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Analysis of Ecological Efficiency and its Influencing Factors in Developing Countries

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ABSTRACT

Eco-efficiency emphasises potential for sustainability, indicating the way societies consume resources and produce output. Analysis of this notion is indispensable for developing countries because of the increase in both environmental challenges and economic activity. Recent study analyses variations in ecological footprint per unit of Gross Domestic Product (ecological efficiency). By using weighted least square method, the effect of multiple influencing factors on ecological efficiency are examined for samples of 91 developing countries. Major findings include the validity of cross national EKC between eco-efficiency and GDP per capita with turning point of income at around US$ 7663, which suggests that ecological efficiency improves at higher level of economic development. Other findings include positive effect of population density, negative effect of higher latitudes and no significant effect of industrialisation on eco-efficiency. Overall, this study suggests that current level of economic development in developing nations is insufficient to achieve sustainability and may lead to higher environmental burden.

Keywords: Ecological Footprint; Ecological Efficiency; STIRPAT Model; Weighted Least Square

I. INTRODUCTION

Humans are primarily dependent on the availability of natural resources and ecosystem services Capacity of the planet to deliver ecosystem services determines the economic prosperity and social wellbeing of the human kind [World Wild Life Fund (2014)]. Human pressure on ecosystem services is continuously increasing [Global Footprint Network (2010)] and ecological Footprint developed by Wackernagel and Rees (1998), measures anthropogenic pressure on the environment shows that how much of productive land area is required to support our lives in the future. And due to increasing stress on environment, 1.5 Earths are required to produce all reproductive resources we use globally which is resulting in mounting shortage of the ecological resources [Global Footprint Network (2010)]. Alarming global impact is produced by human beings by using natural resources to support increasing population and economic prosperity in last few decades. Particularly, developing countries are experiencing major demographic and economic transitions [Martínez-Zarzoso and Maruotti (2011)]. These countires are home to five of the world's seven billion people and total population of these countries is expected to increase from about 5.3 billion in 2005 to 7.8 billion till 2030 by the mid of this century. At the same time, they represent about one third of global GDP and economic growth rates are more than those of the developed economies in most of the developing countries due to the development in manufacturing sector and exports. [Organisation Of Economic Co-operation and Development (2012)].

The process of economic growth is normally resource dependent and is accompanied with the increasing environmental burden [United Nations (2014)]. Relationship between economic activity and stress on ecosystem is indispensable in developing countries which increase both environmental challenges and economic activity. Most of developing countries depend on natural resources for economic growth and are vulnerable to water and food scarcity, and consequences of climate change. Therefore, it becomes critical for

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Acknowledgement: We are grateful to Global Footprint Network USA, for providing latest data on Ecological Footprints for this research.

these countries to explore the potential of sustainable economic growth [United Nations Department of Economic and Social Affairs (2013)].

World Business Council for Sustainable Development presented the idea of resource efficiency in 1992 during United Nations Conference on Environment and Development (UNCED). In 2002, Johannesburg Plan of Implementation (JPOI) was launched in World Summit on Sustainable Development (WSSD), which focused on the promoting economic and social development, within the carrying capacity of ecosystem and delinking the economic growth from environmental degradation. Later on, "Marrakesh Process" in 2003 offered new prospects for developing countries to "do more and better, with less", by enhancing resource efficiency, in order to redesign economic growth saving environmental degradation [United Nations Environment Programme (2014)]. The concept of eco-efficiency has received attention and expresses the efficiency of economic activities with respect to the use of natural resources and final goal of providing governments with tool for measuring their performance in the context of eco-efficiency as a pre requisite of environmental sustainability [Economic and Social Commission on Asia and Pacific (2009)].

Analysis of Multiple Environmental Impact Using STIRPAT Model

In order to develop the understanding of principle driving forces behind the anthropogenic impacts on the environment, IPAT identity is a widely recognised framework. The identity shows that environmental impacts are the multiplicative product of three key driving forces: population, affluence and technology (impact per unit of consumption or production). [Ehrlich and Holdren (1971)].

A stochastic model[1] has been used widely to analyse the effects of multiple influencing factors on different types of environmental impacts [Dietz and Rosa (1994); Fan, Liu, Wu, and Wei (2006); York, *et al*. (2003b)]. The renowned IPAT identity can be presented in the form of STIRPAT model and ecological elasticity can be calculated with respect to the population, affluence and some other factors [York, *et al*. (2003b)]. A significant body of research is available on the STIRPAT model exploring the impact of multiple driving forces on variety of environmental impact indictors. Environmental impacts increase with the population size and also that GDP per capita has non-decreasing effect on these impacts [Rosa and York (2002)]. Whereas the impact of population growth on emissions is highly elastic [Martínez-Zarzoso and Maruotti (2011); York, *et al*. (2003b)]. The impact of population, affluence and technology on total CO_2 emissions and energy consumption of the countries

[1]In order to check non proportionate impact, York, Rosa, and Dietz (2003b) reformulated this identity as, "Stochastic Impacts by Regression on Population, Affluence and Technology".

shows that economic growth has largest impact on environmental degradation at global level [Fan, *et al*. (2006); Liddle (2014)]. For large economies of China and India, population, affluence (GDP per capita) and technology were identified as major driving forces to pollution using basic IPAT equation [Hubacek, Guan, and Barua (2007)]. Affluence level not only has a significant effect on different indicators of environmental quality but also most of these indicators decrease as income rises. [Ehrhardt-Martinez, Crenshaw, and Jenkins (2002); Shafik and Bandyopadhyay (1992)].

Ecological Footprint (EF) as Environmental Impact Indicator

Among all, collective analysis of resource consumption and waste generation could be the most comprehensive and meaningful indictor to assess environmental performance along with economic and demographic changes [York, Rosa, and Dietz (2004)]. Ecological foot print is found by adding biologically productive area needed to sustain a country's demand for natural resources. [Wackernagel and Rees (1998)]. In the field of ecology and environmental social sciences, it is regarded as a reliable indicator of anthropogenic pressure on the environment [Tang, Zhong, and Liu (2011)].

Investigations made on identifying the potential of major economic, bio-geographical and political economy variables driving ecological footprint of global nations, show that of Population size and affluence are principle drivers of anthropogenic environmental stress [Dietz, Rosa, and York, (2007); York, Rosa, and Dietz (2003a)]. Also, examination of Environmental Kuznets Curve (EKC) hypothesis using the Ecological footprint as a comprehensive indicator of environmental degradation, shows no evidence of decline in ecological footprint with the rising level of economic growth. Hence EKC was not validated in cross national and national level [Bagliani, Dalmazzone, and Giaccaria (2008); Hervieux and Darné (2015); Tang, *et al*. (2011)].

Analysis of Eco-Efficiency

Concept of eco-efficiency is pre-requisite for sustainable development because it focuses on creating more goods and service using fewer resources, generating less waste and less pollution. [Economic and Social Commission on Asia and Pacific (2009)].

Main finding of eco-efficiency assessment of global nations with help of STIRPAT model shows, that more affluent nations are more ecologically efficient, and relationship between impact intensity (EF/GDP) and GDP per capita is nonlinear and consistent with the predictions of EKC. Moreover, the trends in total ecological footprint, per capita footprint and ecological footprint intensity (EF/GDP), for China, India, Japan and the United States found that EF intensity declined for entire time period [York, Rosa, and Dietz (2009)]. However, existence of EKC is not validated by taking environmentally efficient wellbeing (ratio of ecological footprint per capita and the life expectancy at birth) as impact indicator and ecological burden of producing wellbeing increases with the rise in affluence level [Dietz, Rosa, and York (2012)].

The goal of this study is to provide a cross national analysis of ecological efficiency (calculated in terms of ecological footprints per unit of economic activity) and to check the effect of multiple influencing factors on ecological efficiency, with the most recent data available for the developing countries. Ecological footprint intensity may be affected by many economic, demographic and climatic factors. Identifying the potential of major drivers behind the ecological footprints per unit of economic activity, particularly for developing countries, will help shaping credible economic and ecological polices.

Present research focuses on assessment of ecological efficiency performance via Ecological Footprint per unit of GDP and identify the potential of major influencing factors to affect ecological efficiency for group of 91 developing countries. Cross section data of the year 2011 (the most recent year for which data on ecological footprint is available) is used and the STRRPAT model is applied with the help of weighted least square regression, which is the contribution to the existing literature**.** The questions addressed by this research are: What is the relative position of each developing country in terms of ecological footprint intensity of economic output (eco- efficiency)? How major economic and biogeographical factors affect ecological efficiency?

Thus, the objectives of this studies are, ranking the developing countries according to ecological efficiency performance and to identify potential effects of each influencing factors on relative eco-efficiency.

II. THEORETICAL BACKGROUND, METHODOLOGY AND DATA SOURCES

STIRPAT Model

There had been a huge debate in literature for last two decades, about the driving forces which are producing massive environmental changes. In this regard, IPAT identity was used by Ehrlich and Holdren (1971) to analyse proportionate impact of growing population on the environment. It is given by;

$$I = P.A.T \qquad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \qquad (1)$$

Where, I shows the environmental impact, P is the population and A stands for Affluence, and all are used to solve for T, the technology generally taken as resource intensity.

The idea was refined by York, *et al*. (2003b) into a stochastic version of a model named as STIRPAT, to analyse the non-proportionate impact of population on environment. The model can be specified as:

$$I = aP^b_i \; A^c_i \; T^d_{i\;e} \qquad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \qquad (2)$$

In an additive from regression model can be written as follows:

$$ln\ (I_{it}) = a + b\ (lnP_{it}) + c(lnA_{it}) + d(lnT_{it}) + lne \quad \ldots \quad \ldots \quad \ldots \quad (3)$$

The subscript i with each variable in Equations (2) and (3) shows that the quantities of I, P, A and T, differ through the units observed; t means the year, a is constant and e is the error term. Where, b, c and d are exponents of P, A and T respectively in Equation (2), and coefficients of the driving forces in Equation (3). These coefficients will show that the percentage change in environmental impact as a result 1 percent change in any one of the driving force. Equation (3) shows the linear relationship between population, affluence (GDP per capita) and technology.[2]

The advantage of using STIRPAT model is that, it can easily include many additional variables [Dietz, *et al*. (2007)]. Also as both dependent and independent variables are in log form, therefore, their coefficient can be interpreted easily ecological elasticities for showing responsiveness of any environmental impact to change in any one of the driving force [York, *et al*. (2003b)].

It is important to adopt a suitable environmental impact indicator in STIRPAT model for comparison of environmental performance of the group of countries which can minimise the synergies between multiple types of impacts.

Ecological Footprint

The Ecological Footprint (EF) is the measures which shows aggregate of productive land area of a country that would be required to sustain its resource consumption and waste generation. It is therefore an indicator showing the overall the natural resource demand of the nation [Rees (1996)]. Six type of areas are added up in order to get total ecological footprints [World Wild Life Fund (2014)]:

- *Cropland Footprint* aggregate of the area used to produce crop for human consumption, fodder for livestock, oil crops.
- *Grasing Land Footprints* aggregate of the area used to raise livestock for meat, dairy, leather products.
- *Fishing Grounds Footprint* is calculated from the estimated primary production required to keep the fish and sea food caught.
- *Forest Footprint* is the total of the amount of wood and timber products and fuel wood consumed by a country each year.
- *Carbon Uptake Footprint* is calculated as the amount of forest land crucially required to absorb CO_2 emissions from burning fossil fuels.

[2]Basic STIRPAT model had been widely used in the literature , For detail see, York, *et al*. (2003a, 2003b), York, Rosa, and Dietz (2004), Dietz, *et al*. (2007), Tang, *et al*. (2011), Liddle (2014).

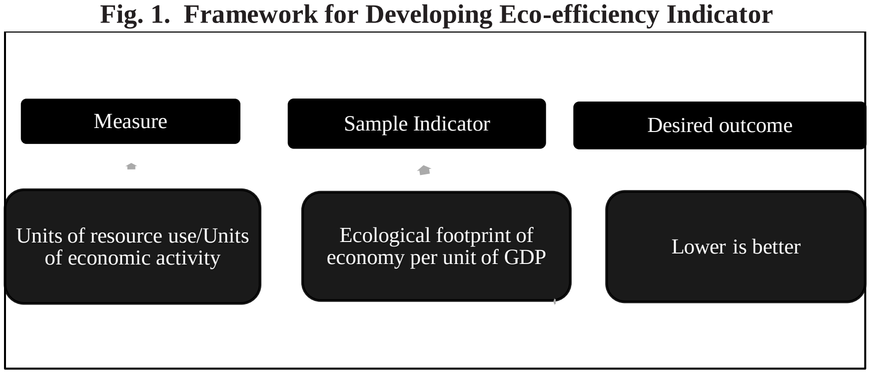
- *Built-up-Land Footprint* is the summed up area of land covered by human infrastructure, including transportation, housing and industries.

It is a comprehensive measure of all the impacts and is calculated by adding imports and subtracting exports from production to show cross border natural resource consumption of the country. Therefore, it does includes and copes with the impacts which are transmitted by international trade. Among the variety of environmental impact indicators, ecological footprint can be taken for being most comprehensive sample indicator which addresses the resource consumption and environmental impact in the form of carbon emissions together for the assessment of the environmental performance of the nations [Economic and Social Commission on Asia and Pacific (2009)].

The Ecological Efficiency

Economic and Social Commission on Asia and Pacific redefined the idea of eco-efficiency which was initially introduced during United Nations Conference on Environment and Development (UNCED) in 1992. As, being the inverse of intensity, the eco efficiency is simply the wise use of resources, and refers to reducing the society's ecological footprint along with increase in level of development, and hence shows a combination of economy, ecology and efficiency [Economic and Social Commission on Asia and Pacific (2009)]. According to the conceptual definition, eco-efficiency may be derived by looking at the intensity of resource use, intensity of environmental impacts or both. It is expressed as the ratio of environmental cost and economic activity. Framework for developing the eco efficiency indicator is given in Figure 1.

Fig. 1. Framework for Developing Eco-efficiency Indicator



In this study data on EF measure is used, for the assessment of eco-efficiency performance. National Footprint Accounts (NFA) are released annually by Global Footprint Network USA and most recent Edition is issued in

2015 that has calculated Ecological Footprint and bio capacity of more than 200 countries globally for year 2011.

The study is mainly based on the comparative analysis of the levels of ecological footprint per unit of GDP, and the basic influencing factors on this resource intensity. It therefore makes no claims about finding sustainable level of resource consumption.

Data Discription and Sources

This study has used cross section data of all 91 developing countries: according to World Bank classification (See Appendix 1) for the year 2011 (latest data on ecological footprint was available for this year). Data on ecological footprints was provided by Global Footprint Network, from National Footprint Accounts Edition 2015. Whereas, Affluence level of the economy (GDP per capita) is an important explanatory variable, data of which is collected from data published in World's Economic Outlook by International Monetary Fund (2014). Data on industrialisation and population density was taken from database of World Development Indicators (2011). However, the countries are categorised according to their latitude i.e., tropical if the latitude is less than 30 degree, arctic/sub-arctic if the latitude is more than 55 degree and temperate if nation is located at the latitude between 30 and 55 degree. Data on nation's classification according to the latitude is taken from the database of World Atlas (2011).[3]

Because of data limitations, the study might have a limitation that all dimensions of changes in eco-efficiency over the time may not be discovered by cross section data. So the study cannot discourse what might be done by forceful policies based on the analysis, because time series analysis carries realistic feasibility of sustainability policies. Ecological footprint is a newly developed environmental indicator, adequate time series data for most of the countries is not available. However, study may provide useful foundation at least for the beginning of such discussion among the group of developing countries.

Construction of Eco-Efficiency Coefficient

In the present study, eco-efficiency is measured as:

RI= Nation's EF (in global Hectares) / Nation's Total GDP in Purchasing Power parity … … … … (4)

This resources intensity (RI) is taken as the proxy for eco-efficiency, as York et al. (2004) did in their study. Lower the number of resources intensity, higher will be the ecological efficiency per unit of GDP. In order to make the

[3]Latitude is the angle ranging between 0^0 at the equator and 90^0 at both the poles (North & South) and measure in Degrees. http://www.worldatlas.com/aatlas/imageg.htm

comparative analysis, the RI has been divided by the cross national average of relative resource intensity (relative eco-efficiency).[4] Therefore, the relative resource intensity (RRI) is calculated as:

RRI= Resources Intensity of the nation (RI) / cross national average of resource intensity of all the developing nations (Mean of RIs) … … … … (5)

The relative resource intensity is also calculated as:

RRI= Resources Intensity of the nation (RI) / resource intensity of the best performer in terms of minimum value of RI in the sample nations … … … (6)

If RRI is less, it means nation is more ecologically efficient than others in the group RRI and greater RRI means nation is less ecologically efficient than others in the group. Finally, all 91 countries are ranked against their ecological performance evaluated on the basis of Equations (5) and (6). Rank 1 is given to the most efficient nation (lowest RRI) and rank 91 is given to least eco-efficient nation (highest RRI) (See Appendix 2).

Specification of the Model

The STIRPAT model has been applied with help of weighted least Square Regression Analysis. In order to overcome the regression biases which may arise because of the heterogeneity in the population in the sample nations weights are given as follow:

$$W = P_i / P_n \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (7)$$

Where, W is weight, P_i is population of each developing country and P_n in Total population of the group. STIRPAT Model is applied by using the Weighted Least Square estimation method to identify the potentially influencing factors on relative resource intensity (inverse of ecological efficiency), by incorporating relative resource intensity as dependent variable and GDP per capita, quadratic term of GDP per capita , population density, industrialisation, dummy variables indicating the latitude of the countries (Arctic or tropical), as independent variables. Equation is presented as:

$$\ln RRI = \alpha o + \alpha_1 \ln GDP\,pc + \alpha_2 \ln GDP\,pc^{\wedge 2} + \alpha_3 \ln Inds + \alpha_4 \ln Pop\,Density + \alpha_5 D_1 + \alpha_6 D_2 + \mu \quad \ldots \quad \ldots \quad \ldots \quad (8)$$

RRI = Relative Resource intensity of each country (in ln Form)
GDPpc = GDP per capita in current US $ (in ln Form)

[4] "This linear transformation of RI will only scale RI and provides an easy reference point to assess the Eco-efficiency of a country relative to others in a cross national analysis." [York, *et al*. (2004)].

GDPpc^2 = Quadratic term of GDP per capita to check the curvilinear relationship between the level of economic development and environmental impact. (in ln Form)

Inds = Industrialisation (% Share of GDP from industry) (in ln Form)

Pop Dense = Population Density (per square km of land area) (in ln Form)

Arctic (D1) = Dummy variable, taking value 1, if country is located in arctic/subarctic region (if country's latitude is greater than 55 degrees and 0 otherwise.

Tropical (D2) = Dummy Variable, taking value 1 if country is located in tropical region (if country's latitude is less than 30 degree) and 0 otherwise.[5]

Moreover, turning point for relative resource intensity is also calculated to check validity of EKC. For that, first derivative with respect to GDP per capita will be set equal to zero and income threshold will be calculated as following:

$$Y = \alpha_1 / \alpha_2 * 2 \qquad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \qquad (9)$$

Where, Y is the income threshold level, α_1 coefficient of linear term of GDP per capita and α_2 is quadratic term of GDP per capita.

Description of the Study Variables

Dependent Variable

Relative resource intensity (RRI) is taken as the dependent variable. Which is a ratio of ecological footprint and Gross Domestic Product of the nations. The coefficient of RRI is interpreted as inverse of ecological efficiency.

Independent Variables

Independent variables are divided into two categories:

(1) Human ecology variables: In this category, main latitude of the nation is included as dummy variable and population density is the number of people per square km of the land area (an inverse of the land area per capita)[6] are indicator of climate conditions and land availability of the countries respectively.

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[5]According to World Atlas, the climate of the nations can be dived into three categories based on their latitude, Arctic/ Subarctic: Latitude > 55 degree, temperate: > 30 and < 55, Tropical: latitude < 30 degree.

[6]York, *et al.* (2004) had used population density as inverse to land area per capita of the nations.

(2) Modernisation Variables: GDP per capita is included as an indicator of affluence level of the nations. GDP per capita and the quadratic term of GDP per capita are taken as the indicator of economic development. These variables have been frequently been taken in the literature to examine the cross national validity of EKC. York, *et al*. (2003a), and Dietz et al. (2007), checked the curvilinear relationship between the level of economic development and the environmental impacts in the form of ecological footprints. Industrialisation (percentage of country's industrial share in GDP) as a general indicator of economic structure of the economies.

These driving forces have been commonly identified as potential influencing factors on the total ecological footprint and ecological footprint intensity and can be categorised as human ecology and modernisation variables [Dietz, *et al*. (2007); York, *et al*. (2003a, 2004)]. All variables are in included in the natural log form, expect the dummy variable (latitude). However, dummy variables can also be understood in the STIRPAT model, because if a dummy variable is coded as 1, then antilog of the coefficient of the dummy variable shows the multiplier effect of that dummy variable on the dependent variable.[7]

III. EMPIRICAL RESULTS AND DISCUSSION

Descriptive Statistics of Study Variables

Table 1 shows the descriptive statistics of the study variables. Average value of RRI is 1.20, indicating that on average the relative value of resource intensity (ecological efficiency) of all developing countries is higher than the its average value.

Magnolia, where deforestation is very high stands at position of least eco-efficient nation with maximum value of RRI i.e. 3.31, and its GDP per capita stands at US $ 7400. Minimum value of RRI belongs to Timor Leste, where almost 70 percent population lives in rural areas and depend on natural resources.

In separate calculations for developed countries, Estonia has Maximum value of RRI i.e. 1.68 for and GDP per capita of 23,540 US $. And Norway is most eco- efficient nation having RRI value of 0.14 and GDP per capita of 62648.19US$. This situation clearly indicates that resource intensity is mainly affected by the affluence level of the nations. On the other hand, average value of the industrialisation is 33.03 percent of GDP, showing that on average almost 1/3[rd] of GDP is contributed by industrialisation in developing countries. Whereas, maximum value is 76.63 percent which is for Congo and minimum

[7]According to York, *et al*. (2004), "antilog of the coefficient of the dummy variable, shows the effect of that variable on the log formed dependent variable".

value belongs to Albania. Average of population density is almost 99 persons per square km, whereas for developed countries the average value of population density stands at 411.91 persons per square km (Self Calculation). Maximum value of population density belongs to Mauritius and minimum value is for the most ecological inefficient nation (Mongolia). Resource intensity seems to be reduced (eco-efficiency improves) at comparatively high levels of population density.

Table 1

Descriptive Statistics of Study Variables

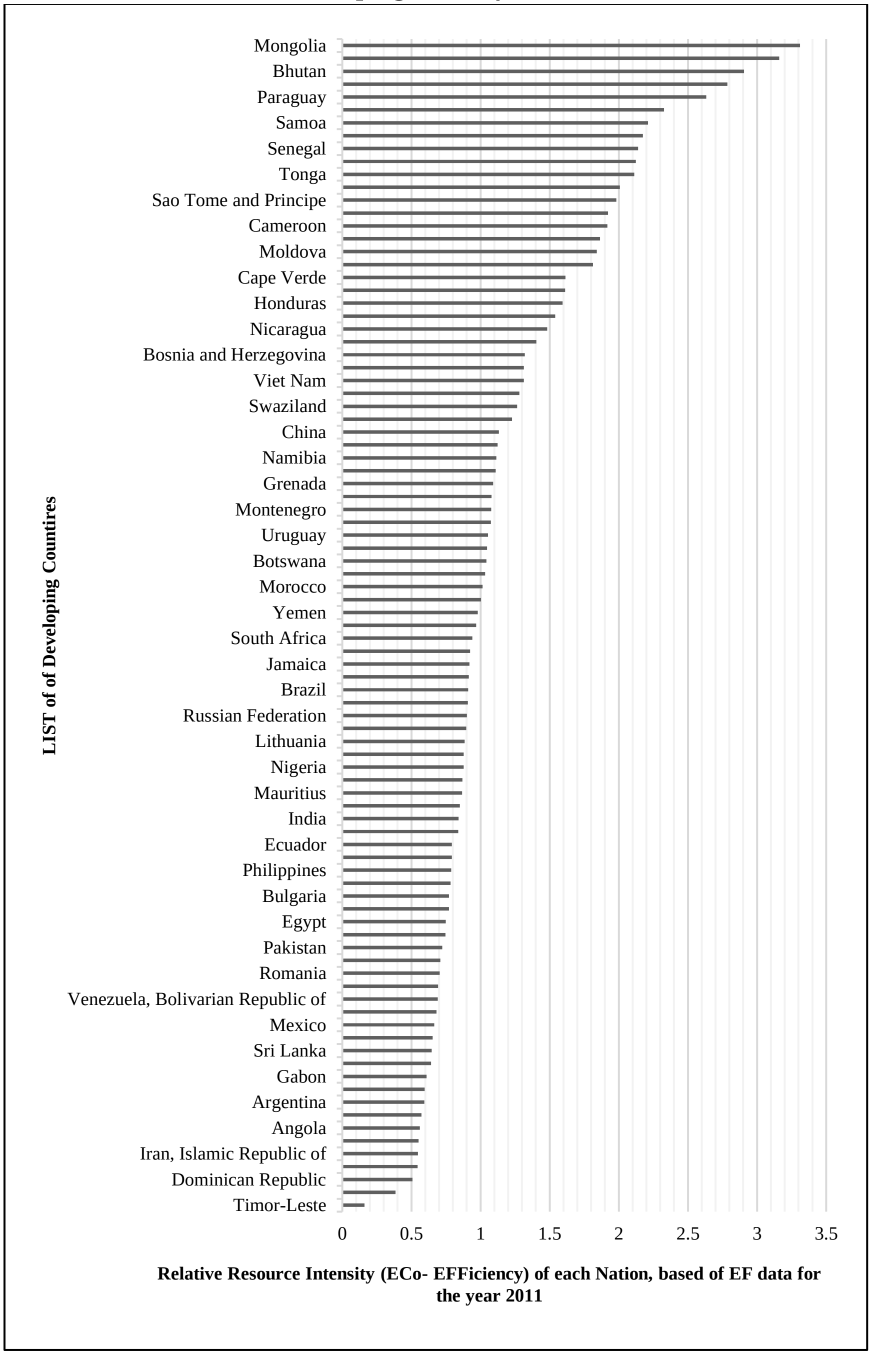
Statistics	RRI (RI/ Mean of all the values of RI, where RI=EF/GDP)	Gross Domestic Product Per Capita (ppp) In US Dollars	Industrialisation (% Share of GDP from Industry)	Population Density (Number of people per square meter of land area)
Mean	1.20	10356	33.03	98.95
Median	0.98	9968.99	30.02	69.10
Maximum	3.31	22563.63	76.63	633.52
Minimum	0.16	2150.73	14.25	1.77
Std. Dev.	0.64	5535.03	12.69	109.75

Source: Author's calculation.

Analysis of Eco-Efficiency Performance of Developing Countries

In this section, cross national variation in relative resource intensity is examined. Calculated values of RI represents ecological footprint intensity per unit of gross domestic product. And relative resource intensity (RRI), of nations is calculated by dividing RI by the average of all values of RI (0.0002196 is the cross national mean of RI). Relative resource intensity is also calculated by dividing the values of RI by the value of RI of the best performer in the sample countries.

Fig. 2. Relative Resource Intensity (Eco-Efficiency) of Each Developing Country



Ranks are given according relative resource intensity calculated by both methods and finally RRI calculated in terms of mean of RI is used as a proxy for eco-efficiency, as York, *et al*. (2004) did in their study. Higher the value of relative resource intensity, lower will be eco-efficiency of the country and vice versa. For example, rank of Timor-Leste is 1, because RRI is lowest for this country (most eco-efficient), where 91 rank is given to Mongolia for having the highest value of RRI (see Appendix 2).

Figure 1 shows the ecological performance (RRI) of all the developing countries. Variability in ecological performance of the developing countries is higher, because difference in values of RRI depicting eco-efficiency of both Timor Leste and Mongolia (Maximum and Minimum eco-efficiency) is 20 fold (3.310/0.161 ≈ 20).

Factors Influencing Relative Resource Intensity in the Developing Countries

In order to analyse the relationship between relative resource intensity (ecological efficiency) and different influencing factors weighted least square regression model has been estimated, with results reported in Table 2. Coefficient of determination is 0.828 showing almost 83 percent of the total variation in RRI is explained by the explanatory variables, which is quite satisfactory. Value of VIF is showing no evidence of multicollinearity among the regressors[8] Log of GDP per capita was centered by subtracting mean of log of GDP per capita and squaring the value.[9] Because there is possibility of multicollinearity, if square terms of any variable is included as an explanatory variable. Correlation Matrix, given in See Appendix 3, shows no evidence of multicollinearity among the independent variables. White heteroscedasticity test is performed in E-views shows no evidence of heteroscedasticity in the data.

Furthermore, while using the ratio as an indicator, if coefficient of variation of numerator and denominator are different, the ratio can be driven by the numerator or the denominator [Dietz, *et al*. (2012)]. To avoid this problem, coefficient of variation of both the ecological footprint (numerator) and GDP (denominator) was checked. It was found that the CV of ecological footprint was 0.40 and of total GDP was 0.38. Thus there is no possibility that variation in any of one of the denominator or numerator will drive the overall ratio.

Most important finding of the analysis is that coefficients of GDP per capita is positive and its squared term is negative and both are significant at 1 percent level of significance. Result shows that 1 percent increase in GDP per capita increases the relative resource intensity of developing nations by 6.44 percent i.e. eco-efficiency decreases. Furthermore, coefficient of

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[8]Gujrati D., (2009), “Basic Econometrics” Fifth Edition.

[9]According to York, *et al*. (2003a), “if the log of a variable is centered by subtracting the mean of the variable and then squared, it will reduce the chance of multicollinearity.

quadratic term of GDP per capita is -0.36, indicating RRI declines at later stages of economic development. Theoretically, if coefficient of GDP per capita is positive and GDP per capita $^{\wedge 2}$ is negative, the validity of EKC holds. Environment Kuznet Curve hypothesis suggests that the environmental impacts increase at the initial level of development and tend to decrease with further increase in the level of economic development. [Grossman and Krueger (1995)]. Because at higher levels of development, structural change towards industries and services, coupled with increased environmental regulations and better technology results in gradual decline in environmental degradation [Stern (2004)].

In the present study, relationship between GDP per capita (indicating the level of economic development) and relative resource intensity (indicating environmental degradation) shows a curvilinear trend among the group of developing countries. And the threshold level of GDP per capita stands at US$ 7662. These results satisfy the findings of York, *et al*. (2004), who had also found, in their analysis that the EF intensity per unit of GDP is lower for the more affluent nations globally. According to York, *et al*. (2004), "more affluent nations are more eco-efficient and use the lesser amount of resources per unit of economic activity".

Nevertheless, most of the literature reviewed shows nonexistence of EKC while taking ecological footprints as the indicator of environmental degradation [Dietz, *et al*. (2007); York, *et al*. (2003a)]. But this study shows the cross national validity of curvilinear relationship between RRI (EF/GDP) and GDP per capita. This phenomenon is possibly due to the shift in the economic structure of developing countries from high natural resource intensive segments of the economy (Agriculture) towards less resource intensive sectors [United Nations Department of Economic and Social Affairs (2013)]. Figure 2 shows the relationship between GDP per capita and RRI values and suggests three important results: First: relationship between RRI and affluence level shows that impact per unit of GDP declines as the affluence level rises within the group. Second: almost all the decline in RRI occurs at the low level of income. Third: there is lesser variability in RRI as affluence level rises and more variability in RRI among the nations having low level of incomes.

Least eco-efficient nations (highest RRI) are at lesser income level e.g., Lesotho, Senegal, Mongolia, Bhutan, Djibouti, and Mauritania. But some low income countries are highly eco-efficient (lesser RRI), e.g., Sri Lanka, Indonesia, Pakistan, Angola. Also value of range of RRI at lower income level (lower middle income countries between US$ 2150 & US$ 10,500) range is 3.14 and range of RRI at higher income level (upper middle income countries between US $ 10,800 to US$ 22563) is 0.78. Suggesting there is high variation at the lower level of income than at the higher income levels.

Table 2

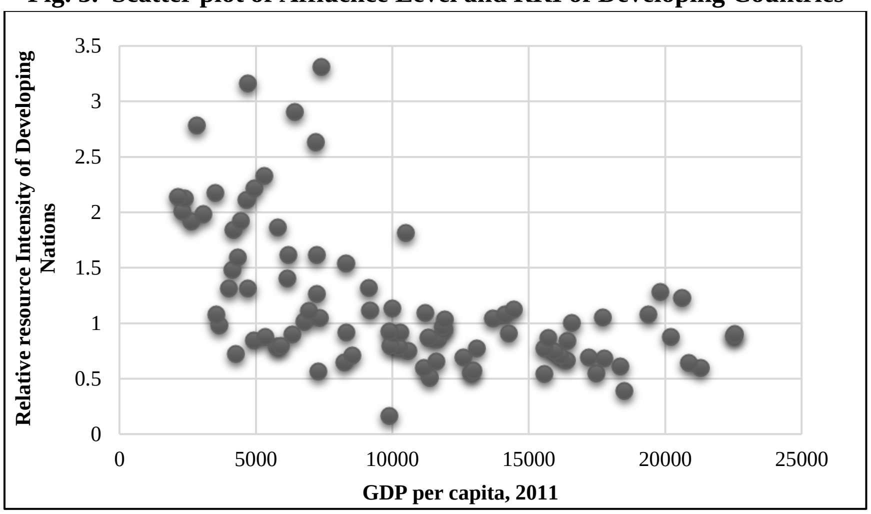
Results of Weighted Least Square Regression Model based on Factors Influencing RRI

Method: Least Squares				
Included observations: 91				
Dependent Variable RRI				
Weighting series: Population				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-28.45879	11.77032	-2.417844	0.0178
ln (GDPPC)	6.44498	2.664912	2.418278	0.0178
ln (GDPPC)^2	-0.365508	0.146833	-2.489278	0.0148
ln (INDS)	-0.093928	0.126398	-0.753112	0.4595
ln (POPDENSITY)	-0.027098	0.012426	-2.1838720	0.0247
ARACTIC	0.210198	0.143139	1.468487	0.0457
TROPICAL	-0.236277	0.037003	-6.385295	0.0000
Weighted Statistics				
R-squared	0.828506	Mean dependent var	-0.088284	
Adjusted R-squared	0.816256	S.D. dependent var	0.595136	
S.E. of regression	0.255107	F-statistic	68.35686	
Log likelihood	-1.168887	Prob(F-statistic)	0.000000	

Source: Author's calculation.

Thus, upper middle income countries being more affluent in the group might have lower relative resource intensity but at the same time lesser variability and potential for further improvement in the ecological performance.

Fig. 3. Scatter plot of Affluence Level and RRI of Developing Countries



In addition to GDP per capita, industrialisation (INDS) has a negative effect on relative resource intensity for developing nations with coefficient value of -0.09, which shows that 1 percent increase in level of industrialisation decreases the RRI (ecological footprint intensity) by 0.09 percent, hence eco-efficiency improves with more industrialisation. But the coefficient of industrialisation is statistically insignificant. York, *et al*. (2004) and Dietz, *et al*. (2007), had included the percentage of GDP from non-services sector in the analysis but did not find any significant effect of non-service sector development on the resource intensity and total ecological footprint respectively. Tang, *et al*. (2011), have included industrialisation, and found a positive but insignificant effect on total ecological footprint of China.

For this study, including industrialisation (% of GDP from the industrial sector) as an influencing factors of eco-efficiency is more relevant, for two reasons: firstly, this analysis is specific for developing countries, where economic growth process is based on industrial sector development. And share of industrial sector in developing countries GDP has almost doubled in the past 20 years, from 18 percent in 1992 to 35 percent in 2012 [United Nations Industrial Development Organisation (2014)]. Secondly, carbon footprint is the major part of ecological footprint, which shows the carbon emissions to the environment, and its amount is mainly determined by the industrial process in the economies. GDP growth has been taking place in developing countries because of industrial development. Therefore side effect of industrialisation cannot be denied [United Nations Industrial Development Organisation (2014)].

Negative effect of industrialisation on relative resource intensity is consistent to that anticipated by ecological modernisation theorists who stated that more modernisation can tackle ecological problems through more industrialisation and urbanisation [Gouldson and Murphy (1996)]. Also satisfies investigations made about the industries located in developing countries, that improvements in environmental performance of developing countries are made as compared to developed countries since the Rio Earth Summit of 1992 [Luken and Van Rompaey (2007)]. Especially, Most of the industrial units and manufacturing plants in large developing economies e.g. China, India, Mexico, Thailand, and Indonesia now meet the international environment standards [United Nations Conference on Sustainable Development (2012)]. However, coefficient value indicates that RRI is highly inelastic to the changes in level of industrialisation and also statistically insignificant. Reasons behind this finding may be that the process of industrialisation, its nature and performance and finally the impact on resource intensity may be different across the countries. Also burning of fossil fuels to meet energy demand of highly industrialised economies, might have resulted in increasing the carbon part of ecological footprints per unit of economic activity [United Nations Industrial Development Organisation (2014)]. Moreover, industrial development in Latin America, Europe and Africa is based on increasing exports of many agricultural products based processed food. This phenomenon is driving deforestation in these countries because forest cover is being removed for agro forestry, and commercial cropping to fuel the industries in the developing countries [Hosonuma, *et al*. (2012)]. Which might have pulled the impact of industrialisation on relative resource intensity to be little and statistically insignificant

Population density has negative effect on the relative resource intensities of sample nations, with coefficient value of -0.03 and the result is statistically significant at 1 percent level of significance. The coefficient value of population density shows that 1 percent increase in the population density decreases the relative resource intensity by 0.03 percent, hence eco-efficiency improves. Result is consistent with the findings of York, *et al*. (2004), York, *et al*. (2003a) and Dietz, *et al*. (2007) who has also found that high population density has a significant negative effect on the resource intensity and effect of land area (an inverse of population density) on total ecological footprint was positive for the global nations. Furthermore, for more concentrated population, it is convenient and possible to build efficient housing structures and transportation systems. Also when a certain mass population is reached it becomes economically viable for countries to deliver many infrastructure projects, such as public transportation [Nations (2014)].

Latitude (dummy coded) of the country indicating climatic conditions of developing nations also appeared to be an important factor with significant coefficient value of 0.21 for the arctic nations, and -0.23 coefficient value for tropical nations. Since dependent variable is in log form therefore, antilog of the coefficient of dummy variables are checked.[10] Antilog of the coefficient of first dummy variable (D_1) is 1.23, indicating its effect on RRI is 1.23 times higher than the reference category (temperate nations) and antilog of the coefficient of second dummy variable (D2) is 1.25, showing lesser effect than the reference category. The results are significant at 1 percent level of significance. York, *et al*. (2004), York, *et al*. (2003a) and Dietz, *et al*. (2007), had also included latitude of the nations as the influencing factor that affects resource intensity and total ecological footprints respectively and found that arctic nations have positive effect on resource intensity and also that the coefficient of arctic nation is greater than topical nations.

A nations biogeographical features may affect its resource intensity directly by the use of ecological resources traditionally and indirectly through climatic conditions which can drive energy consumption and types of human dwellings. For example a country which is located at high latitudes (far from

[10] According to York, *et al*. (2004), if we take the antilog of the coefficient of dummy variable, the resulting value will show the multiplier effect of dummy variable on the logged form dependent variable.

equator) uses more energy resources for heating and consumes more animal proteins because of colder climate and thus have higher effect on EF relative to GDP. But the tropical countries, located at low latitudes require lesser amounts of resources for sustaining lives as they are located closer to the equator and hence the demand for energy for these countries is lower. Rather, they are naturally benefited by the heavy amount of precipitation, sunlight and forests and are able to produce more by employing lesser amount of natural resource [Dietz, *et al*. (2007); York, *et al*. (2003a)].

IV. CONCLUSION AND POLICY IMPLICATIONS

We assessed the ecological efficiency via ecological footprint intensity (RRI) for 91 developing nations and found that the cross national variations in eco-efficiency among the developing countries are high for lower middle income countries and low for upper middle income countries, portraying that there are restrictions to further increases in eco-efficiency among the nations which are more affluent in the sample. The analytical framework of STIRPAT model was used and weighted least square regression model was estimated for the assessment of potential effects of major drivers on RRI which is used as proxy for eco-efficiency. The coefficient of linear term of GDP per capita is positive and that of quadratic term is negative, satisfying EKC hypothesis, telling that eco-efficiency initially declines but improves once income threshold of US $ 7662 occurs. Other potentially identified key influencing factors on the RRI (eco-efficiency) are industrialisation (indicating economic structure), population density (availability of land area) and latitude (climatic conditions). Industrialisation do not significantly reduce RRI, suggesting that modernisation of economic structure is unlikely to lead towards sustainability along with economic development by improving eco-efficiency. Population density affected RRI negatively, suggesting that environmental impacts in the form of ecological footprint intensity will be lesser if the population is living densely. Latitude, as an indicator of climatic conditions, affects the RRI positively if a country is located in arctic regions and negatively if a country is located in tropical regions and having favourable climate for resource productivity. Overall findings showed that eco-efficiency rises with the movement towards high affluence level in the group. However, higher EF intensity for most of the countries belonging to lower middle income group and low variability in ecological efficiency of more economically developed nations demonstrates strong restraint among eco-efficient countries for further improvement in ecological efficiency performance. Also, industrialisation did not significantly decrease the ecological footprint intensity (RRI), showing that the effect of structural shift of economic structure towards industrialisation and modernisation is multifaceted and do not necessarily lead towards sustainability. These findings suggest that developing nations cannot be optimistic about achieving sustainability, because current economic structure continues to place burdens on environment. Besides, both the modernisation of economic structure and economic development together may lead to environmental sustainability. Developing countries must give priority to reduce the carbon footprints, which account for more than half of total ecological footprints.

Appendix 1

List of the Developing countries, as categorised by GNI, (World Bank, 2015)

Lower-Middle-Income Economies ($1,046 to $4,125)

Armenia	Kiribati	São Tomé and Principe	Honduras
Bhutan	Kosovo	Senegal	Indonesia
Bolivia	Kyrgyz Republic	Solomon Islands	India
Cameroon	Lao PDR	South Sudan	Paraguay
Cabo Verde	Lesotho	Sri Lanka	Philippines
Congo, Rep.	Mauritania	Sudan	Samoa
Côte d'Ivoire	Micronesia, Fed. Sts.	Swaziland	Yemen, Rep.
Djibouti	Moldova	Syrian Arab Republic	Zambia
Egypt, Arab Rep.	Mongolia	Timor-Leste	
El Salvador	Morocco	Ukraine	
Georgia	Nicaragua	Uzbekistan	
Ghana	Nigeria	Vanuatu	
Guatemala	Pakistan	Vietnam	
Guyana	Papua New Guinea	West Bank and Gaza	

Upper-Middle-Income Economies ($4,126 to $12,745)

Angola	Fiji	Palau	Costa Rica
Albania	Gabon	Panama	Cuba
Algeria	Grenada	Peru	Dominica
American Samoa	Hungary	Romania	Dominican Republic
Argentina	Iran, Islamic Rep.	Serbia	Marshall Islands
Azerbaijan	Iraq	Seychelles	Mauritius
Belarus	Jamaica	South Africa	Mexico
Belize	Jordan	St. Lucia	Montenegro
Bosnia and Herzegovina	Kazakhstan	St. Vincent and the Grenadines	Turkmenistan
Botswana	Lebanon	Suriname	Tuvalu
Brazil	Libya	Thailand	Venezuela, RB
Bulgaria	Macedonia, FYR	Tonga	Ecuador
China	Malaysia	Tunisia	Namibia
Colombia	Maldives	Turkey	

Appendix 2

Ranking of Developing Countries According to Their Eco-Efficiency Performance

Country/Region	RRI Relative to Best Performer (RI/ RI of Best Performer)	RRI relative to Average (RI /Mean Of RI)	Eco-Efficiency Rank
Timor-Leste	1	0.16	1
Cuba	2.40	0.38	2
Dominican Republic	3.16	0.50	3
Azerbaijan	3.37	0.54	4
Iran	3.39	0.55	5
Iraq	3.42	0.55	6
Angola	3.49	0.56	7
Algeria	3.55	0.57	8
Argentina	3.68	0.59	9
Jordan	3.69	0.59	10
Gabon	3.79	0.61	11
Malaysia	3.98	0.64	12
Sri Lanka	4.01	0.64	13
Colombia	4.06	0.65	14
Mexico	4.12	0.66	15
Turkey	4.22	0.68	16
Venezuela (BR)	4.28	0.69	17
Thailand	4.30	0.70	18
Romania	4.38	0.70	19
Indonesia	4.40	0.70	20
Pakistan	4.49	0.72	21
Panama	4.62	0.74	22
Egypt	4.64	0.74	23
Costa Rica	4.79	0.77	24
Bulgaria	4.80	0.78	25
Tunisia	4.86	0.78	26
Philippines	4.89	0.78	27
Congo	4.92	0.79	28
Ecuador	4.93	0.79	29
Lebanon	5.21	0.83	30
India	5.22	0.84	31
Libya	5.28	0.85	32
Mauritius	5.37	0.86	33
Saint Lucia	5.39	0.86	34
Nigeria	5.44	0.87	35
Chile	5.45	0.87	36
Lithuania	5,49	0.88	37
Georgia	5,57	0.89	38
Russian Federation	5.58	0.90	39
Dominica	5.63	0.91	40
Brazil	5.64	0.91	41
Peru	5.68	0.91	42
Jamaica	5.70	0.91	43

Continued—

Appendix 2—(*Continued*)

Albania	5.73	0.92	44
South Africa	5.83	0.94	45
Serbia	6.00	0.96	46
Yemen	6.08	0.97	47
Belarus	6.21	1.00	48
Morocco	6.29	1.01	49
Macedonia TFYR	6.41	1.02	50
Botswana	6.46	1.03	51
El Salvador	6.50	1.04	52
Uruguay	6.53	1.05	53
Zambia	6.67	1.06	54
Montenegro	6.68	1.07	55
Saint Kitts and Nevis	6.69	1.08	56
Grenada	6.77	1.09	57
Guatemala	6.88	1.10	58
Namibia	6.91	1.11	59
Suriname	6.97	1.12	60
China	7.03	1.13	61
Kazakhstan	7.61	1.23	62
Swaziland	7.84	1.26	63
Latvia	7.95	1.28	64
Viet Nam	8.14	1.29	65
Lao (PDR)	8.15	1.30	66
Bosnia Herzegovina	8.18	1.31	67
Armenia	8.70	1.40	68
Nicaragua	9.19	1.48	69
Ukraine	9.55	1.53	70
Honduras	9.88	1.59	71
Fiji	10.01	1.60	72
Cape Verde	10.02	1.61	73
Turkmenistan	11.23	1.81	74
Moldova	11.43	1.84	75
Guyana	11.56	1.86	76
Cameroon	11.89	1.91	77
Uzbekistan	11.93	1.92	78
Sao Tome P	12.37	1.98	79
Côte d'Ivoire	12.46	2.00	80
Tonga	13.01	2.11	81
Lesotho	13.18	2.12	82
Senegal	13.27	2.13	83
Ghana	13.49	2.17	84
Samoa	13.73	2.21	85
Bolivia	14.44	2.32	86
Paraguay	16.33	2.63	87
Mauritania	17.28	2.78	88
Bhutan	18.03	2.90	89
Djibouti	19.61	3.15	90
Mongolia	20.54	3.31	91

Source: Author’s calculation based on the EF and GDP data for the year 2011.

Appendix 3

Correlation Matrix of Dependent and Independent Variables

	RII	GDPPC	GDPPC^2	INDS	POPDENSITY
RII	1.000000	-0.565677	-0.472527	-0.163600	-0.202476
GDPPC	-0.565677	1.000000	0.473367	0.134989	-0.070848
GDPPC^2	-0.472527	0.473367	1.000000	0.105264	-0.098892
INDS	-0.163600	0.134989	0.105264	1.000000	-0.357100
POPDENSITY	-0.202476	-0.070848	-0.098892	-0.357100	1.000000

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