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ECOLOGICAL FOOTPRINT, ENVIRONMENTAL INTENSITY AND INCOME INEQUALITY

Hazrat YOUSAF*, Anwar HUSSAIN and Samina KHALIL*****

Abstract

This paper examines as to how the resources are used in the form of total ecological and CO_2 footprints, environment intensity and income inequality distributed in the period 2003-2011, between high and middle income countries, by using the Atkinson Index. From the findings, it is revealed that high income countries have greater demand for total ecological and CO_2 footprints than the middle income countries, which leads to generate more pronounce difference in its per capita income and the environment intensity. The estimated values of Atkinson Index demonstrate that reduction in distribution of environmental intensity and the per capita income inequality in these regions will lead to reduce its demand for total ecological and CO_2 footprints and consequently the environmental sustainability will improve.

Key words: Ecological Footprint; Environmental Impact Intensity; Income Inequality.
JEL Classification: Q570, I320.

I. Introduction

The environmental sustainability of the globe is one of the leading issues among different regions of the world [Duro (2016)]. It is on the summit of climate change, resources consumption and other environmental related areas and is being addressed for the last two decades. Because of climate change and consumption of resources in form of fossil fuels, crops-land grazing, forestry and fishing grounds have led to increase the negative global externality in terms of CO_2 emission which consequently reduce globe's bio-capacity [Anand and Sen (2000), Juan and Jordi (2013), GFN (2016)]. Due to favourable terms of trade the High Income Countries (HICs)[1] externalize their environmental degradation to resources abundant countries because they import raw material at lower cost in order to accelerate their economic development to maintain higher standards of living [Jorgenson

* PhD Scholar, Pakistan Institute of Development Economics, **Assistant Professor, Department of Environmental Economics, PIDE, Islamabad, ***Research Professor, Applied Economics Research Centre, University of Karachi, Pakistan.

[1] The High and Middle income countries are based on classification of the World Bank Dataset (2016), where the Middle Income Countries consist of per capita gross national income between $1,036 and $12,235, while the High Income Countries consist of per capita gross national income which is $1,236 or more.

and Burns (2007)]. On the other hand, the Middle Income Countries (MICs) push their economic growth upward and claim their share on pie of the world's resources [UNEP (2007), Wiedmann, et al. (2015), Jordi, et al. (2016)]. These two effects, along with anthropogenic increase in population and difference in per capita consumption of goods and services leads to create inequality in resources consumption in context to the ecological footprint[2] among different regions of the world [White (2007), Juan and Jordi (2013)].

The ecological footprints of HICs reached to 6.39 *gha*[3] in the year 2005 while it was only 3.62 *gha* per capita in the year 1960, which shows 76 per cent increase in its ecological footprint. During the same period, the ecological footprints of MICs increased by 20 per cent between the period of 1960-2005. These differences lead to explain inequality in crop-land, forest, grazing, fisheries and the built-up land between HICs and MICs [Galli, et al. (2012), GFN (2014)].

The ecological footprint was developed and explored by Wackernagel and Rees (1996). It quantifies the productive area of land required in order to support humanity's demand for crop-land, forest, grazing, fisheries and urban activities in the form of built-up land and for assimilation of CO_2 emission and waste, which are generated by human's activities in a year. The literature in the field of environmental sociology and environmental economics have addressed as to what are the influencing factors and which ones of them leads to increase the ecological footprint [Jill, et al. (2009), Kaneko and Poumanyvong (2010), Mostafa (2010), Andrew and Brett (2011), Clark and Jorgenson (2011), Ilhan and Ali (2013), Knight, et al. (2013), Yong, et al. (2013), Gulden and Mehmet (2014), Usama, et al. (2014)].

However, the studies like White (2007), Juan and Jordi (2013), Duro (2016), Hao, et al. (2016), Jordi, et al. (2016), Hubler (2017), and Jorgenson, et al. (2017) addressed the cross countries inequality in resource consumption and the environmental degradation. Duro (2016) argued that due to increasing trend in CO_2 emission, cross countries have led to increase world's environmental inequalities in term of resources consumption. He further argued that by ignoring cross countries environmental, inequality would lead to provide biasness in policy implementation process for reduction of CO_2 emission. The biasness would occur in utilization of low level of CO_2 emission raw material, in implementation of environmentally friendly technology in one point agenda across countries. It is a collective agreement across countries in order to reduce its CO_2 emission. Hao et al. (2016) argued that due to difference in income, inequality leads to increase in CO_2 emission between different regions of China and consequently it improve environmental degradation of the globe.

[2] The impact of human activities in the form consumption of food, forest, fishes, energy, housing and transportation services environment are expressed as an amount of cropland, forest, fishing grounds, grazing and built-up lands. It is also known as the consumption-based environmental impact indicator and is measured in term of global hectare [Wackernagel and Rees (1996) Anders and John (2009) GFN (2012)].

[3] global hectare *gha* is a measure unit of ecological footprint and biocapacity accounts. The ecological footprint consist of six subcomponents (i.e., cropland, forest land, grazing land, fishing grounds, built-up land and carbon; and each of them is expressed in term of *gha* where one ecological footprint is equal to one hectare and one hectare is equal to approximately 2.47 acres [GFN (2016)].

Jorgenson et al. (2017) argued that influencing factors which leads to a positive association between CO_2 emission and income distribution are politics and Veblen effects, because the strong political power and more equal level of income distribution leads to increase energy consumption, and consequently increase the CO_2 emission. Hubler (2017) however, argued that lower trade practices, foreign direct investment and less use of modern technology lead to generate negative nexus between income inequality and CO_2 emission, particularly in developing countries because these factors lead to slow the economic growth and consequently increase income inequality which further creates the aforementioned nexus.

Juan and Jordi (2013) have estimated that due to differences in countries' affluence, sector structure and inequality in energy efficiency lead to vary inequality in per capita emission and energy intensity among countries. They argue that due to reduction in difference in affluence, sector structure lead to reduce inequality and consequently improve efficiency in energy intensity. They further argue that more equal affluence distribution, without considering inequality in environmental intensity[4] would not lead to reduce the total ecological footprint inequality because the interaction effect of affluence and environmental intensity plays an important role in reduction of inequality in term of ecological footprint. White (2007) however, argued that on the basis of Gini coefficient, total ecological footprint and its components follows different inequality distribution. This is due to difference of nations demand for resource use for their economic activities. He also argues that on basis of Atkinson inequality index HICs have low level of inequality in its environmental intensity.

These studies are based on considering either the cross sectional dataset or aggregate sample of developed and developing countries, while in this paper it is argued that due to difference in consumption pattern, population, income distribution and variation in demand for energy consumption between High and MICs it leads to generate difference in its ecological footprint as well. This argument leads to conduct the analysis of ecological footprint, environmental impact intensity and income inequality between High and MICs in the period 2003-2011, by borrowing the methodology of Atkinson index of inequality from the literature of welfare economics.

II. Methodology

Following the empirical literature for estimation of ecological footprint, environment intensity and income inequality is based on the method of White (2007); Juan and Jordi (2013); where they used the Atkinson (1970) inequality index by incorporating ecological footprint as:

[4] Environmental intensity is defined as an impact of per unit of economic output on environment, expressed as ecological footprint. It is measured as ecological footprint in the global hectare divided by economic output, expressed as Gross Domestic Product [York, et al. (2004)].

$$A_F = 1 - \frac{F_e}{\mu_F} \tag{1}$$

where A_F is the Atkinson inequality index, F_e is equally distributed of footprint, and μ_F is the mean of ecological footprint. The index value of Atkison index ranges from zero to one. If ecological footprints are equally distributed, i.e., $F_1=F_2=F_3=\ldots..=F_n$, then A_F will be zero and will be one in case of total inequality in ecological footprint.

The ecological footprint however, can be defined with innovation of environmental intensity as:

$$F_i = P_i * y_i * \frac{F_i}{Y_i} \tag{2}$$

where F_i is ecological footprint of country i, P_i is its population, y_i is its per capita income and (F_i/Y_i) is the impact of per unit economic output on ecological footprint. The per capita ecological footprint can be expressed as:

$$F_i = y_i * w_i \tag{3}$$

where F_i is per capita ecological footprint of country i and w_i are environmental impact intensity (or ecological inefficiency). The Atkinson inequality index is further expressed by White (2007); Juan and Jordi (2013) as:

$$A_F = 1 - \prod_{i=1}^{n} \left\{ \frac{F_i}{\mu_F} \right\}^{1/p_i} \tag{4}$$

where μ_F is a mean value of per capita ecological footprint and p_i is the relative population of country i. After innovation of environmental intensity in Equation (3), the Atkinson index can be expressed as:

$$1 - A_F = \prod_{i=1}^{n} \left\{ \frac{y_i * w_i}{\mu_F} \right\}^{1/p_i} \tag{5}$$

$$1 - A_F = \left\{ \frac{\mu_y \mu_w}{\mu_F} \right\} \prod_{i=1}^{n} \left\{ \frac{y_i * w_i}{\mu_y * \mu_w} \right\}^{1/p_i} \tag{6}$$

$$1 - A_F = \left\{ \frac{\mu_y \mu_w}{\mu_F} \right\} \prod_{i=1}^{n} \left\{ \frac{y_i}{\mu_y} \right\}^{1/p_i} \prod_{i=1}^{n} \left\{ \frac{w_i}{\mu_w} \right\}^{1/p_i} \tag{7}$$

where μ_y is a mean value of per capita income and μ_w is a mean value of environmental impact intensity. However, this study estimate and compare the Atkinson index of footprints (i.e., total ecological footprint and CO_2 footprint), environment intensity and per capita income of high and middle income countries for the period 2003-2011 as:

$$1 - A_F = \left\{ \frac{\mu_y \mu_w}{\mu_F} \right\} (1 - A_y) * (1 - A_w) \tag{8}$$

where

$$\mu_F = \frac{\sum_{t=2003}^{2011} \left(\text{total ecological footprint}_t \big/ \text{population}_t \right)}{n} \tag{9}$$

$$\mu_w = \frac{\sum_{t=2003}^{2011} \left(\text{total ecological footprint}_t \big/ \text{GDP}_t \right)}{n} \tag{10}$$

$$\mu_y = \frac{\sum_{t=2003}^{2011} \left(\text{GDP}_t \big/ \text{population}_t \right)}{n} \tag{11}$$

$$(1 - A_w) = \prod_{i=1}^{n} \left\{ \frac{\left(\text{total ecological footprint}_t \big/ \text{GDP}_t \right)_i}{\frac{\sum_{t=2003}^{2011} \left(\text{total ecological footprint}_t \big/ \text{GDP}_t \right)}{n}} \right\}^{1/p_i} \tag{12}$$

$$(1 - A_y) = \prod_{i=1}^{n} \left\{ \frac{\left(\text{GDP}_t \big/ \text{population}_t \right)_i}{\frac{\sum_{t=2003}^{2011} \left(\text{GDP}_t \big/ \text{population}_t \right)}{n}} \right\}^{1/p_i} \tag{13}$$

The Atkinson indices of ecological footprint, income and environmental impact intensity are shown by A_F, A_y and A_w. The value of 1-A indicates an Atkinson measure of equality where perfect equality would be equal to one and complete inequality would be equal to zero [White 2007)].

Thus, the interpretation of Equation (8) is straightforward. The Atkinson index (1-A_F) of ecological footprint depends on distribution of income and environmental impact intensity (ecological inefficiency), and the mean of these variables. It is commonly argued that domestic income inequality is inversely related to a nation's ecological footprint. The argument is that nations with higher income inequality would have low per capita ecological footprint because they have relative lower income and mainly focus on export of raw materials and agriculture commodities [White, (2007), Jorgenson (2009), Juan and Jordi 2013)].

III. Data Description

The dataset of ecological footprint is derived from the Global Footprint Network (GFN) is one of the international organizations. It documents the ecological footprint by dividing the yearly consumption of cropland, forest, grazing land, fishing grounds, CO_2 footprint and built-up land activities from the production of land measures in hectares. This ratio is multiplied by the yield and equivalence factors as derived by the GFN. In the second stage all areas of land required for cropland, forest, grazing land, fishing grounds, CO_2 footprint and built-up land aggregates in the form of total ecological footprint global hectares in a given year. At every stage of computation the process of ecological footprint is taken, but double counting is avoided in order to improve accuracy of environmental impact indicator, i.e., the total ecological footprint. This is a comprehensive measure because raw input data for computation of national ecological footprint is obtained from different sources, for example, Food and Agriculture Organization (FAO), International Energy Agency (IEA), United Nations Commodity Trade Statistics Database (UN COMTRADE), World Development Indicators Database (WDI), The conference board, Centre for Sustainability and the Global Environment (SAGE), and other Databases.

The Global Footprint Network (GFN) covers 152 countries, different regions and the World. The data of Gross Domestic Product (GDP) in US million dollars at purchasing power parity and population in millions are obtained from the World Bank dataset.

IV. Results and Discussion

The following results assess the mean outcomes and inequality in ecological footprint, CO_2 footprint, its environment intensity and per capita income. Table 1 displays the estimated mean value of total ecological footprint, environmental intensity and per capita income for period 2003-2011.

It can be concluded from the findings that HICs have larger per capita income than the MICs which consequently accelerate the ecological footprint. This finding is consistent with the report of Global Footprint Network (2016), where it is stated that to maintain higher standards of living the HICs extract larger amount of ecological footprint than the MICs. However, the role of better technology use in increasing productivity cannot be ruled out.

The environmental impact intensity of per unit economic output in MICs is larger than the HICs which lead to explain that these regions have more differences in the demand for resources consumption. As there are 9 fold (\$35036/\$3919) difference in per capita income and 2.4 (5.375/2.234) differences in total ecological footprint leads to 5 fold (0.926/0.192) difference in the environment intensity by these regions which is consistent with Galli, et al. (2012), GFN (2014).

Table 2 display the comparison between CO_2 footprint and its environment intensity, in case of High and MICs. It is concluded from the finding that more difference exist in demand for the area of land required for assimilation of CO_2 emission and the environment impact intensity of per unit economic output between these regions. There are 4 fold (3.09/0.83) and 3 fold (0.288/0.11) differences in CO_2 footprint and the environmental intensity between High and MICs, respectively. It shows that HICs have 4 times larger CO_2 footprint in the entire period and have 3 times lower environment intensity than MICs. The EII of CO_2 emission declines overtime, in case of MICs because better utilization of raw material in term to accelerate its economic development.

In Table 3, the Atkinson index of equality is estimated for total ecological footprint, environment intensity and per capita income. The findings conclude that distribution of per capita income and environment intensity demonstrates more inequality in MICs while, distribution of ecological footprint demonstrate more inequality in HICs than the MICs. There are two folds (0.80/0.37) and five folds (0.57/0.13) difference in per capita income and the environmental intensity inequality between these regions, which leads to 1.2 times (0.66/0.55) difference in its demand of ecological footprint. The per capita income inequality across the group of High and Middle income countries declined overtime, except for the year 2009 (in case of HICs) and 2011 (in case of MICs); due to global economic recession in the year 2008 which quickly increased the inequality of HICs and later, in case of MICs. However, according to the findings of this

TABLE1

Total Ecological Footprint, Per Capita Income and Environmental Impact Intensity

Year	Mean Values of HICs			Mean Values of MICs		
	Per capita income	EII of EF	EF	Per capita income	EII of EF	EF
	US$	per $1000 of income	*gha*/ per person	US$	per $1000 of income	*gha*/ per person
2003	$26,743	0.261	5.480	$2,234	1.36	2.23
2005	$31,978	0.207	5.503	$3,057	1.01	2.05
2007	$37,831	0.178	5.680	$4,145	0.86	2.39
2009	$36,226	0.172	5.192	$4,513	0.80	2.30
2011	$42,400	0.142	5.020	$5,644	0.60	2.20
Mean	$35,036	0.192	5.375	$3,919	0.926	2.23

EII: Environmental Impact Intensity. EF: Ecological Footprint.
HICs: High Income Countries. MICs: Middle Income Countries. *gha*: global hectare.
Source: Author Estimation based on Global Footprint Network (GFN) and World Bank Dataset.

TABLE 2

CO_2 Ecological Footprint and its Environmental Impact Intensity

Year	Mean Values of HICs		Mean Values of MICs	
	CO_2	EII of CO_2	CO_2	EII of CO_2
	gha/ per person	per $1000 of income	*gha*/ per person	per $1000 of income
2003	3.250	0.156	0.70	0.45
2005	3.154	0.115	0.75	0.32
2007	3.232	0.101	0.93	0.28
2009	2.880	0.096	0.90	0.20
2011	2.980	0.084	0.87	0.19
Mean	3.090	0.110	0.83	0.28

EII: Environmental Impact Intensity. HICs: High Income Countries.
MICs: Middle Income Countries. *gha*: global hectare.
Source: Author Estimation based on Global Footprint Network (GFN) and World Bank Dataset.

TABLE 3

Atkinson Index of Equality:
Total Ecological Footprint, Per Capita Income and Environmental Impact Intensity

Year	Atkinson Indices of HICs			Atkinson Indices of MICs		
	Per capita income	EII of EF	EF	Per capita income	EII of EF	EF
	$(1-A_y)$	$(1-A_{wEF})$	$(1-A_{EF})$	$(1-A_y)$	$(1-A_{wEF})$	$(1-A_{EF})$
2003	0.633	0.680	0.550	0.270	0.113	0.600
2005	0.814	0.570	0.560	0.350	0.120	0.628
2007	0.890	0.567	0.598	0.390	0.127	0.736
2009	0.813	0.517	0.505	0.450	0.101	0.670
2011	0.852	0.518	0.537	0.410	0.167	0.687
Mean	0.800	0.570	0.550	0.370	0.130	0.660

EII: Environmental Impact Intensity. EF: Ecological Footprint. HICs: High Income Countries.
MICs: Middle Income Countries. *gha*: global hectare. $(1-A_y)$ = Atkinson Index of per capita income.
$(1-A_{wEF})$ = Atkinson Index of Environmental Impact Intensity. $(1-A_{EF})$ = Atkinson Index of Ecological Footprint.
Source: Author Estimation based on Global Footprint Network (GFN) and World Bank Dataset.

study, the per capita income inequality and EII of ecological footprint are greater in the MICs than in the HICs, overtime. This could be because HICs utilises its raw material in a more productive way due to better technology.

Table 4 demonstrate the estimated Atkinson index of CO_2 and its environmental impact intensity. According to the findings, distribution of CO_2 footprint shows two folds (0.83/0.38) inequality difference between High and the MICs, while the CO_2 environmental impact intensity shows 1.5 fold (0.41/0.28) differences. This explanation however, leads to conclude that HICs have large variation in CO_2 footprint distribution while MICs have more variation in the environmental impact intensity. Similarly, the Atkinson index EII of CO_2 of MICs declines due to increase in demand for fossil fuel and hence there is an increase in CO_2 footprint overtime.

V. Conclusion and Policy Implications

In this paper we examine the relationship between the resources used (ecological footprint and CO_2 footprint, environmental impact intensity and income inequality along with its mean outcomes, both High and MICs for the period 2003-2011. It is concluded from the discussion that HICs have greater demand for total ecological and CO_2 footprints and therefore, reduction in these environmental impact indicators through the implementation of different policy measures concerned with components of total ecological footprint will lead to reduce their environment intensity. Similarly, the MICs have greater environment intensity which leads to suggest that appropriate planning for the adaptation of environmental friendly technology and for the acceleration of economic growth will lead at least to reduce the environment intensity. The findings of Atkinson indices demonstrate that reduction in environmental impact intensity and income inequality in case of MICs will lead to reduce inequality in total

TABLE 4

Atkinson Index of Equality:
CO_2 Ecological Footprint and Environmental Impact Intensity

Year	Atkinson Indices of HICs		Atkinson Indices of MICs	
	CO_2	EII of CO_2	CO_2	EII of CO_2
	$(1\text{-}A_{CO_2})$	$(1\text{-}A_{w\,CO_2})$	$(1\text{-}A_{CO_2})$	$(1\text{-}A_{w\,CO_2})$
2003	0.520	0.634	0.70	0.46
2005	0.318	0.334	0.75	0.31
2007	0.380	0.397	0.93	0.28
2009	0.340	0.342	0.90	0.20
2011	0.367	0.354	0.87	0.14
Mean	0.380	0.410	0.83	0.28

HICs: High Income Countries. MICs: Middle Income Countries *gha*: global hectare.
$(1\text{-}A_{co_2})$ = Atkinson Index of CO_2. $(1\text{-}A_{wco_2})$ = Atkinson Index of Environmental impact intensity of CO_2.
Source: Author Estimation based on Global Footprint Network (GFN) and World Bank Dataset.

ecological footprint because the total ecological footprint is basically derived from interaction effect of environment intensity and the per capita income. In this regard, it is suggested that there should be collective bargaining for mitigation of environment intensity and income inequality among them. The distribution of CO_2 footprint exhibits more inequality and low environment intensity in HICs than the MICs. It is therefore suggested that these regions should implement the policy through which distribution of CO_2 footprint must be lower than its biocapacity. However, this study is limited to High and MICs. There are still other areas where similar research is can be conducted. First, it is possible to estimate inequality in resource-use by taking into account the ecological deficit and surplus countries, separately; second, inequality in resource-use of each country is possible to estimate in case of time series data availability.

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APPENDIX

List of High Income Countries

Australia	France	Netherlands	Spain
Austria	Germany	New Zealand	Sweden
Bahrain	Greece	Norway	Switzerland
Belgium	Hungary	Poland	Trinidad
Canada	Ireland	Portugal	UAE
Cyprus	Israel	Qatar	UK
Czech Republic	Italy	Saudi Arabia	USA
Denmark	Japan	Singapore	
Estonia	Korea	Slovakia	
Finland	Kuwait	Slovenia	

List of Middle Income Countries

Albania	Dominican	Lithuania	Serbia
Algeria	Ecuador	Macedonia	South Africa
Angola	Egypt	Malaysia	Sri Lanka
Argentina	El Salvador	Mauritania	Swaziland
Armenia	Gabon	Mauritius	Syrian
Azerbaijan	Georgia	Mexico	Thailand
Belarus	Ghana	Moldova	Timor-Leste
Bolivia	Guatemala	Mongolia	Tunisia
Bosnia	Honduras	Montenegro	Turkey
Botswana	India	Morocco	Turkmenistan
Brazil	Indonesia	Namibia	Ukraine
Bulgaria	Iran	Nicaragua	Uruguay
Cameroon	Iraq	Nigeria	Uzbekistan
Chile	Jamaica	Pakistan	Venezuela
China	Jordan	Panama	Viet Nam
Colombia	Kazakhstan	Paraguay	Yemen
Congo	Latvia	Peru	Zambia
Costa Rica	Lebanon	Philippines	
Côte d'Ivoire	Lesotho	Romania	
Cuba	Libya	Russia	