Kuznets's Inverted U Hypothesis: The Relationship Between Economic Development and Ecological Footprint

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Abstract. Sustainable development is defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs". The concept of sustainable development contains both environmental sustainability and economic development. One simple way to assess sustainable development is to use the Ecological Footprint and Human Development Index (HDI). HDI measures a country's average achievements in the areas of health, knowledge, and standard of living. The Ecological Footprint measures a country's demand on nature and can be compared to available bio capacity. The HDI-Footprint, using simple indicators, prominently reveals how far removed the world is from achieving sustainable development. For all countries, the goal should be high human development and a low ecological footprint per capita. Environmental Kuznets Curve is located in the sustainable economic development literature puts forward that the inverse U shape relationship between the level of economic development and environmental degradation. In this study, the ecological footprints of countries are compared with the level of human development and the validity of Kuznets inverted U hypothesis being investigated. Measuring these two variables reveals that very few countries come close to achieving sustainable development.

Keywords: Economic development · Human development index
Ecological footprint · Biological capacity · Environmental kuznets curve

1 Introduction

Sustainable development is a commitment improving the quality of human life while living within the carrying the capacity of supporting ecosystems. "Development" is shorthand for committing to well-being for all. "Sustainable" implies that such development must come at no cost to future generations. In other words, development is required to occur within what the planet's ecosystems are able to provide season after season, year after year. It needs to be enabled within the means of nature [1]. For all countries, the goal should be high human development and a low ecological footprint per capita. However only a few countries come close to creating such a globally reproducible high level of human development without exerting unsustainable pressure on the planet's ecological resources [2]. Unfortunately, human beings cut trees faster

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than they mature, harvest more fish than the oceans can replenish, or emit more carbon into the atmosphere than the forests and oceans can absorb. The sum of all human demands no longer fits within what nature can renew. The consequences are diminished resource stocks and waste accumulating faster than it can be absorbed or recycled, such as with the growing carbon concentration in the atmosphere [3].

One simple way to assess sustainable development is using the Ecological Footprint and Human Development Index (HDI). The United Nations HDI is an indicator of human development that measures a country's achievements in the areas of life expectancy, education, and income. The Ecological Footprint measures a people's demand on nature and can be compared to available bio capacity. The HDI-Footprint, using simple indicators, prominently reveals how far removed the world is from achieving sustainable development [2].

An Ecological Footprint less than 1.7 global hectares per person makes those resource demands globally replicable. The United Nations considers an HDI over 0.8 to be "very high human development". These two thresholds define two minimum criteria for global sustainable development—an average Footprint (significantly) lower than 1.7 gha per person and an HDI of at least 0.8. Measuring these two variables reveals that very few countries (Cuba, Sri Lanka etc.) come close to achieving sustainable development [1].

The general proposition that economic growth is good for the environment has been justified by the claim that there exists an empirical relation between per capita income and some measures of environmental quality. It has been observed that as income goes up there is increasing environmental degradation up to a point, after which environmental quality improves. (The relationship has an "Inverted-U" shape.) [4]. In this paper we investigate the relationship between economic development (by using HDI) and environmental degradation (by using ecological footprint). According to Environmental Kuznets Hypothesis (EKH), as economies developed, reduces ecological footprint. But unfortunately, data says developed countries have high ecological footprint scores.

2 Kuznets's Inverted U Hypothesis

The Environmental Kuznets Curve (EKC) hypothesis postulates an inverted U shaped relationship between different pollutants and per capita income. Environmental pressure increases up to a certain level as income goes up; after that, it decreases. Environmental quality deteriorates at the early stages of economic development and subsequently improves at the later stages. In other words, environmental pressure increases faster than income at early stages of development and slows down relative to Gross Domestic Product (GDP) growth at higher income levels. This systematic relationship between income change and environmental quality has been called the Environmental Kuznets Curve [5]. The EKC is named for Simon Kuznets (1955) who hypothesized that income inequality first rises and then falls as economic development proceeds [6].

In the first stage of industrialization, pollution grows rapidly because high priority is given to increase material output, and people are more interested in jobs and income

than clean air and water. People are too poor to pay for abatement, and/or disregard environmental consequences of growth [7]. The rapid growth inevitably results in greater use of natural resources and emission of pollutants, which in turn put more pressure on environment. Environmental degradation increases with growing income up to a threshold level beyond which environmental quality improves with higher income per capita. This relationship can be shown by an inverted U shaped curve. Figure 1 demonstrates EKC [8]. As can be seen on figure, the EKC proposes that indicators of environmental degradation first rise, and then fall with increasing income per capita.

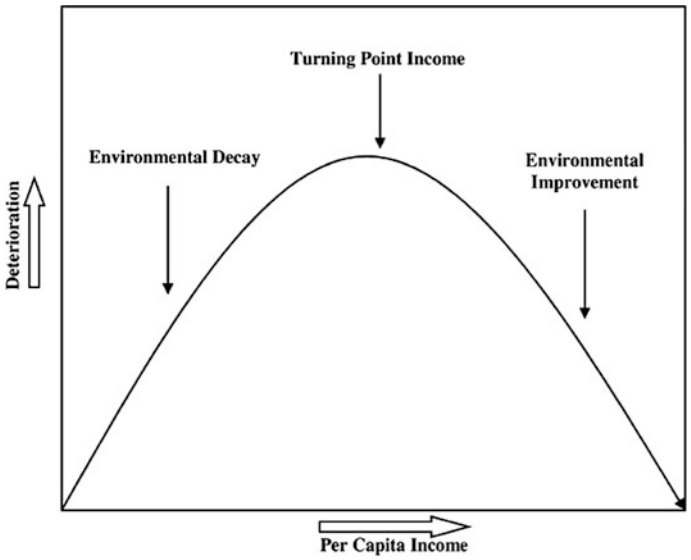

Fig. 1 Environmental Kuznets curve

As economic development accelerates with the intensification of agriculture and other resource extraction, at the take-off stage, the rate of resource depletion begins to exceed the rate of resource regeneration, and waste generation increases in quantity and toxicity. At higher levels of development, structural change towards information-intensive industries and services, coupled with increased environmental awareness, enforcement of environmental regulations, better technology and higher environmental expenditures, results in levelling off and gradual decline of environmental degradation. As income moves beyond the EKC turning point, it is assumed that transition to improving environmental quality starts. Thus, it could be a depiction of the natural process of economic development from a clean agrarian economy to a polluting industrial economy, and, finally, to a clean service economy [5].

3 Methods

Sustainable development is defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs". The concept of "sustainable development" contains both environmental sustainability and economic development. One simple way to assess sustainable development is to use the Ecological Footprint and Human Development Index (HDI).

We examine sustainable development in terms of its two dimensions. We assess progress in development with the HDI because it is one of the most widely used overall measures of human well-being. The other dimension of sustainable development is the commitment to develop within the ecological capacity of planet Earth. This can be measured with the Ecological Footprint, a resource accounting tool that assesses how much of the regenerative capacity of the biosphere is occupied by human activities.

3.1 Human Development Index

HDI measures a country's average achievements in the areas of health, knowledge, and standard of living. Since 1990, the United Nations Development Program (UNDP) has used the Human Development Index in its annual Human Development Report. The purpose of the report is to show how well the management of economic growth and human development is actually improving human well-being in the nations of the world. The report defines human development as the "process of enlarging people's choices to live a long and healthy life, to be educated, have access to resources needed for a decent standard of living. So the index focuses on "health, education and the standard of living" as proxies for people's ability to live long and prosperous lives [9].

The health dimension is measured using life expectancy at birth. This also serves as a proxy for other aspects of well-being such as adequate nutrition and good health.

The education dimension is measured by mean of years of schooling for adults aged 25 years and more and expected years of schooling for children of school entering age. These two separate indicators are intended to reflect the level of knowledge of the adult population as well as the investment in the youth.

A the standard of living dimension is measured by gross national income per capita adjusted to reflect purchasing power parity. The HDI uses the logarithm of income, to reflect the diminishing importance of income with increasing Gross National Income [10]. The HDI is the geometric mean of normalized indices for each of the three dimensions. Figure 2 demonstrates dimensions and indicators of HDI [11].

Fig. 2 Human development index

An HDI value of 1.0 implies that a country has achieved the maximum value for each sub-index, and a value of zero implies that the country is at or below the minimum value for all sub-indices. UNDP defines an HDI score of 0.8 as the limit between high and very high human development.

Figure 3 shows human development map prepared for 2015 [12]. According to the map the North America (USA and Canada), Argentina and Chile in the Latin America,

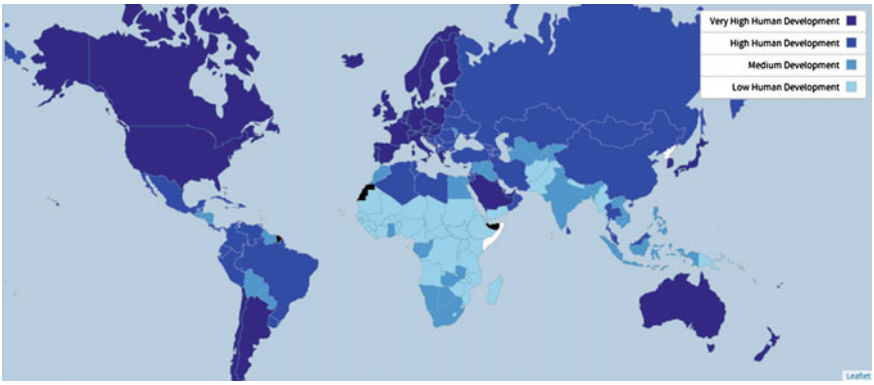

Fig. 3 Human development map (2015)

all of the East European countries and Australia and Nez Zealand have high human development. On the other hand, most African countries have low human development.

3.2 Ecological Footprint

Ecological footprint is a natural resource accounting tool that measures the ecological sustainability. The simplest way to define ecological footprint would be to call it the impact of human activities measured in terms of the area of biologically productive land and water required to produce the goods consumed and to assimilate the wastes generated.

The Ecological Footprint (EF) was developed by Mathis Wackernagel and William Rees as a way to account for flows of energy and matter into and out of the human economy and convert those flows into a measure of the area of productive land and water required to support those flows. The EF is intended to be used as a resource management tool for assessing whether and to what extent an individual, city, or nation is using available ecological assets faster than the supporting ecosystems can regenerate those assets [10].

The Ecological Footprint measures how much of the regenerative capacity of the biosphere is used by human activities. It does so by calculating the amount of biologically productive land and water area required to support a given population at its current level of consumption and resource efficiency. A country's Footprint is the total area required to produce the food, fibre and timber that it consumes, absorb the waste it generates, and provide area for its infrastructure [13]. Because trade is global, an individual or country's Footprint includes land or sea from all over the world. Without

further specification, Ecological Footprint generally refers to the Ecological Footprint of consumption. The most commonly reported type of Ecological Footprint is Ecological Footprint of consumption (EFC). It is defined as the area used to support a defined population's consumption.

The consumption Footprint (in gha) includes the area needed to produce the materials consumed and the area needed to absorb the carbon dioxide emissions. The consumption Footprint of a nation is calculated in the National Footprint Accounts as a nation's primary production Footprint plus the Footprint of imports minus the Footprint of exports, and is thus, strictly speaking, a Footprint of apparent consumption. The national average of per capita Consumption Footprint is equal to a country's Consumption Footprint divided by its population.

EF always compares bio capacity. Bio capacity serves as a lens, showing the capacity of biosphere to regenerate and provide for life. It allows researchers to add up the competing human demands, which include natural resources, waste absorption, water renewal, and productive areas dedicated to urban uses. As an aggregate, bio capacity allows us to determine how large the material metabolism of human economies is compared to what nature can renew [13].

In contrast to the Footprint, which addresses demand on ecosystems, bio capacity describes the supply side—the productive capacity of the biosphere and its ability to provide a flux of biological resources and services useful to humanity. Both Footprint and bio capacity are measured in global hectares (gha). Global hectare represents a hectare of land with world average bio productivity. In 2015, the global per capita Footprint was 2.7 gha, and the per capita Footprint of nations with available data ranged from 0.4 gha/cap in Eritrea to 15.8 gha/cap in Luxembourg. In 2015, globally available bio capacity was 1.7 gha/cap.

Figure 4 shows Ecological Deficit/Reserve Map prepared by Global Footprint Network. While greens are biocapacity creditors, reds are bio capacity debtors [14]. If a

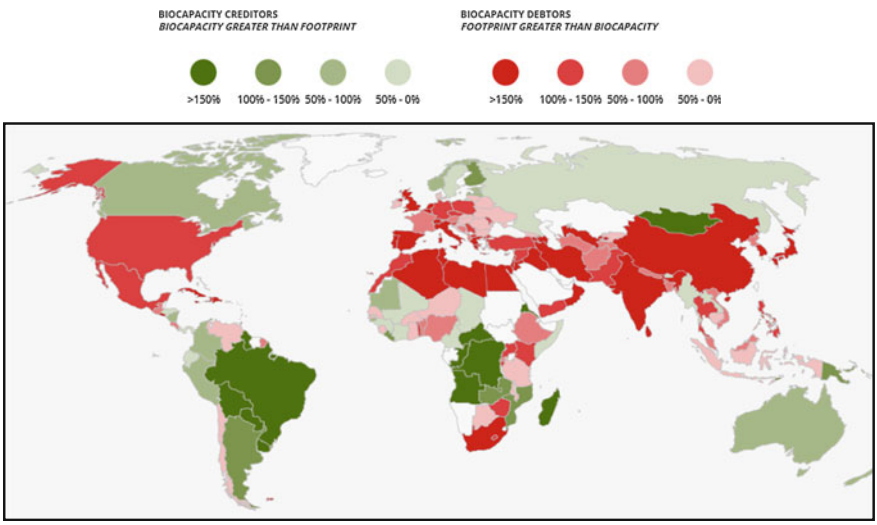

Fig. 4 Ecological deficit/reserve map

country Ecological Footprint is bigger than bio capacity, it is bio capacity debtors or vice versa. Note that developed countries are debtors, developing countries are creditors.

4 Measuring Sustainable Development

Sustainable development is a commitment improving the quality of human life while living within the carrying the capacity of supporting ecosystems.

SUSTAINABLE: Living within the means of planet Earth requires an average Ecological Footprint per person of less than 1.7 global average hectares (the supply of biologically productive planetary surface area that exists per person). The Ecological Footprint measures how much of the planet's surface people demand from nature for food, fiber, timber, and waste absorption (particularly for CO_2 from fossil fuel). Currently, the Footprint of humanity is 2.7 global average hectares per person.

DEVELOPMENT: Human Development Index On a scale of zero to one, 0.8 is considered the threshold for a very high level of development.

Successful sustainable development requires that the world, on average meets at a minimum these two criteria. These two thresholds define two minimum criteria for sustainable development. We argue that an HDI of no less than 0.8 and a per capita Ecological Footprint less than the globally available bio capacity per person (less than 1.7 global average hectares) represent minimum requirements for sustainable development that is globally replicable. For all countries, the sustainable development goal should be high human development and a low ecological footprint per capita.

Figure 5 illustrates combined the Human Development Index and Ecological Footprint of Nations in a graph [1].

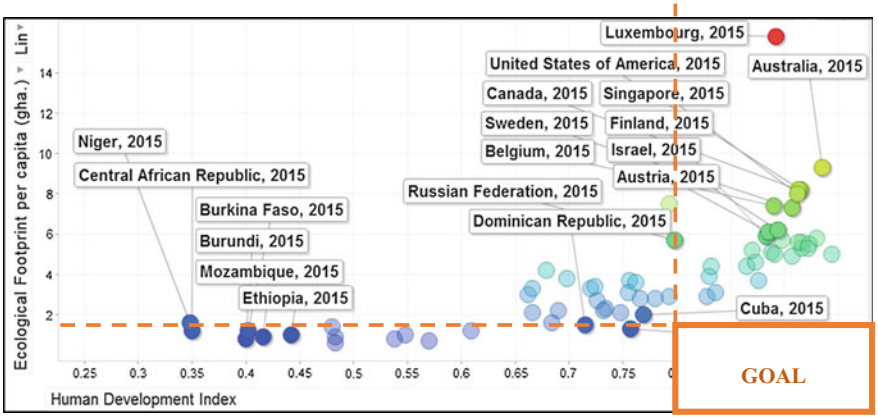

Fig. 5 Human development index and ecological footprint of nations (2015)

The graph exemplifies the challenge of creating a high level of human well-being without depleting the planet's or a region's ecological resource base. This indicates that

Table 1 Human development index and ecological footprint values of selected countries

Countries	HDI		Ecological footprint per capita (gha)	
	Ranking	Value	Ranking	Value
Luxembourg	19	0.892	1	15.8
Australia	2	0.935	2	9.3
USA	8	0.915	3	8.2
Canada	9	0.913	4	8.2
Singapore	11	0.912	5	8.0
Trinidad and Tobago	64	0.772	6	7.9
Oman	52	0.793	7	7.5
Belgium	21	0.890	8	7.4
Sweden	14	0.907	9	7.3
Estonia	30	0.861	10	6.9
Latvia	46	0.819	11	6.3
Israel	18	0.894	12	6.2
Mongolia	90	0.727	13	6.1
Austria	23	0.885	14	6.1
Finland	24	0.883	15	5.9
Lithuania	37	0.839	16	5.8
Slovenia	25	0.880	17	5.8
Switzerland	3	0.930	18	5.8
South Korea	17	0.898	19	5.7
Russia	50	0.798	20	5.7
New Zealand	9	0.913	21	5.6
Ireland	6	0.916	22	5.6
Denmark	4	0.923	23	5.5
Turkmenistan	109	0.688	24	5.5
Germany	6	0.916	25	5.3
Netherlands	5	0.922	26	5.3
Czech Rep.	28	0.870	27	5.2
France	22	0.888	28	5.1
Belarus	50	0.798	29	5.1
Japan	20	0.891	30	5.0
Norway	1	0.944	31	5.0
UK	14	0.907	32	4.9

countries in Europe and North America have very high Ecological Footprints and acceptable Human Development Indexes (above 0.8), while countries in Africa have unacceptably low Human Development Indexes (below 0.8) but have Ecological Footprints within the biosphere's allowable capacity per person. The lower right

quadrant represents the goal of sustainable development, i.e., high human development, within levels of resource consumption that can be extended globally. Measuring these two variables reveals that very few countries (Cuba, Sri Lanka etc.) come close to achieving sustainable development. Despite growing global adoption of sustainable development as an explicit policy goal, we find that in the year 2015 (latest available) any countries surveyed met both of these minimum requirements.

Table 1 shows Human development index and ecological footprint values of some countries. Data shows high human development countries have high ecological footprint scores. An overall trend in high-income countries over the past twenty-five years that improvements to HDI come with disproportionately larger increases in Ecological Footprint, showing a movement away from sustainability.

5 Conclusions

Sustainable development represents a commitment to advancing human well-being, with the added constraint that this development needs to take place within the ecological limits of the biosphere. Progress in both these dimensions of sustainable development can be assessed: we use the HDI as an indicator of development and the Ecological Footprint as an indicator of human demand on the biosphere. The Ecological Footprint and HDI represent strict, yet widely accepted, metrics for ecological sustainability and human development.

We examine sustainable development in terms of its two dimensions. We assess progress in development with the HDI because it is one of the most widely used overall measures of human well-being. The other dimension of sustainable development is the commitment to develop within the ecological capacity of planet Earth. This can be measured with the Ecological Footprint, a resource accounting tool that assesses how much of the regenerative capacity of the biosphere is occupied by human activities.

Environmental Kuznets Curve is located in the sustainable economic development literature puts forward that the inverse U shape relationship between the level of economic development and environmental degradation. In the early stages of economic growth degradation and pollution increase, but beyond some level of income per capita, which will vary for different indicators, the trend reverses, so that at high income levels economic growth leads to environmental improvement. This implies that the environmental impact indicator is an inverted U shaped function of income per capita.

In this study, the ecological footprints of countries are compared with the level of human development and the validity of Kuznets inverted U hypothesis being investigated.

We argue that an HDI of no less than 0.8 and a per capita Ecological Footprint less than the globally available bio capacity per person (less than 1.7 global average hectares) represent minimum requirements for sustainable development that is globally replicable. Despite growing global adoption of sustainable development as an explicit policy goal, we find that in the year 2015 any countries surveyed met both of these minimum requirements. We also find an overall trend in high-income countries over the past twenty-five years that improvements to HDI come with disproportionately larger increases in Ecological Footprint, showing a movement away from

sustainability. Some lower-income countries, however, have achieved higher levels of development without a corresponding increase in per capita demand on ecosystem resources.

Kuznets's Inverted U hypothesis has been tested in many studies. There is little evidence for a common inverted U-shaped pathway that countries follow as their income rises. For all countries, the goal should be high human development and a low ecological footprint per capita. However unlike Kuznets, data shows high human development countries have high ecological footprint scores.

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