A Consumption Based Human Development Index and The Global Environmental Kuznets Curve*

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ABSTRACT

We extend the analysis of Jha and Murthy (2003) to relate consumption to environmental degradation (conceived of as a composite) within a cross-country framework. We use the method of Principal Components Analysis (PCA) to construct an Environmental Degradation Index (EDI) for each country and global environmental degradation (GED) as the sum of the EDI's. We then identify outliers and influential observations among both the environmental and consumption related variables. Canonical Discriminant analysis is then used to classify development classes along environmental lines. We then estimate a simultaneous equation model to analyze the pattern of causation between per capita income, consumption and environmental degradation. We estimate a Global Environmental Kuznets curve (GEKC) as a relation between EDI ranks and ranks of the consumption-based EDI. A cubic representation is most appropriate with high-consumption countries contributing excessively to GED and middle-consumption countries slightly less. Low-consumption countries are contributing insignificantly to GED. Finally we present an alternative consumption-based Human Development Index to UNDP's income-based Human Development Index. We then compare the ranking of countries according to the consumption-based HDI ranks with their ranking according to their EDI. Two sets of data drawn from the Human Development Report (HDR) UNDP(2000)) are used in the analysis. One relates to the environment and the other to developmental variables. For the formation of a composite index that would enable the estimation of a GEKC for 174 countries, we used cross-sectional data used in the HDR. The two main contributions of this paper are to build a consumption based HDI and to estimate a Global EKC based on consumption. A simultaneous equations model explains the causal structure that is responsible for Global Environmental Degradation. Further, with Canonical Discriminant Analysis it has been shown that GED does not have geo-physical basis but an anthropogenic basis. As a part of the system of equations a Global Consumption Function has been estimated that displays interesting results. In net, the paper attempts to establish that a certain 'type of development' that characterizes high consumption countries is primarily responsible for Global Environmental Degradation.

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I. Introduction

The interdependence between levels of economic development and environmental degradation[1] has typically been explained by the Environmental Kuznets Curve (EKC). Some commentators argue that the EKC, which is purported to be an inverted *U*- shaped curve between select pollutants and per capita income (PCI), supports the contention that so long as developing countries are below the threshold of development, their growth would only increase the Global Environmental Degradation (GED). Since developed countries lie beyond the peak of the EKC, further economic growth would only lower GED. A corollary is that developing countries must sacrifice growth and developed countries should enhance growth for the sake of a healthy global environment. This argument, would thus achieve global inter-temporal efficiency by fostering global atemporal (spatial) inequity.

On the other hand, we believe that "the applicability of the notion of sustainability has ultimately got to be *universal and refer to the indefinite future*" and must be related to consumption (Jha and Bhanu Murthy (2000) p.3).[2] In particular, Jha and Whalley (2001) have argued that the notion of the EKC (typified as a relation between per capita incomes and select pollutants as in the extant literature) for any given country is tenuous, at best.[3]

One problem with extant EKC formulations is that the analysis is confined to a few select pollutants and to a narrow measure of economic development (per capita income). In particular, there has been little effort to relate per capita income (or some other broad measure of economic development) to a composite index of environmental degradation in a cross section of countries. Jha and Murthy (2003) have estimated a Global EKC (GEKC), for 174 countries using a more complete measure of economic development than per capita income – the Human Development Index[4] (HDI) ranks of countries- and relate these to the levels of environmental degradation of these countries as captured in a composite Environmental Degradation Index (EDI). We established that this GEKC assumes a cubic form with developed countries contributing the lion's share of GED. This paper was a forerunner of the present paper. Our attempt here is to shift the focus in the growth-environment debate[5] towards consumption.

This paper is organized as follows. Section II recounts the notion of global environmental degradation whereas section III evaluates the existing consumption- based approaches. The fourth lays out the methodology for our analysis and data sources and section V reports the results. Section VI concludes.

II Global Environmental Degradation

When analyzing GED, a number of issues have to be addressed: does it arise from local phenomenon restricted to individual countries? Is income per capita an appropriate basis for tracing the EKC? Is GED a consequence of geophysical phenomenon or is it anthropogenic? What are the specific causative factors responsible for GED? What is the structure of causal factors? Why is GED a composite? What are the implications of these questions for methodology?[6] A considered response to these questions would involve a fresh examination of the empirical form and analytical content of the GEKC as a manifestation of GED. In this respect, if the intention is to study the composite phenomenon, all factors responsible for GED must be included in the analysis.

There seems to be a consensus that the following four factors are primarily responsible for environmental degradation: a) Pollution – of various types; b) Lack of bio-diversity; c) Waste- toxic and non-toxic; and d) Erosion of the natural resource base due to phenomenon like deforestation, depletion of fresh water resources, paper consumption, etc. Levels of these indictors or the like, define the '**state of the world**' in an entropic context. In the pristine natural state there is no entropy. Hence, there is no degradation or disorganization of the 'state of the world'. Entropy occurs as unwarranted human activity takes place. As long as anthropogenic activity is in consonance with and commensurate to the 'state of the world' there is no environmental degradation. Our basic hypothesis is that excessive and lop-sided consumption patterns of human consumption are the most fundamental 'cause' of entropy. Especially,

[1] It is so called because Kuznets (1955) had found a similar inverted – *U* shaped relationship between income growth and income inequality.

[2] A number of definitions of sustainability are discussed here, *ibid.* p. 4– 8.

[3] For a further review of empirical studies on EKC see Jha and Murthy (2003).

[4] As is well known, the HDI rank is an ordinal index.

[5] For a review of the growth-environment debate see Jha and Murthy (2003).

[6] "Trans-boundary pollution has been overemphasized in literature, as the cause of GED. So it must be pointed out that it is responsible only for the spread of pollution and would nevertheless remain only one of the factors responsible for GED, not the entire 'cause'.

extreme events cause severe degradation. Therefore, it is important to identify outliers and influential observations and to measure their contribution to global environmental degradation.

GED occurs as a result of an accumulation of local phenomenon. Often GED has been treated as a geographic and natural phenomenon and not explicitly as an economic phenomenon, more particularly one that arises out of a certain 'type of economic development'. GED is a composite because such phenomena mutually influence each other. For instance, excessive paper consumption would result in deforestation, which would cause a fall in water resources and a growth in CO2 levels, which would then cause global warming, soil degradation and denudation, which would adversely affect bio-diversity and so on. Therefore, we would prefer to call them indicators of GED. *In our understanding, the composite of GED is caused by a certain type of development.*

A maintained hypothesis of the present paper is that global environmental problems are rooted in local phenomena. If this were true then the GEKC would arise within a collective cross-sectional (cross-country) framework. A major issue with regard to the EKC is that extant studies have taken for granted the conceptual phenomenon of its empirical basis. GED is an economic phenomenon being 'caused' by certain 'latent' factors, related to economic development. We conceptualize GED as a "composite" since it would be simplistic to assume otherwise and conceive of this as a conglomerate of many factors that may be acting as vectors in different directions, with the resultant vector having a certain central tendency (*the grand mean*). A secular increase (both temporally and spatially) in this conglomerate of factors would 'cause' entropy and would be indicative of the phenomenon of GED. The composite of GED is in this sense, 'caused' by another composite of economic development, with each of the composites appropriately weighted. It is important to both conceive of and measure this composite and relate it to the 'type of development' that leads to degradation.

At the empirical level, these indicators involve both simultaneity and multicollinearity. The regression approach (to the EKC) has this limitation of multicollinearity as well as the need to assume normality. In contrast, Principal Components Analysis (PCA) performs well in relation to removing these weaknesses of regression analysis. PCA is based on a linear transformation of the 'regressors' such that they are orthogonal to each other by design. Hence, the information contained in the all points in the event space is retrievable. None of it is treated as a random error (that is orthogonal to the best fit line). Secondly, the normality assumption is not essential. In the real world, where there are wide differentials amongst countries, and between individual effects of indicators, such an assumption is dispensable. Thirdly, with such a dispersed set of outcomes, PCA is ideally suited because it maximizes the variance rather than minimizing the least square distance. For these reasons we chose PCA.

III Existing Consumption-based approaches

While it is common to relate environmental degradation to PCI certain studies have argued that factors related to production are the possible reasons behind environmental degradation (Grossman & Krueger, 1992, 1994; Radetzki, 1992; Panayotou, 1993; Grossman, 1995).[7] Nonetheless, there have been a few studies (e.g. Ehrlich and Holdren (1971)) that have attempted to relate degradation to consumption. They introduced the Ehrlich identity:

$I \equiv PAT$, where

I = Environmental Impact
P = Population
A = Affluence
T = Technology

Ekins and Jacobs (1995) and Dietz and Rosa (1994) have rephrased this identity as

$I \equiv PCT$, where:

C = Consumption

Other authors (Amalric (1995), Ekins and Jacobs (1995) and Raskin (1995)) have used the composition of consumption. On the whole the IPAT approach provides the basic reference point for consumption based approaches. The broader question that is being asked is whether environmental degradation is anthropogenic or natural.

[7] The early discussion is based on Rothman (1998).

Production based approaches emphasize scale, composition and technique of production (Grossman & Krueger, 1992; Panayotou, 1993). The scale of production is responsible for reducing the per unit energy use. As the composition of national income moves from agriculture to industry and then to services, an inverted u-shaped pattern in terms of the corresponding pollution levels is expected to emerge. Along with economic development better techniques of production and hence lower pollution per unit would result.

There are reasons to believe that the analysis of environmental degradation in terms of consumption based approaches can be seen as being analogous to production based approaches. The scale of production is related to the size of the market and hence to population. As the composition of the national income shifts from agriculture, that is subsistence-based, up to services there could be an initial rise in consumption levels due to 'pent-up' demand and a subsequent fall. The parallel between technique and technology is straightforward. Hence, the parallels to scale, composition and techniques can be seen as population, consumption and technology, which are the broad planks of the IPAT framework.

Although there is a parallel between the two approaches certain problems exist in relation to production-based approaches. The most fundamental of them is that demand for production activity is derived demand[8] (Rees, 1995; Daly, 1996; Duchin, 1998). Further, Ekins (1977) argues that,

> if the shift in production patterns has not been accompanied by a shift in consumption patterns two conclusions follow: (1) environmental effects due to the composition effect are being displaced from one country to the other rather than reduced; and (2) this means of reducing environmental impacts will not be available to the latest developing countries, because there will be no coming-up-behind them to which environmentally intensive activities can be located.

Furthermore, production-based approaches do not capture the degradation that is caused directly by consumption, in terms of production and disposal of waste, vehicular pollution, excessive drawal of water resources, final consumption of energy and paper, etc. Another problem relates to taking income (as a proxy for production). While consumption may be a derivative of income, and may be closely related to it, there is reason to believe that consumption may nonetheless be a better measure than income in relation to the impact on environmental degradation. For instance, the problem at hand may be the measurement of pollution intensity across countries. The chosen measures could be either:

$$I_{pi} = \frac{E_i}{NI_i} \quad \text{or} \quad X_i = \frac{E_i}{C_i}$$

where,

Xi = Consumption pollution intensity in the i th country
Ci = Consumption level of i th country

and I_{pi} is the Income-pollution intensity in the i th country with
E_i = Emissions of the i th country
NI_i = National Income of th i the country

Now, if the propensity of consumption in the j th country is half that of the i th country and if consumption level replaces NI in the denominator then

$$\frac{X_j}{X_i} = 2$$

whereas

[8] If Say's law does not hold good.

$$\frac{I_{pi}}{I_{pj}} = 1$$

This illustrates the point that income based measures may tend to unduly narrow differentials where they exist.

While studying consumption some of the extant studies have termed waste as a problem of 'non-consumption' (Hawken, 1995; Rees, 1990). However, there is a measurement problem if such an approach is taken to its logical conclusion. For instance, if energy intensity is being measured one may write

$$C = C_a + C_w$$

where,

C_a = Actual consumption

C_w = Waste during consumption

and

$$N_p = \frac{V}{NI}$$

$$N_c = \frac{V}{C}$$

$$N_a = \frac{V}{C_a}$$

V = Energy use

N_p = Production based measure of energy intensity

N_c = Total consumption based measure of energy intensity

N_a = Actual consumption based measure of energy intensity

The relationship between the three measures is

$$N_p < N_c < N_a$$

This would obviously create problems when measuring the performance across countries since the level of both consumption as well as waste would differ. Further, both these dimension cannot be mechanically subsumed within production.

In the context of international trade Diwan and Shofik (1992) and Pearce and Warfood (1993) have emphasized that the North can improve local environmental quality at the cost of global pollution due to the 'debunking' technologies that they possess (Pollution Haven Hypothesis). To this must be added the fact that if consumption and disposal patterns were taken into account, the global pollution inequalities would get accentuated because in the north high levels of consumption (C) can continue at the cost of Cw being transferred to the South. Therefore, a consumption-based approach to the EKC whose interest is in knowing the levels of global environmental degradation and, more importantly, the distribution of degradation across the globe should be preferred.

Two recent consumption-based studies are Rothman (1998) and Suri and Chapman (1998). The former provides a useful review and meticulously charts the relationship between consumption and GDP and establishes an inverted U (EKC type) pattern in the case of certain commodities but does not go beyond that. It must be pointed out here that EKC does not imply that the consumption pattern has an inverted U shape – only that environmental degradation has an inverted U shape when plotted against PCI. The contribution of Rothman lies in raising the question, "Is it possible to go further to more explicitly and completely link a measure of environmental impact to consumption?" (Rothman, 1998). On the other hand, Suri and Chapman (1998) have concentrated on 'energy consumption itself, as a chief source of a number of environmental problems'. Their model begins by estimating pollution as:

$P_{ij} = a_{ij}E_i$

where,

a_{ij} = Emission/unit-energy (emission co-efficient)

E_i = Energy consumption

P_{ij} = Pollutant *j* from energy source *i.*

Subsequently they substitute pollution intensity with energy intensity. (Since high energy intensity also generally implies high pollution intensity, the two terms are used interchangeably). Their final model uses GDP:

$$\log E_i/\text{per capita} = f(GDP, (GDP)^2)$$

Hence they neither directly measure pollution (let alone environmental degradation, which is a broader concept) nor do they introduce consumption *per se* as an explanatory variable. Their subsequent models only include manufacturing and trade-related variables as explanatory variables. But nothing is done to modify the dependent variable - energy consumption. Effectively, then, there is no study that estimates the behaviour of environmental degradation against consumption.

IV Methodology and Data

Our *modus operandi* for arriving at a better understanding of the links between environmental degradation and consumption is as follows. Along the lines of Jha and Murthy (2003) we use the method of Principal Components Analysis (PCA) to construct an Environmental Degradation Index (EDI) for each country. We then identify outliers and influential observations among both the environmental and consumption related variables. Canonical Discriminant analysis is then used to classify development classes along environmental lines. We then estimate a simultaneous equation model to model the pattern of causation between PCI, consumption and environmental degradation. Finally we present an alternative consumption-based Human Development Index to UNDP's income-based HDI. We then compare the ranking of countries according to the consumption-based HDI ranks with their ranking according to their EDI.

Two sets of data drawn from the Human Development Report (HDR) (UNDP (2000))[9] are used in the analysis. One relates to the environment and the other to developmental variables. For the formation of a composite index that would enable the estimation of a GEKC for 174 countries, we used cross-sectional data used in the HDR. The HDR contains data on the following environmental variables.

a. Internal renewable water resources per capita (cubic meters/ year);
b. Annual fresh water withdrawals per capita (hundred cubic meters);
c. Annual fresh water withdrawals as a percentage of water resources;
d. Average annual rate of deforestation (per cent);
e. Printing and writing paper consumed per 1000 persons;
f. Total CO2 emission (million metric tons);
g. Share of world total CO2 (per cent);
h. Per capita CO2 emissions (metric ton);
i. SO2 emissions per capita (kilograms).

Environmental Degradation Index

Data on SO2 was scanty so it was dropped. Internal renewable water resources per capita are very large in comparison to the other variables. Hence this variable is dropped. For a similar reason the variable "total CO2 emissions" was also dropped. Thus, we are left with six variables.[10] These are:

1. PCFWW – Annual per capita fresh water withdrawals.
2. CENTFWW - Annual fresh water withdrawals as a percentage of water resources.
3. PAPCPM - Printing and writing paper consumed per capita.
4. PCCO2 - Per capita CO2 emission.
5. CO2SH - Share of world total CO2.
6. DEFOR – Rate of deforestation.

Surely, there are additional indicators of GED such as bio-diversity, waste and soil degradation but paucity of comparable data prohibits us from using these variables. The selected variables were

[9] The subsequent volumes did not contain specific variables that were of interest to us

[10] Lewis-Beck (1994) (an authority on Factor Analysis) argues that care must be taken about the scale and code of variables

expressed as ratios or as per capita measures, in order to minimize scale problems. In certain cases, DEFOR was negative implying reforestation, for this reason and other reasons DEFOR was dropped. Data gaps (there were very few) were filled with help of substitute means based on values for neighboring countries[11].

The 174 countries covered by the HDR have been classified into three classes according to the following criteria:

a. Human Development Index ≥ 0.8 - High Human Development. This included Countries with HDI rank from 1 to 45.
b. Human Development Index 0.5 to 0.799 - Medium Human Development. This included countries with HDI rank from 46 to 139.
a. Human Development Index < 0.5 -Low Human Development which include countries with HDI rank (HDIR) from 140 to 174.

The HDR 2000 contains certain developmental variables related to consumption. We use the following to understand the underlying developmental causal factors.

1. Per Capita Consumption (CONS).
2. GDP per capita in PPP $ (GDPPC$).
3. Energy consumption per capita (ENERGY).
4. Value of international trade (exports plus imports) (TRADEV).
5. Rate of urbanization (URBAN)

If the objective is a simple summary of the information contained in the raw data, the use of component scores is desirable. It is possible to represent the components exactly from the combination of raw variables. The scores are obtained by combining the raw variables with weights that are proportional to their component loadings. In our case the component scores have been used for determining the weight of each of the raw variables in constructing a composite EDI for the ith country and, similarly, for other countries. As more and more components are extracted, the measure of the explanatory power would increase. However, this would defeat the purpose of reducing the dimensionality. It is necessary to strike a balance between parsimony and explanatory power.

Both the unrotated and rotated solutions explain exactly the same amount of variation in the variables. The choice between them hinges upon the interpretative power of each solution. Once the number of retained principal components is determined and the rotated component scores obtained, we have the choice of using the principal components as such or selecting a subset of variables from the larger set of variables.

We were able to narrow down the number of variables from six to four. [12] However, the principal components were themselves not directly used. We discard two variables, viz., the second (CENTFWW)

$$EDI_i = \sum_{j=1}^{5} w_j . x_{ji}$$

and the sixth (DEFOR)) and define the EDI for the ith country as:

where;

w_j = j th component score,
x_{ji} = value of the j th variable for the i th country; and j = 1,3,4 and 5.
GED is given by:

$$GED = \sum_{i=1}^{174} EDI_i$$

Identifying outliers and influential observations

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[11] SPSS package was used for estimation. It provides for substitute means being used for missing values. Neighboring data points were used for generating these substitute means. In any case, there were very few missing data points.

[12] This discussion is postponed until the exercise of Discriminant Analysis is done.

Principal Component Analysis allows identification of outlying observations. This is done by plotting the first two components, that are the most significant and observing which countries are beyond reasonable limits. An outlier could be so in a relative sense, if it significantly differs from the norm, in comparison with its neighbors. Three figures have been drawn for observing this – one each for the three development classes. But here a distinguishing feature is that while all influential observations are outliers, all outliers are not influential observations. The difference lies in the fact that influential observations have a significant impact on the component scores. The methodology involves the elimination of each suspect observation and re-estimation of the component scores. If the ratio of the original score to the new score remains the same then the particular country is not an influential observation. Especially, if the sign changes and the ratio is different from unity the particular country is to be treated as an influential observation, i.e., its absence leads to radical changes in the overall component scores.

Canonical Discriminant Analysis

There could be various viewpoints about the causal links of GED. We consider three of these.

1. Human development that is broad-based and includes economic as well as social factors.
2. Consumption that is molded by economic and cultural factors that adjunct to economic factors.
3. Geo-physical factors that can be gauged by the common agro-climatic regions.

We classified the set of 174 countries, on which data are available in HDR 2000, into three classes by Canonical Discriminant Analysis, according to the criteria laid down in HDR i.e., on the basis of the level of the HD index. The null hypothesis is that environmentally degrading countries can be classified upon the basis of consumption-related causes. The alternative is that the classification should be according to geophysical causes and not consumption related factors. Thus, two exercises were done: (i) to classify the same set of countries on the basis of environmental degradation variable according to HDI and (ii) to classify them by consumption related variables according to HDI. If the null hypothesis were correct, the classification by environmental variables and that by consumption related variables would coincide. On the other hand if geophysical causes were behind degradation then the classification would have to be on a geographical basis.

Simultaneous Equations Model

Since causal factors are so enmeshed it is necessary to establish a causative framework, so as to separate the influence of the individual factors. To accomplish this we construct a simultaneous equations model. Our purpose is three-fold.

1. To explain the income generating factors (that are partly cultural).
2. To estimate a global consumption function based on income.
3. To predicted the GEKC with the help of consumption

We thus have the following three-equation framework.

$GDPPC = a_0 + a_{1*}ENERGY + a_{2*}\ TRADEV + a_{3*}URBAN + U_1$ ---------(1)

$CONSUMPTION\ = b_0\ + b_{1\ *}\ GDPPC + |\ U2$ --------------------(2)

$EDI = c_0 + c_{1*}(HDIR) + c_{1*}\ (HDIR)^{*2} + c_1\ HDIR^{*3}$ ---------------------(3)

We used 2SLS to estimate this set of equations.

Creation of the consumption-based HDI

Our alternative consumption-based Human Development Index is based on three indicators:

1. Life expectancy at birth;
2. Educational attainment[13];
3. Standard of living measured by real GDPPC in PPP $.

Each variable has a minimum and maximum range.

1. Life expectancy: 25 to 85
2. Educational attainment: 0% to 100%
3. Standard of living: (PPP$) 100 to 40000

The general formula for computing each component is:

$$Index(X_i) = \frac{ActualX_i value - \min imumX_i value}{MaximumX_i value - \min imumX_i value}$$

Income is taken to be a proxy for living standard. However, unlimited income may not be necessary to achieving a respectable level of human development. Therefore, over the years a complex formula was

[13] With two-third weightage for primary education.

used for discounting income above a threshold level. Apart from the question of what that level should be, the problem with this procedure was that it discounted higher incomes excessively, as indicated by Anand and Sen (1999). Thereafter, they advocate more moderate discounting as in:

$$W(y) = \frac{\log y - \log y_{\min}}{\log y_{\max} - \log y_{\min}}$$

The justification for this is that this formula does not need a threshold nor does it penalize middle-income countries unduly.

The approach involving discounting clearly has a normative intent since it scales extreme high values. An implication is that even if developing countries so not attain such high values of income they will still benefit and, according to this calculus, the gap between their realized income and the high incomes of the developed countries would be narrower than would have been the case if such discounting had been eschewed. However, if no discounting is used the HDI would reflect how things *stand,* which is a positive approach. As a consequence of following this approach the actual gaps between the levels of income in developed countries and those attainable by developing countries would be revealed. Thus this approach would reveal the true inequalities of income. Once such inequalities are revealed their consequence for environmental degradation would also become relevant.

A measure of the inequalities in consumption related variables and environmental degradation variables can be gauged from Tables 1 to 3. While the proportions may differ the parallelism is striking.

Tables 1-3 here

Table 1 is based on of the mean values of the respective developmental and environmental variables in proportion (Low: Medium: High) to HDI classes. Thus the construction of the HDI as it stands conceals more than it reveals.

We propose a consumption based HDI which can ultimately be used for estimating a GEKC based on a new measure of HDI. The methodology used is as follows. The existing HDI has been deflated to the extent of the component of income resulting in a net value. Per Capita real consumption has been derived from real GDP in PPP$ and added back to the net value. It has then been averaged using equal weights as is done with the original index. Countries in various developmental classes have then been ranked according to the new Consumption based HDI.

V Results

The distributions over the first two components of environmental variables are given in Figures 1 –3. While there may be some others that are outliers we have chosen the following (with reasons appended).

Figures 1-3 here.

1. USA – outlier and large developed market economy.
2. Russia – vast country, an outlier and a non-market, declining economy.
3. China – outlier, vast, populous and non-market developing economy.
4. Finland – outlier (though) small and developed market economy.
5. Japan – small market economy, developed and populous and an outlier.
6. India – large, populous, mixed developing economy, not a significant outlier.

The component scores were worked out after eliminating each of these countries. The results are not reported for want of space. However, the broad conclusion is that the old to new scores remain within 10% of each other in all other cases. The only exception is that of USA. In the case of the USA the deviation is around 40% on an average across all environmental variables. In fact the sign on certain variables also changes and in the case of certain individual variables the change is nearly 100%. Therefore, only USA is an influential observation. In fact, it is very influential. While some other countries are outliers they are not influential. Another significant result is that in both cases – environmental and consumption related variable - the low developmental class has virtually not got any outlier. Their contribution to the environmental degradation is uniformly low. Finally, There is a striking similarity between the two lists of outliers. With some exceptions it can be said the outliers are the same. (Figures 4-6) This provides a preliminary basis for believing that primarily it is consumption that is the 'cause' environmental degradation.

Figures 4-6 here.

In the discriminant analysis we used the Box's M test for testing for the equality of population co-variance matrices. It revealed that they were not equal. F-tests with levels of significance between 5 and 10 per cent were used to include or exclude variables. On this basis we retained variables 1,3,4 and 5 amongst environmental variables. The eigenvalues justified extraction of two linear discriminant functions. The prior probabilities were taken to be equal since there was no other information. These results hold good for both classifications.[14] Finally, both classifications proved that the basis environmental degradation was not geophysical. In the case of environmental variables the classification was 70.1 per cent true. In the other case of classification it was beyond 81 per cent. The countries that have been classified together have little in common in geophysical terms. Hence, it can clearly be stated that human development, consumption and environmental degradation are all positively related. The country groupings are the same for all the three. Thus, urbanized, open, high income and high-energy use economies are clearly associated with a high degree of environmental degradation. Detailed results appear in Tables 4 to 8.

Tables 4 to 8 here.

If the above premise is admitted, it takes us on to the question of the structure of causality. How does this causality work out? There are three stages to analyzing this. First, an economy with high energy use, that is open to international trade and urbanized has the potential to generate high incomes (See equation (4) and Table 9). All coefficients are significant and R bar sq. is 0.87.

Income generation function:

$$GDPPC = 9569 + 0.57_{*}ENERGY + 5.37_{*}\ TRADEV + 42.24_{*}URBAN + U_1 \quad \text{---------}(4)$$

(Intercept for Medium HDI class: 926 and Low HDI class: (-) 199)

All equations have been tested for other functional forms. Also slope and intercept dummies have been tried out in equations 4 and 5. Only the first equation shows significant intercept dummies. Low development countries have a negative intercept such that their income generating potential is low in absolute terms. Second, we also estimated the global consumption function:

Global consumption function:

$$CONSUMPTION = 315.52^{a} + 0.725_{*}\ GDPPC + U2 \quad \text{--------------------}(5)$$

(^{a} not significant)

The estimated equation reveals that high income leads to high consumption (See Table 10) (All coefficients are significant and R bar sq. is 0.853). The estimated global consumption function reveals that (i) it is in accordance with the long-term consumption function (the real consumption function) that does not have an intercept, and (ii) it is possible that even low-income countries have imbibed the consumption patterns of rich countries. This could be on account of openness, globalization and modernization. All this reflect a certain 'type of development'.

Finally, predicted consumption enters in the form of a new consumption based HDI and affects environmental degradation. It is captured in the last equation. (See Table 11) (All coefficients are significant and R bar sq. is 0.77). This is the Consumption-based global environmental Kuznets curve (GEKC).

Consumption based Global Environmental Kuznets Curve:

$$EDI = 73.21 - 2.15_{*}(HDIR) + 0.02_{*}\ (HDIR)^{*2} - 6.05_{*}HDIR^{*3} \quad \text{---------------------}(6)$$

The cubic equation shows that the global EKC is dominated by high development countries. The low and medium countries hardly contribute to environmental degradation. The GEKC is certainly done not have an inverted U shape. Most importantly, the structure of causality is clear. A certain type of development leads to high incomes and consequent high consumption. This results in environmental degradation. The cause of entropy is high consumption. Unsustainable levels of consumption have been reached amongst high development countries. The GEKC is plotted in Figure 7.

Figure 7 here.

A cubic representation for the GEKC appears to be the most appropriate with high-consumption countries contributing excessively to GED and middle-consumption countries slightly less. Low-consumption countries are contributing insignificantly, or even negatively, to GED. This is broadly in agreement with the results on the income-based GEKC reported in Jha and Murthy (2003).

Our final formal analysis consists of comparing consumption based HDI ranks with EDI ranks. If a country has a larger HDI number it indicates a lower ran and, hence, lower potential for degradation. If it has a larger EDI number it has lower potential for degradation. Therefore, a low EDI rank coupled with high HDI rank is desirable. This implies that negative correlation is desirable between HDIR and EDIR.

[14] Such results have not been reported. Interested readers can have the results from the authors.

The formula difference in ranks for comparison is EDIR – HDIR > 0 is desirable. If we observe the developmental classes the results are clear. The high development class has an average of around (–) 5.8 (Σ(EDIR – HDIR)/ no. of countries). The correlation is 0.713 and, hence, undesirable. Medium class countries have a negative average of (-) 4.2 and a correlation of 0.68, which is slightly better, but still undesirable. The low development class has an average of (+) 23 and a correlation of (-) 0.68. Thus, their performance is the best! Detailed results are reported in tables 12 to 14.

Tables 12 to 14 here.

VI Conclusion

The two main contributions of this paper are to build a consumption based HDI and to estimate a Global EKC based on consumption. A simultaneous equations model explains the causal structure that is responsible for Global Environmental Degradation. Further, with Canonical Discriminant Analysis it has been shown that GED does not have geo-physical basis but an anthropogenic basis. As a part of the system of equations a Global Consumption Function has been estimated that displays interesting results. In net, the paper attempts to establish that a certain 'type of development' that characterizes high income countries is responsible for Global Environmental Degradation.

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Figure 1

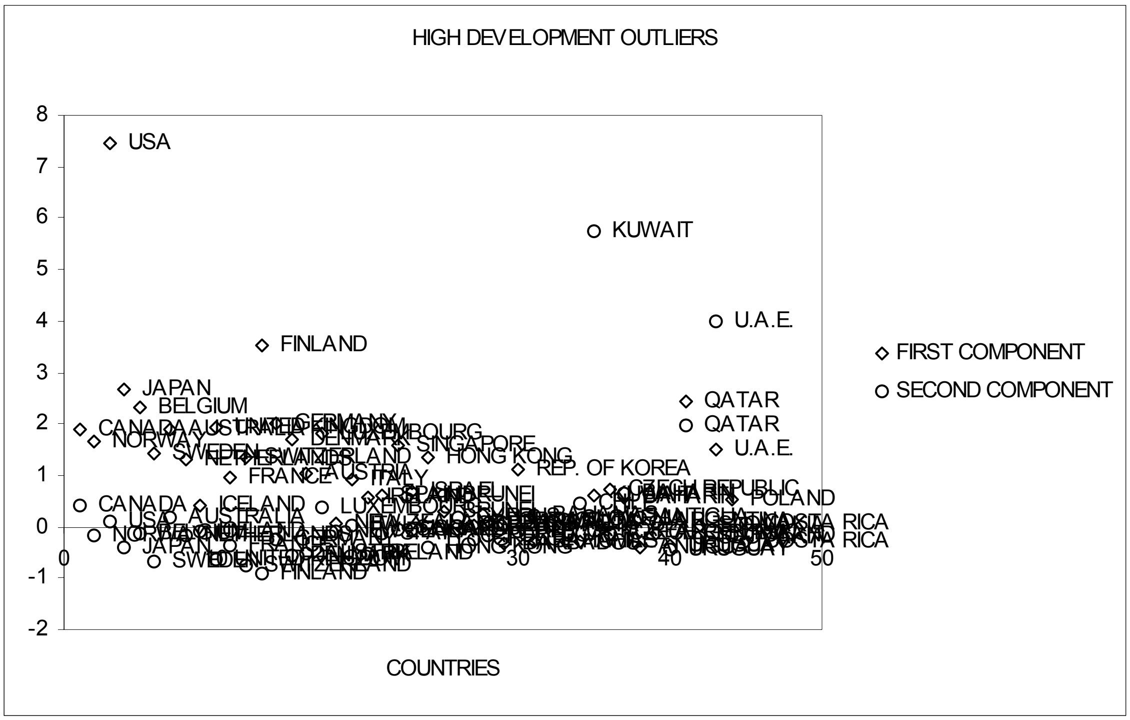

Figure 2

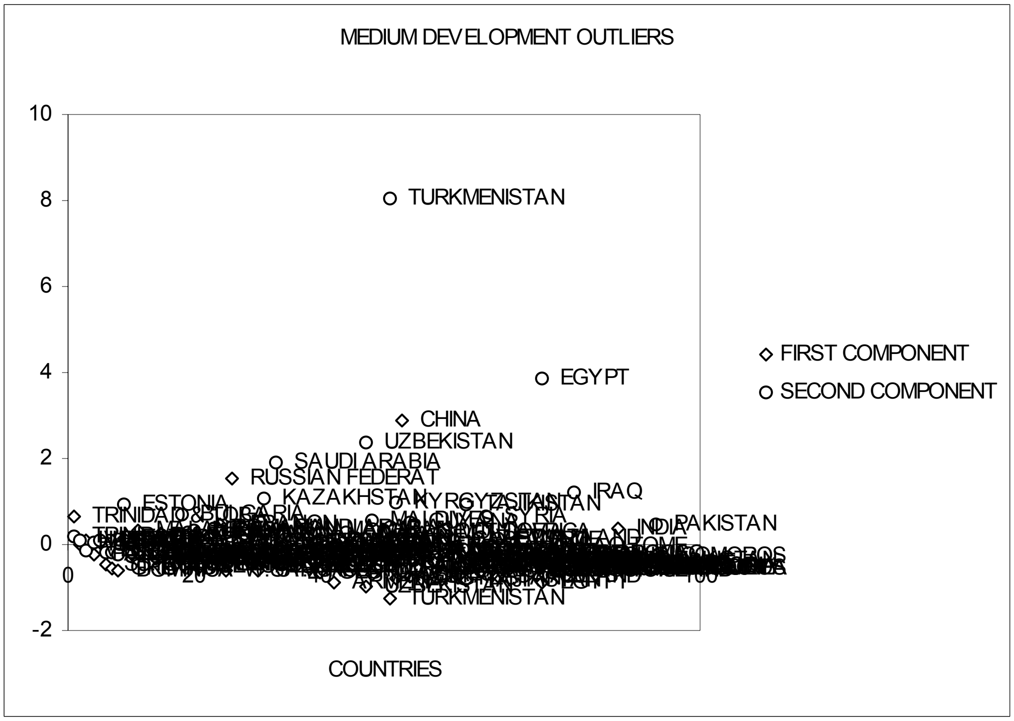
MEDIUM DEVELOPMENT OUTLIERS
10
8
6
4
2
0
-2
TURKMENISTAN
EGYPT
CHINA
UZBEKISTAN
SAUDI ARABIA
RUSSIAN FEDERAT
KAZAKHSTAN
ESTONIA
IRAQ
INDIA
PAKISTAN
TURKMENISTAN
FIRST COMPONENT
SECOND COMPONENT
COUNTRIES

Figure 3

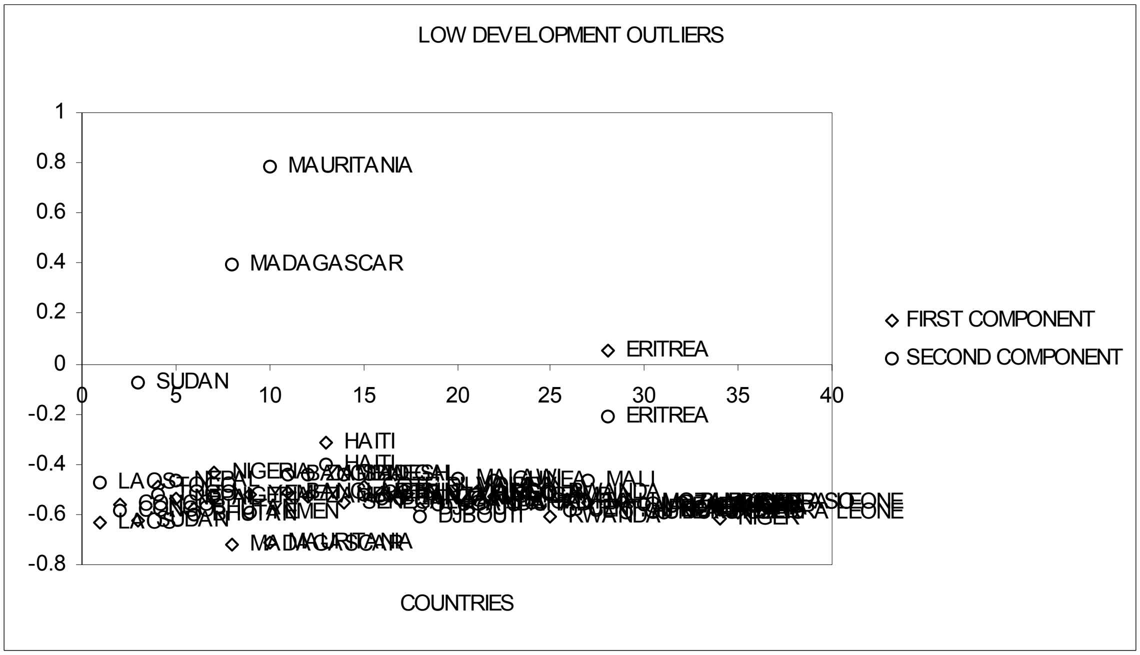

Figure - 4
High Development Countries - Consumption Outliers

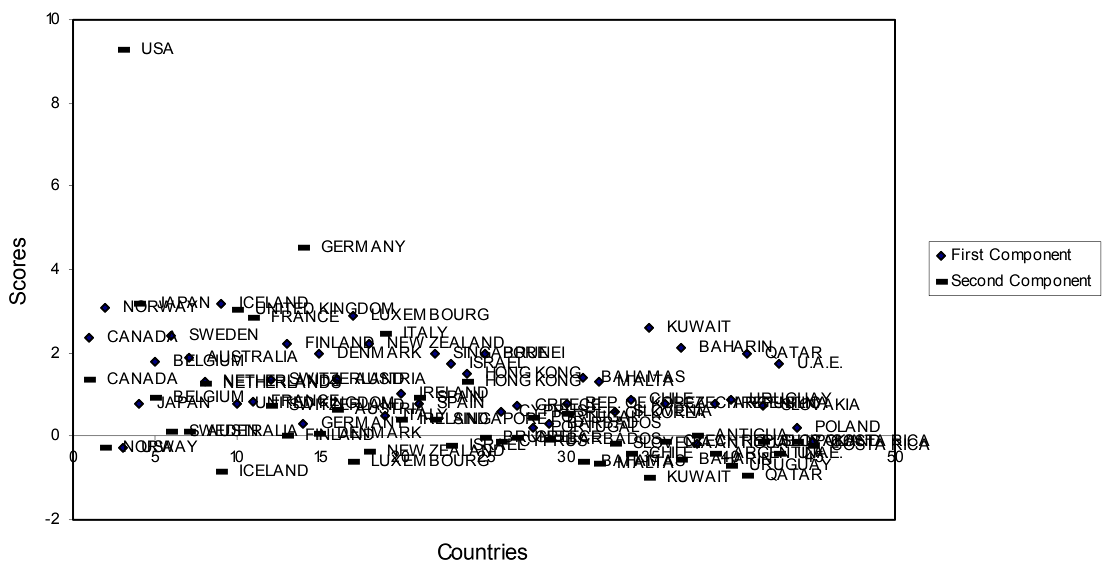

Figure - 5
Medium Development Countries - Consumption Outliers

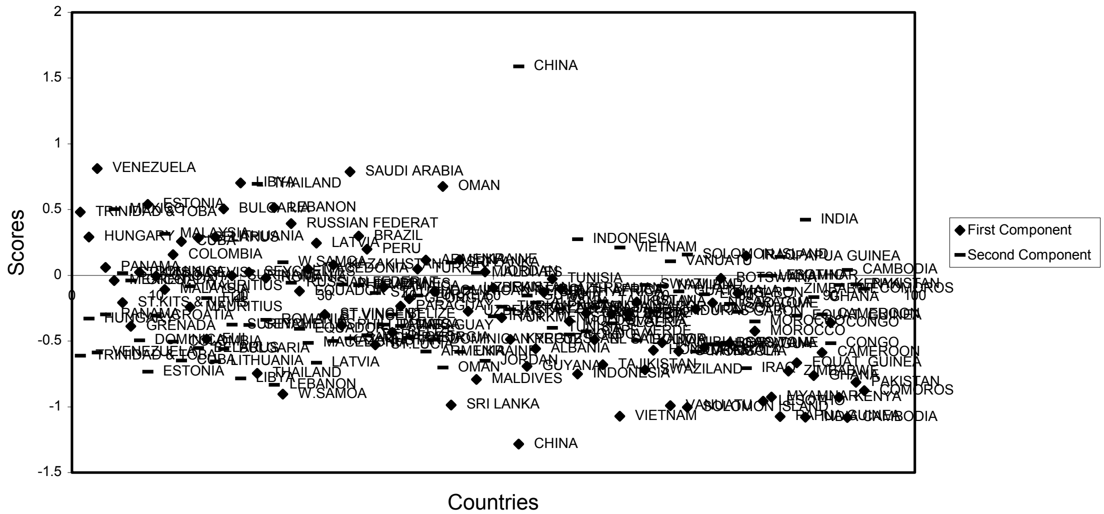

Figure - 6
Low Development Countries - Consumption Outliers

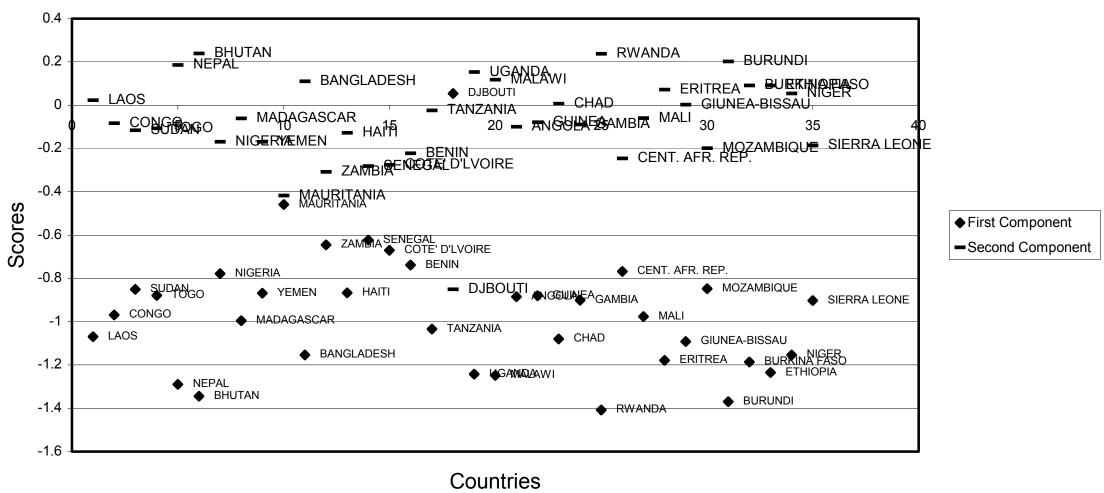

Figure 7

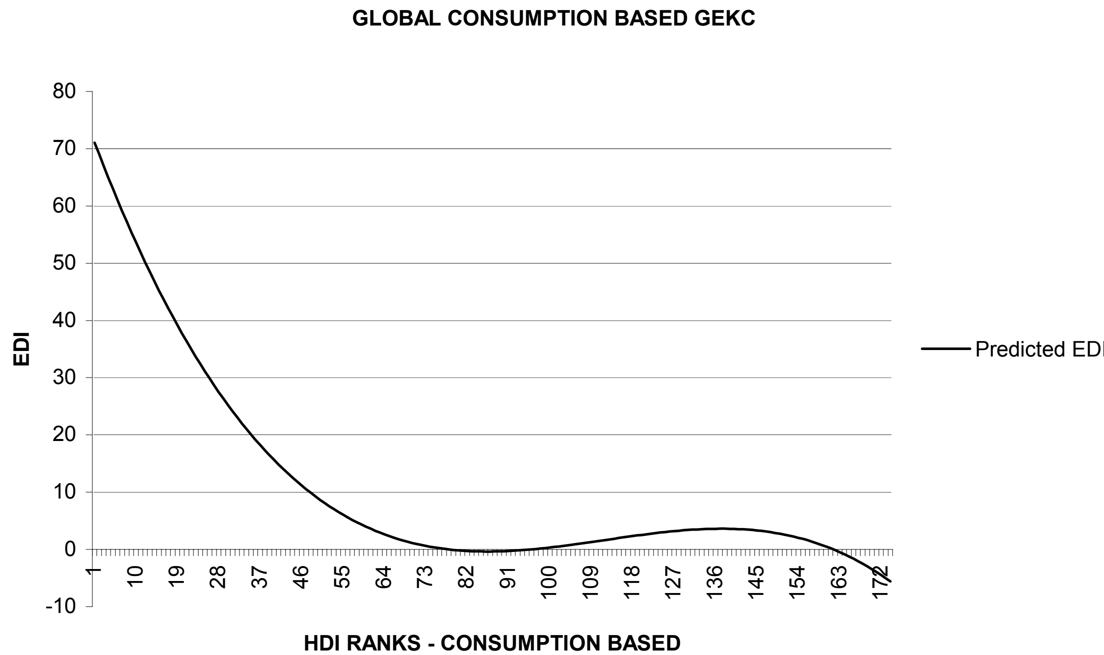

Table 1

DEVELOPMENTAL STATUS	LOW:MIDDLE:HIGH	ENVIRONMENTAL	LOW:MIDDLE:HIGH
Consumption	1 : 3 : 14	Water Consumption	1 : 5 :7
GDP (per capita)	1 : 4 : 18	Paper Consumption	1 : 21 : 240
Energy Consumption	1 : 15 : 77	CO2 (per capita)	1 : 6 : 23
Trade	1 : 10 : 200	CO2 Share	1 : 30 : 60
Urbanization	1 : 2 : 3		

Table 2

Basic Statistics – Environmental Degradation

	PCFWW	CENTFW	PAPCM	PCCO2	CO2SHA	DEFOR
High HDI						
Mean	7.2	107.9	59.66	11.09	1.09	-0.1
S. Dev	4.0	445.1	51.1	9.16	3.36	0.74
CV	0.55	4.12	0.85	0.82	3.08	-6.97
Medium HDI						
Mean	7.08	80.29	4.21	3.03	0.46	0.73
S. Dev	8.93	315.3	5.57	3.24	1.65	1.51
CV	1.26	3.92	1.32	1.07	3.58	2.05
Low HDI						
Mean	1.56	15.02	0.22	0.56	0.017	0.73
S. Dev	3.09	68.8	0.38	1.87	0.05	0.64
CV	1.97	4.58	1.69	3.35	3.31	0.87

Table – 3
Basic Statistics - Consumption Patterns

	CONS	GDPPC$	ENERGY	TRADEV	URBAN
High					
Mean	13801.29Mean	18477Mean	7735.67Mean	231.396Mean	76.207
Std. Dev.	4616.399Std. Dev.	6349.3Std. Dev.	5249.08Std. Dev.	383.481Std. Dev.	16.508
C.V.	0.33449	0.3436	0.67856	1.65725	0.2166
Medium					
Mean	3299.79Mean	4120.5Mean	1494.79Mean	26.4361Mean	51.92
Std. Dev.	1645.595Std. Dev.	2245.2Std. Dev.	1385.27Std. Dev.	55.2395Std. Dev.	18.437
C.V.	0.498697	0.5449	0.92674	2.08955	0.3551
Low					
Mean	979.1671Mean	1095Mean	95Mean	2.81571Mean	28.989
Std. Dev.	325.2334Std. Dev.	392.37Std. Dev.	128.742Std. Dev.	4.45418Std. Dev.	15.192
C.V.	0.332153	0.3583	1.35518	1.5819	0.5241

Table 4
Component Score Coefficient Matrix of Environmental Variables

	Component			
	1	2	3	4
PCFWW	.301	.392	-.111	.459
CENTFW	.243	.532	.354	-.131
PAPCPM	.299	-.451	.066	-.319
PCCO2	.383	-.062	.264	-.506
CO2SHA	.237	-.362	.301	.791
DEFOR	-.270	.011	.905	.016

Extraction Method: Principal Component Analysis.

Table 5

Classification Function Coefficients of Environmental Variables

	CLASS		
	1	2	3
PCFWW	.120	.164	5.292E-02
PAPCPM	8.845E-02	7.363E-03	5.964E-04
PCCO2	.380	8.749E-02	1.792E-02
DEFOR	.181	.747	.575
(Constant)	-6.270	-2.104	-1.356

Fisher's linear discriminant functions

Table 6

Classification Results of Environmental Variables

Classification Results

			Predicted Group Membership			Total
		CLASS	1	2	3	
Original	Count	1	34	10	1	45
		2	2	57	35	94
		3	0	4	31	35
	%	1	75.6	22.2	2.2	100.0
		2	2.1	60.6	37.2	100.0
		3	.0	11.4	88.6	100.0

a 70.1% of original grouped cases correctly classified.

Table 7

Classification Results of Developmental Variables

			Predicted Group Membership			Total
		CLASS	1	2	3	
Original	Count	1	40	5	0	45
		2	0	69	25	94
		3	0	3	32	35
	%	1	88.9	11.1	.0	100.0
		2	.0	73.4	26.6	100.0
		3	.0	8.6	91.4	100.0

a 81.0% of original grouped cases correctly classified.

Table 8

Classification Function Coefficients of Developmental Variables

Classification Function Coefficients

	CLASS		
	1	2	3
cons	1.438E-03	3.540E-04	1.048E-04
gdppc	6.447E-04	-9.956E-05	-1.352E-04
tradev	-7.931E-03	-1.906E-03	-3.554E-04
urban	.160	.169	.103
(Constant)	-22.148	-5.841	-2.570

Fisher's linear discriminant functions

Table 9

PREDICTED GDP PER CAPITA PPP $

Regression Statistics	
Multiple R	0.9353
R Square	0.874786
Adjusted R Square	0.87106
Standard Error	2752.602
Observations	174

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	5	8.89E+09	1.78E+09	234.7414	7.75E-74
Residual	168	1.27E+09	7576816		
Total	173	1.02E+10			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	9569.035	1065.806	8.978215	5.38E-16	7464.936	11673.13
ENERGY	0.574461	0.07791	7.373341	7.23E-12	0.420651	0.72827
TRADEV	5.377281	1.070506	5.023122	1.29E-06	3.263904	7.490658
URBAN	42.24545	12.73208	3.318031	0.001111	17.10995	67.38094
DMHDI	-8642.79	714.0057	-12.1046	1.19E-24	-10052.4	-7233.21
DLHDI	-9768.41	950.6086	-10.276	1.59E-19	-11645.1	-7891.74

Table 10

GLOBAL CONSUMPTION FUNCTION-

Regression Statistics

Multiple R	0.924117563
R Square	0.85399327
Adjusted R Square	0.853144393
Standard Error	2153.682354
Observations	174

ANOVA

	df	SS	MS	F
Regression	1	4666307113	4666307113	1006.027886
Residual	172	797795801.2	4638347.681	Significance F
Total	173	5464102914		8.98378E-74

	Coefficients	Standard Error	t Stat	P-value
Intercept	315.5274658	232.1234466	1.359308895	0.175828244
PreGDPC	0.724375012	0.02283802	31.71794265	8.98378E-74

Table 11

CONSUMPTION BASED GLOBAL EKC

Regression Statistics

Multiple R	0.878615244
R Square	0.771964746
Adjusted R Square	0.767940595
Standard Error	9.733421524
Observations	174

ANOVA

	Df	SS	MS	F
Regression	3	54522.46217	18174.15406	191.8329218
Residual	170	16105.71408	94.73949457	Significance F
Total	173	70628.17625		2.4762E-54

	Coefficients	Standard Error	t Stat	P-value
Intercept	73.20980166	3.016326333	24.27118076	4.01446E-57
HDIR_C	-2.154849616	0.148842285	-14.47740218	1.81519E-31
HDIR_C2	0.020315142	0.001973325	10.29487898	1.26734E-19
HDIR_C3	-6.05419E-05	7.41349E-06	-8.166457921	6.88054E-14

Table 12

High Development Countries - Consumption Based HDI Ranks

COUNTRY	EVN1345	HDIR_C	EDIR	DIFFR
FINLAND	129.1098	8	1	-7
USA	88.28163	1	2	1
BELGIUM	87.45989	12	3	-9
HONG KONG	67.17299	21	4	-17
JAPAN	65.19045	7	5	-2
DENMARK	64.12561	18	6	-12
SWEDEN	62.24197	4	7	3
SWITZERLAND	59.58641	17	8	-9
UNITED KINGDOM	59.06618	9	9	0
CANADA	57.56984	2	10	8
LUXEMBOURG	55.09849	14	11	-3
NORWAY	55.04546	3	12	9
AUSTRALIA	53.97511	11	13	2
GERMANY	50.0116	6	14	8
NETHERLANDS	48.74706	13	15	2
AUSTRIA	46.47768	20	16	-4
SINGAPORE	42.99178	22	17	-5
FRANCE	39.58055	10	18	8
REP. OF KOREA	34.29894	25	19	-6
ITALY	33.47212	16	20	4
IRELAND	32.64211	24	21	-3
ISRAEL	30.42819	23	22	-1
SPAIN	28.87577	19	23	4
ICELAND	24.31512	5	24	19
U.A.E.	23.44568	43	25	-18
CZECH REPUBLIC	22.85472	29	26	-3
QATAR	21.17899	40	27	-13
PORTUGAL	20.58546	41	28	-13
MALTA	20.07649	28	29	1
SLOVENIA	17.52599	32	30	-2
ESTONIA	17.44084	47	31	-16
KUWAIT	17.30319	26	32	6
GREECE	15.45741	27	33	6
MALAYSIA	15.02806	77	34	-43
POLAND	14.13907	39	35	-4
HUNGARY	14.0592	51	36	-15
CYPRUS	13.69349	31	37	6
NEW ZEALAND	13.40563	15	38	23
BAHARIN	13.29049	30	39	9
SOUTH AFRICA	11.93103	109	40	-69
CHINA	10.86087	92	41	-51
TRINIDAD & TOBA	10.53466	49	42	-7
SLOVAKIA	10.40129	34	43	9
THAILAND	9.68284	95	44	-51
ARGENTINA	9.40481	38	45	7
	Mean Difference in EDI and HDI ranks			-5.82857

Correlation between EDI and HDI ranks 0.712928

Table 13
Medium Development Countries - Consumption Based HDI Ranks

COUNTRY	EVN1345	HDIR_C	EDIR	DIFFR
RUSSIAN FEDERAT	9.23079	50	46	-4
CROATIA	8.56382	56	47	-9
CHILE	8.44825	37	48	11
LEBANON	8.33898	75	49	-26
BRAZIL	7.76332	87	50	-37
VENEZUELA	7.71494	55	51	-4
BARBADOS	7.38849	35	52	17
SAUDI ARABIA	7.33001	89	53	-36
BRUNEI	6.85549	42	54	12
TURKEY	6.84998	97	55	-42
URUGUAY	6.37797	36	56	20
MEXICO	6.31405	60	57	-3
MAURITIUS	5.7542	98	58	-40
JAMAICA	5.27603	71	59	-12
PANAMA	4.82035	63	60	-3
COLOMBIA	4.81408	72	61	-11
VIETNAM	4.69372	104	62	-42
INDONESIA	4.62732	110	63	-47
JORDAN	4.60167	90	64	-26
MACEDONIA	4.45582	59	65	6
BAHAMAS	4.42449	33	66	33
ERITREA	4.368	168	67	-101
FIJI	4.25514	69	68	-1
ROMANIA	4.22913	65	69	4
LATVIA	3.93037	64	70	6
ST.LUCIA	3.86032	99	71	-28
LITHUANIA	3.83695	52	72	20
TUNISIA	3.61142	108	73	-35
BULGARIA	3.51158	46	74	28
EL SALVADOR	3.50248	106	75	-31
UKRAINE	3.3924	53	76	23
IRAN	3.2621	103	77	-26
COSTA RICA	3.0706	44	78	34
INDIA	3.04004	127	79	-48
ANTIGUA	2.95549	45	80	35
DOMINICAN REPUB	2.85132	96	81	-15
ALGERIA	2.8436	114	82	-32
PHILLIPPINES	2.63412	73	83	10
KAZAKHSTAN	2.56127	62	84	22
ST.KITS & NEVIS	2.50832	79	85	6

OMAN	2.49502	101	86	-15
PERU	2.4135	80	87	7
LIBYA	2.3716	70	88	18
BELARUS	2.34848	57	89	32
ALBANIA	2.33998	88	90	2
IRAQ	2.18456	124	91	-33
SEYCHELLES	2.17032	94	92	-2
SURINAME	2.01364	68	93	25
GUATEMALA	1.99063	123	94	-29
EQUADOR	1.89427	81	95	14
PARAGUAY	1.84404	86	96	10
GABON	1.4369	135	97	-38
HONDURAS	1.43298	113	98	-15
EGYPT	1.42257	120	99	-21
AZERBAIJAN	1.41965	67	100	33
SRI LANKA	1.40251	91	101	10
MONGOLIA	1.40007	107	102	-5
MOROCCO	1.2786	126	103	-23
BOLIVIA	1.27617	112	104	-8
BELIZE	1.26153	93	105	12
CUBA	1.2514	48	106	58
MOLDOVA	1.22651	78	107	29
MALDIVES	1.201418	100	108	8
W.SAMOA	0.96132	84	109	25
SYRIA	0.94073	111	110	-1
ZAMBIA	0.92572	149	111	-38
KENYA	0.82479	134	112	-22
CONGO	0.7764	130	113	-17
COTE' D'LVOIRE	0.76089	158	114	-44
ZIMBABWE	0.66462	131	115	-16
LESOTHO	0.646675	125	116	-9
BANGLADESH	0.62339	150	117	-33
GRENADA	0.62332	66	118	52
DOMINICA	0.55832	54	119	65
NIGERIA	0.54347	142	120	-22
YEMEN	0.5305	143	121	-22
BOTSWANA	0.48148	133	122	-11
CAMEROON	0.34546	136	123	-13
PAPUA GUINEA	0.31476	132	124	-8
TANZANIA	0.2658	147	125	-22
DJBOUTI	0.234	153	126	-27
HAITI	0.22819	154	127	-27
GHANA	0.20495	129	128	-1
MYAMNAR	0.20217	119	129	10
ST.VINCENT	0.19432	82	130	48
SIERRA LEONE	0.16566	172	131	-41
SOLOMON ISLAND	0.1612	118	132	14

ANGOLA	0.16069	163	133	-30
TOGO	0.15876	148	134	-14
EQUAT. GUINEA	0.14875	128	135	7
GAMBIA	0.1051	164	136	-28
SENEGAL	0.09234	157	137	-20
VANUATU	0.08101	121	138	17
CENT. AFR. REP.	0.06942	165	139	-26
Mean Difference in EDI and HDI ranks				-4.2
Correlation between EDI and HDI ranks				0.680795

Table 14

Low Development Countries - Consumption Based HDI Ranks

COUNTRY	EVN1345	HDIR_C	EDIR	DIFFR
BENIN	0.0083	155	140	-15
BHUTAN	0.12397	151	141	-10
GIUNEA-BISSAU	0.54347	169	142	-27
NAMIBIA	0.5305	122	143	21
UGANDA	1.11557	162	144	-18
BURUNDI	0.40978	170	145	-25
NIGER	0.03682	173	146	-27
NICARAGUA	0.2658	115	147	32
ETHIOPIA	0.15876	171	148	-23
MALAWI	0.92572	156	149	-7
BURKINA FASO	0.62339	174	150	-24
MOZAMBIQUE	0.06721	167	151	-16
CAMBODIA	0.15509	137	152	15
CONGO	0.234	140	153	13
RWANDA	0.22819	159	154	-5
CHAD	0.06776	160	155	-5
NEPAL	0.00966	146	156	10
GUINEA	0.09234	166	157	-9
COMOROS	0.76089	139	158	19
MALI	0.02105	161	159	-2
LAOS	0.02822	141	160	19
MAURITANIA	0.08246	152	161	9
GUYANA	0.0354	102	162	60
GEORGIA	0.16069	58	163	105
SAO TOME	0.1051	116	164	48
PAKISTAN	0.06942	138	165	27
SUDAN	0.03986	145	166	21
ARMENIA	0.0058	61	167	106
CAPE VERDE	4.368	105	168	63
SWAZILAND	0.06389	117	169	52
MADAGASCAR	0.0354	144	170	26
KYRGYZSTAN	0.00967	83	171	88
UZBEKISTAN	0.16566	76	172	96
TAJIKISTAN	0.03373	85	173	88
TURKMENISTAN	0.00663	74	174	100

Mean Difference in EDI and HDI ranks	23
Correlation between EDI and HDI ranks	-0.68226