index has been based on 5 core dimensions, which are derived from 20 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, South 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 South Korea shows an average performance, a lot of countries outperform South 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 shows 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, on average. In the literature, EKC hypothesis is usually tested by modelling an indicator of pollution as a function of GDP per capita; the results are checked for whether they present a support for an inverted-U type relationship between pollution and income.

In our set-up, we present a more general analysis, and instead of using a specific pollutant, we focus on an indicator of overall environmental sustainability. In such a set-up, if EKC hypothesis is to hold, one would expect that the gradients (representing the impact of a change in income on the environmental sustainability) would be negative for the low and middle-income economies, and positive for the higher income groups. Our estimation results do not support the EKC hypothesis.

We also demonstrate that an increase in GDP per capita will have a higher impact on the environmental sustainability index (ESI) in South Korea as compared to the averages of both developing countries and developed countries. This finding indicates that for South 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 towards higher economic growth to protect their environment; development and sustainability can be complementary if suitable policies on development and environment are implemented jointly.

## APPENDIX

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."

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 and Consumption Pressures

Consumption pressure per capita
Radioactive waste

- Reducing Population Pressure
  Total fertility rate
  % change in projected population between 2000 and 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

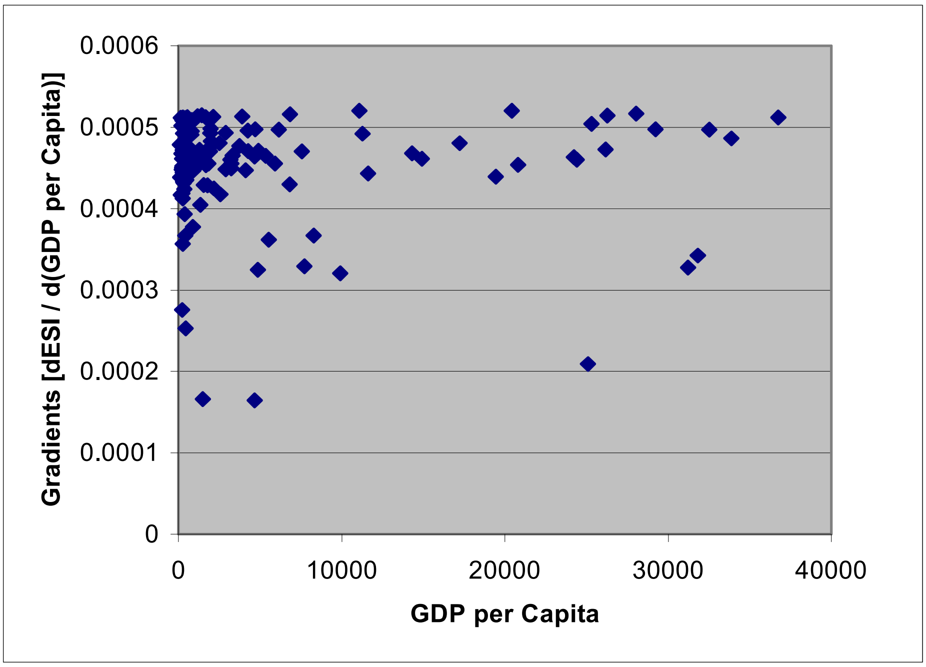
The Environmental Sustainability Index (ESI) is calculated by taking the average values of the 20 indicators, which are computed from the variables.

**Table A1**

| | ESI | ENVIR. SYSTEM | REDUC. STRESS | HUMAN VULNER. | SOC.INST CAPACITY | GLOBAL STEW. |
|---|---|---|---|---|---|---|
| South Korea | 35.9 | 21.7 | 15.6 | 81.7 | 58.6 | 35.1 |
| Developed Countries (Average Scores) | 57.7 | 53.6 | 37.8 | 82.9 | 73.0 | 50.0 |
| Developing Countries (Average Scores) | 48.6 | 50.1 | 54.7 | 46.2 | 41.7 | 51.4 |

Source: ESI Report (2002).

**Figure A1 Gradients * versus GDP per Capita**




Note: * The gradients represent the impact of a change in GDP per capita on the environmental sustainability index (ESI).

## REFERENCES


Agras, J. and D. Chapman, "A Dynamic Approach to the Environmental Kuznets Curve Hypothesis," *Ecological Economics*, 28, 1999, pp. 267-277.

Alpay, S., *Trade and the Environment: Analysis of Reciprocal Interactions*, Boston: Kluwer Academic Publishers, 2002.

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

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

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

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

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

_____________, "Environmental Impacts of North American Free Trade Agreement," in *The US-Mexico Free Trade Agreement*, P. Garber (ed.), Cambridge, MA: MIT Press, 1993.

_____________, "Economic Growth and the Environment," *Quarterly Journal of Economics*, 110, 1995, pp. 353-377.

Hettige, H., M. Mani, and D. Wheeler, "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, 1999.

Holtz-Eakin, D. and T. M. Selden, "Stoking the Fires? $CO_2$ Emissions and Economic Growth," *Journal of Public Economics*, 57, 1995, pp. 85-101.

Kaufmann, R. K., B. Davidsdottir, S. Garnham, and P. Pauly, "The

Determinants of Atmospheric $SO_2$ Concentrations: Reconsidering the Environmental Kuznets Curve," *Ecological Economics*, 25, 1998, pp. 209-230.

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

Racine, Jeff, N© BETA, *Computer Software*, University of South Florida, 1999.

Rothman, D. S., "Environmental Kuznets Curves-Real Progress or Passing the Buck? A case for Consumption-Based Approaches," *Ecological Economics*, 25, 1998, pp. 177-194.

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

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

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

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

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

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

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

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

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