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# Reducing Ecological Footprint: Examining Panel Data

Neil Belford, Jordan Humes, Manasi Murde, Bruce Rehburg,

Oklahoma State University

ABSTRACT

Degradation of the global environment is occurring at an alarming rate. It is feared by many that the current path of economic development is unsustainable. In this paper, worldwide panel data is explored to develop a model that can be used to find characteristics that are associated with a nation's ecological impact, as measured by Ecological Footprint Accounting. Through panel regression in SAS®, several factors are found that are associated with a reduction in Ecological Footprint among OECD countries after controlling for GDP and population size. These findings point to general policy objectives that can be used by industrialized and industrializing countries to reduce their ecological impact.

INTRODUCTION

Scientists agree that mankind has impacted Earth in profound and, in some cases, irreversible ways. One way to measure humanity's ecological impact is Ecological Footprint and Biocapacity Accounting. The Global Footprint Network measures biocapacity by tracking how much biologically productive land is available to a nation to provide the resources its population consumes and to absorb its wastes. It measures Ecological Footprint by measuring how much land is needed to provide for the population of that nation and their demands. These demands include, among others, agricultural space, absorption of carbon dioxide emissions, and accommodating built infrastructure ("Data and Methodology" 2019). These accounts are measured in standardized units called "Global Hectares" and compared across nations. By subtracting biocapacity from footprint, it can be shown whether a nation, or the world as a whole, is using more or fewer natural resources than are available. This net footprint has been increasing globally for decades:
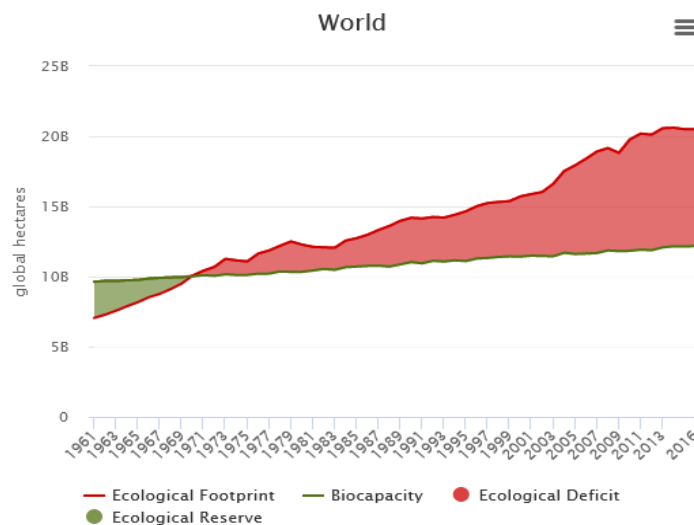
1 This is only a brief introduction to The Global Footprint Network's Footprint and Biocapacity Accounting. The full methodology can be found at https://www.footprintnetwork.org

In other words, humanity is consuming the Earth's natural resources faster than they can be replenished, and that overshoot continues to increase. Due to this, many people believe that the current trend is unsustainable.

Biocapacity, as measured here, is very stable over time with only small changes, mostly due to methodological changes in how it is measured. Ecological footprint on the other hand, is a direct result of human activity. This means that footprint can be influenced by government and industry policies. If nations around the globe can find ways to reduce that Ecological Footprint, then it would be possible to begin to close the gap between global ecological impact and the ability of the Earth to absorb that impact.

The goal of this research is to find ways through which nations can decrease their Ecological Footprint. This paper aims to do so by examining time series data across many countries to find factors that are associated with changes in Ecological Footprint. These factors can then be used as the basis for policy changes that can contribute to reductions in ecological impact.

DATA

The dataset used for this analysis came from two main sources. The first, Global Footprint Network (https://www.footprintnetwork.org/), contained Ecological Footprint and biocapacity data for countries from 1961-2016. The second, the World Bank (https://data.worldbank.org/) contained various economic indicators for all nations from 1960-2016. Both sets of data are available from the websites of the two organizations for public use.

DATA PREPARATION

The two data sets needed to be combined into one master data set for the purpose of this research. The creation of the master data set involved several data cleaning steps:

First, the datasets had to be transposed into a format that was appropriate for time-series analysis. In the original data, each year was a separate column with each row corresponding to a single measurement across all of the years. Using PROC TRANSPOSE, the datasets were transposed so that each column was a variable and each row was an individual record. "Country Name" and "Year" columns uniquely identify each observation. Once the format was consistent across datasets, they were merged, using the "Country Name" and "Year" columns as keys to combine each row.

The full master dataset contains 10,755 rows and 153 columns. However, the master dataset also contained large amounts of missing data. Much of the missing data was for years before 1995, so only the data for years 1995 to 2015 was considered for the purpose of analysis in this research. The dataset was also filtered to only contain countries from the Organization for Economic Cooperation and Development (OECD). The OECD is an intergovernmental economic organization founded in 1961 to stimulate economic progress and world trade. The OECD countries tend to be more economically developed and have a more complete set of independent variables to use. Another consideration is that countries with a high level of economic development tend to also have a greater ecological impact and thus have a greater capacity to lower their Ecological Footprint. According to the International Monetary Fund, the three dozen OECD countries account for over 60% of nominal global Gross Domestic Product, also known as GDP (International Monetary Fund, 2019). After filtering, the master dataset used in the final model contained 1,914 rows.

ANALYSIS

TARGET VARIABLE

One significant driver of Ecological Footprint is economic development. For example, it is hard to imagine that subsistence farming could be more damaging to the environment than

a factory. Indeed, the dataset bears this out. When considering all countries across all years in the full dataset, there is a strong correlation between Ecological Footprint and GDP (R^2 = 0.969). The other significant driver of Ecological Footprint is population. Again, it is intuitive that, all else equal, a larger population will put a larger strain on local natural resources than a smaller one. This, too, is borne out in the data, and the correlation is even stronger than GDP (R^2 = 0.979). Even when only looking at the OECD countries, there is still a very strong relationship between total Ecological Footprint with GDP (R^2 = 0.925) and population (R^2 = 0.940). Of course, it is theoretically possible to reverse GDP and population growth, but in a practical sense, the authors do not believe it is feasible or desirable to do so. In addition, these two factors share a large amount of covariance with many, if not all, other indicators. To control for these relationships, the authors chose to shift their target from total Ecological Footprint to a derived variable: Ecological Footprint per $1000 of GDP. Using per capita measures to create the variable also reduced the impact of total population.

Ecological Footprint per GDP, or EFperGDP, is derived as follows:

$$Ecological\ Footprint\ per\ GDP = \frac{Footprint\ per\ Capita}{GDP\ per\ Capita} * 1000$$

EFperGDP should make it possible to find factors that drive reductions in Ecological Footprint, independent of changes in GDP or Population. EFperGDP for all OECD countries is shown in Table 2 (and visualized in Figure 1) in the appendix.

MODELING

The final dataset is panel data because it contains both cross-sectional and time series data. Panel data can be modelled using Panel Regression, which can control for unobserved variables that might cause variation between groups (countries in this case) and over time. By using panel data, one can look at how each individual country's Ecological Footprint varied over time, and find those variables that are consistently associated with a specific change in EFperGDP.

Variables were selected for modelling from four main sources: Existing literature, intuition, correlation analysis, and traditional multiple regression performed across a single year. After choosing candidate variables, the next step was to perform multiple panel regressions to find which variables were significant, and to discover which variables were redundant. Many of the variables were highly correlated with one another, so variable redundancy became an important factor in selecting variables for the final model. Due to limitations in data availability, a few nations were removed for the following analysis, which brought the total number of OECD countries in the analysis to 31. See Table 3 (in the Appendix) for full descriptions of the selected variables.

For the panel regression there are two main types of models: Random Effects models and Fixed Effects models. When modelling the data with a Random Effects model, the Hausman test is significant, which signifies that the unobserved variables are correlated with the observed variables. This means that the Fixed Effects model is preferred, as it can control for those unobserved factors, which allows the effect of the selected variables to be measured independent of those that are not in the model. Within the Fixed Effects model, the F Test for No Fixed Effects is significant, which signals that at least some of the variation within EF Per GDP can be attributed to the unobserved variables that are not in the model. This led to the final model choice of a two-way fixed effects model that controls for the aforementioned unobserved variation, which occurs over time and between countries.

RESULTS

Table 1 below shows the parameter estimates and significance of each variable within the final panel regression. The first six variables were significant, and can be placed into three

categories. The first is population dynamics, which in this case includes population growth and percentage of the population residing in cities. Both of these factors, as expected, have a positive relationship with EF per GDP. Both of these factors are difficult to control or reduce in any practical sense. The second group is general societal health, education, and happiness, here measured by life expectancy, homicide rate, and education spending. While panel regression makes no assumption of causality, it is especially difficult to judge if these variables can be used as drivers for improving EFperGDP, considering the possible correlations with unobserved variables. The authors believe that this may also be a case of reverse causation where a population may become healthier and happier because the country has a lower Ecological Footprint. This is an area that should be explored further, although it is beyond the scope of this paper. The third group, consisting of one variable is, energy efficiency. Energy efficiency was significant in every iteration of the model, and stands apart from the variables in the first two groups because it is more easily influenced by public policy, while also having a straightforward causal link with Ecological Footprint.

Selected Variable	Parameter Estimate
Population Growth	0.0944**
Urban Population	0.0234***
Education Spending	0.0405***
Life Expectancy	-0.1338***
Homicide Rate	0.0302**
Energy Use per GDP	0.0139***
Electricity from Coal	0.0022
Electricity from Nuclear	-0.0035*
Electricity from Hydro	0.0039
Electricity from Renewables	0.0058
*** Significant at $p < 0.01$ **Significant at $p < 0.05$ *Significant at $p < 0.1$	

Table 1 - Model Estimates

Unlike the first six factors, the electricity production variables were not all significant. In fact, only Electricity Production from Nuclear was significant. The percentage of electricity production derived from coal, hydro, or renewables were not found to be significantly associated with EFperGDP. It is notable that Electricity Production from Renewable Sources was not associated with a smaller EF per GDP. Ecological Footprint Accounting considers more than just emissions, and it is possible that some forms of renewable energy have a significant impact on the environment in other ways besides emissions. This is just one of many possibilities for this result. It should be noted, however, that while this analysis did not find a significant relationship between renewable electricity production and EFPerGDP, that does not mean that renewable electricity production is not a worthwhile endeavor. It does suggest, though, that renewable electricity production alone may not be enough to significantly reduce Ecological Footprint.

GENERALIZATIONS

One reason this paper focused on OECD countries is because of the outsized ecological impact of industrialized nations. With the rest of the world industrializing as well, the global ecological burden is only going to increase. As an example, if all nations on Earth consumed at the same rate as the industrialized countries, then it is estimated that the equivalent of three Earths would be needed to absorb humanity's Ecological Footprint ("Sustainable Consumption and Production") which is nearly double our current global footprint. It is important for all nations to monitor their footprint and look for ways to reduce their ecological impact. This analysis can be applied to any industrialized or industrializing country as a list of places to look for possible reductions in Ecological Footprint.

FUTURE STUDIES

Perhaps the most important opportunity for further research in this space is to find instances where specific policy initiatives have been put in place that increased energy efficiency or moved electricity production to nuclear. Investigating and quantifying the impact of such policies on Ecological Footprint could validate our results. Additionally, by studying when the policy went into effect, the time it took to make a tangible impact, and the significance of that impact, future researchers could pinpoint which policies are successful in reducing ecological impact. The feasibility of our suggestions could also be explored through cost-benefit analysis of those and other policies. Finally, inconsistent and missing data were also significant issues in this dataset. Further studies would benefit from more complete and uniform data.

CONCLUSION

While Ecological Footprint Accounting is not perfect, it does provide a powerful method to measure humanity's national and global impact on the Earth. This paper shows that there are specific factors associated with decreases in Ecological Footprint, independent of GDP or population size. The analysis finds that energy efficiency and increasing the use of nuclear electricity production are two effective ways to reduce national Ecological Footprint. By focusing government and industry efforts on increasing energy efficiency and expanding the role of nuclear energy, this analysis concludes that nations around the world can reduce their individual Ecological Footprint. By doing so, they would be contributing to a global reduction in humanity's ecological impact, benefiting all generations, present and future.

REFERENCES

Bovee, G. (2009, April 9). Why we should use more nuclear power as an energy source. Retrieved November 23, 2019, from http://www.egcitizen.com/news/why-we- should-use-more-nuclear-power-as-an-energy/article_3e1cd6c5-c1c6-5200-8818- f94260bac842.html.

Filho, W. L., Morgan, E. A., Godoy, E. S., Azeiteiro, U. M., Bacelar-Nicolau, P., Ávila, L. V., … Hugé, J. (2017, September 14). Implementing climate change research at universities: Barriers, potential and actions. Retrieved November 23, 2019, from https://www.sciencedirect.com/science/article/pii/S0959652617320954.

Global Footprint Network. "Data and Methodology." Retrieved December 4, 2019 from https://www.footprintnetwork.org/resources/data/

International Monetary Fund. "World Economic Outlook Database." Retrieved Decmber 4, 2019, from https://www.imf.org/external/pubs/ft/weo/2018/01/weodata/index.aspx

United Nations. "Sustainable consumption and production". (n.d.). Retrieved November 23, 2019, from https://www.un.org/sustainabledevelopment/sustainable-consumption-production/.

CONTACT INFORMATION

Your comments and questions are valued and encouraged. Contact the author at:

Neil Belford
Oklahoma State Univeristy
neil.belford@okstate.edu

Jordan Humes
Oklahoma State Univeristy
jordan.humes@okstate.edu

Manasi Murde
Oklahoma State Univeristy
Manasi.murde@okstate.edu

Bruce Rehburg
Oklahoma State Univeristy
bruce.rehburg@okstate.edu

APPENDIX

Figure 1 - Map showing 2016 EFperGDP for all OECD countries

Switzerland	0.62013	Canada	1.54300
Norway	0.65089	United States	1.56849
Japan	0.94886	Israel	1.73090
Germany	1.08520	Portugal	1.81063
United Kingdom	1.10036	OECD Average	1.81399
Netherlands	1.10239	Greece	1.82451
Sweden	1.11087	Slovenia	2.07599
France	1.12497	Slovak Republic	2.26011
Australia	1.5970	Turkey	2.41411
Luxembourg	1.19426	Hungary	2.42372
Denmark	1.19523	Mexico	2.55578
Austria	1.24715	Czech Republic	2.59843
Finland	1.29019	Poland	2.84852
Spain	1.30234	Chile	2.91097
Italy	1.30975	Lithuania	3.64368
Belgium	1.41354	Estonia	3.99514
New Zealand	1.41623	Latvia	4.38574

Table 2 – 2016 Footprint per $1000 GDP - All OECD Countries

Variable	Description
Population Growth	Population Growth (year over year %)
Urban Population	Percent of Population living in Urban areas
Education Spending	Total Government Spending on Education as a % of Total Government Spending
Life Expectancy	Life Expectancy at Birth
Homicide Rate	Homicide rate (per 100,000 people)
Energy Use per GDP	Energy Use per $1000 of GDP (kg of oil equivalent)
Electricity from Coal	Percent of Total Electricity Production derived from Coal
Electricity from Nuclear	Percent of Total Electricity Production derived from Nuclear
Electricity from Hydro	Percent of Total Electricity Production derived from Hydroelectric
Electricity from Renewables	Percent of Total Electricity Production derived from Renewables (Excluding Hydro)

Table 3 - Description of Selected Variables

Variable	DF	Estimate	Standard Error	t Value	Pr > |t|
EG_USE_COMM_GD_PP_KD	1	0.013855	0.00105	13.19	<.0001
SE_XPD_TOTL_GB_ZS	1	0.040514	0.0118	3.44	0.0006
SP_DYN_LE00_IN	1	-0.13383	0.0329	-4.07	<.0001
VC_IHR_PSRC_P5	1	0.030167	0.0122	2.48	0.0135
SP_URB_TOTL_IN_ZS	1	0.023354	0.00810	2.88	0.0041
SP_POP_GROW	1	0.09441	0.0397	2.38	0.0178
EG_ELC_COAL_ZS	1	0.002204	0.00310	0.71	0.4775
EG_ELC_NUCL_ZS	1	-0.00347	0.00193	-1.80	0.0731
EG_ELC_HYRO_ZS	1	0.003904	0.00394	0.99	0.3220
EG_ELC_RNWX_ZS	1	0.005798	0.00379	1.53	0.1269

Table 4 - Panel Regression Results (Two-Way Fixed Effects)