POSSIBILITIES OF ECONOMETRIC MODELING OF ECOLOGICAL FOOTPRINT. CASE STUDY: EUROPEAN COUNTRIES

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Abstract
Since the introduction of the Ecological Footprint concept, the researchers have analyzed its main determinants and have tried to continuously improve the computing mechanism of Ecological Footprint, taking into account different driving forces and using different models. The difficulty of this process is fueled by the very complexity of the concept. In the present analysis, three main pillars were outlined: *Economic Development* pillar (through *GDP per capita* variable), *Social Development* pillar (through the *Population with tertiary education%* variable) and *Environmental Quality/ Pollution* Pillar (through the *Greenhouse Gas Emissions* variable), to which it was added a variable that characterizes the sustainability of development and which has common points with all three pillars: the *Share of renewable energy* (%).The multiple linear regression model developed brought together the four explanatory variables and the Ecological Footprint of Production as the explained variable. The results revealed that the four explanatory variables have a significant direct influence on the dependent variable, the model explaining 79,5% of its variability.

Keywords
Ecological Footprint, Biocapacity, Biocapacity deficit/reserve, Regression model.

JEL Classification
C10, C20, Q01, Q20, Q50

Introduction. Literature review

Increasing human pressure on the environment, extensive and, sometimes, chaotic use of resources, global warming, new natural resource constraints have amplified the importance of quantifying and monitoring ecological footprint. These developments lead to an increase in the environmental footprint, to a decrease in the Earth's biocapacity and, as such, to the decrease of the biocapacity reserve. Currently, according to the Global Footprint Network's National Footprint Accounts 2017 Edition, the world needs 1.7 Earth planets to provide the resources for everything it consumes.

Given the complexity of the concept, quantifying the components of the Ecological Footprint is not very easy. The concept of Ecological Footprint was introduced by Rees & Wackernagel, 1996, in "*Our Ecological Footprint: Reducing Human Impact on the Earth",* as an attempt to determine whether the environment resources and the nature regeneration capacity can face the people higher demand. It has been performed over time using different models, some of them been improved since then. Tang Wei et. al. 2011 identified the population as the most important driving force of Ecological Footprint; in addition, they revealed a positive association of the urbanization process and the share of industrial GDP, on one hand, and the Ecological Footprint, on the other hand. Kazutoshi Tanabe & Takahiro Suzuki, 2013 considered various factors in accurately measuring the Ecological Footprint, like the meat consumption, air pollution, population and land area or GDP. Thi Anh Dam et. al., 2017 have taken into consideration the biocapacity per capita in order to explain the net export or import of Ecological Footprint. Based on a cross-section regression model applied on EU-countries, Magdaléna Drastichová, 2016 revealed a significant positive relation between the Ecological Footprint and the standard of living. Hyung Cheal Ryu, 2005 revealed that education have a positive impact on personal ecological footprint, highly educated people tend to increase their footprint, especially through the consumption of goods and services and the shelter component.

Recent evolutions of Ecological Footprint

The Ecological Footprint includes the following components: Cropland, Forest land, Fishing grounds, Grazing land, Built-up land and Carbon footprint. The last component – the „Carbon"component - has the highest share in the total Ecological Footprint, of 60% for the whole world. This component is an equivalent of the *Forest Land* required to annihilate CO emissions from the use of fossil fuel (Global Footprint Network - National Footprint Accounts 2017 Edition).

In many developing countries, an acceleration in the pace of development or the economic growth can often be achieved through extensive, rather than intensive means, hence the need to increase their environmental footprint, sometimes up to at unsustainable levels. On the opposite side there are the developed countries, which have the largest ecological footprint, although they have greater and advanced technologies to use of renewable energy. According to the previously mentioned *Report*, low-income countries are characterized by a balance between the Ecological Footprint and the Biocapacity, the Biocapacity deficit being close to 0. The situation is changed for high-income countries: the Ecological Footprint (consumption-based) is approximately two times higher than the Biocapacity, being necessary the resources of 3,71 Earth Planets to cover their consumption. The gap is, however, very large between the two categories of countries. Thus, the Ecological Footprint of a high-income country is 6.42 higher and, correspondingly, its Biocapacity is 6 times higher than the ones of a low-income country (Fig. no. 1).

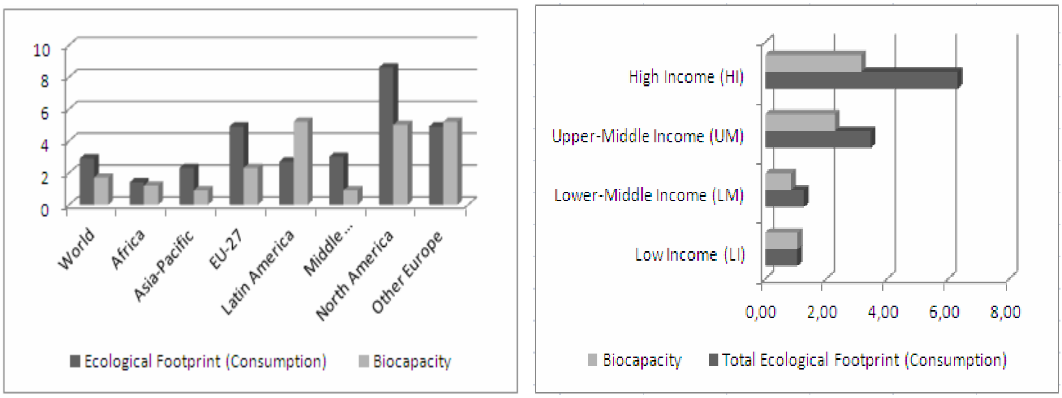


Fig. no. 1 Ecological Footprint and Biocapacity

a) By continents **b) by income-category countries**

Source: authors' processing, based on data provided by Global Footprint Network, National Footprint Accounts 2017 Edition.

By continents, the supremacy is held by North America, with an Ecological Footprint of 8.6 global hectares per person (here, an important role is played by the United States of America, which occupies –together with Canada, a leading place in the top world countries by the Ecological Footprint), followed by Europe (EU) - with about 5 global hectares per person. These continents have also the highest Biocapacity deficit. Among European countries, Luxembourg has the highest Ecological Footprint (13,1 global hectares per person), followed by Estonia (7,0 global hectares per person). Romania is among the countries with a low environmental footprint (2.6 global hectares per person) and with an approximately equal biocapacity. To the opposite side, Latin America has the largest biocapacity reserve (2,5 global hectares per person) (Fig. no. 2).

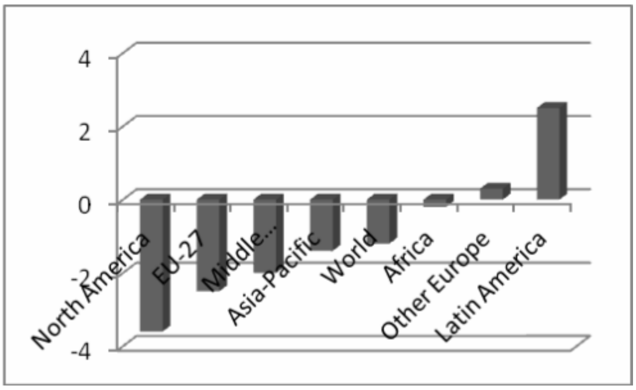


Fig. no. 2 Biocapacity Deficit/Reserve (Global Hectares per Person)
Source: authors' processing, based on data provided by Global Footprint Network, National Footprint Accounts 2017 Edition.

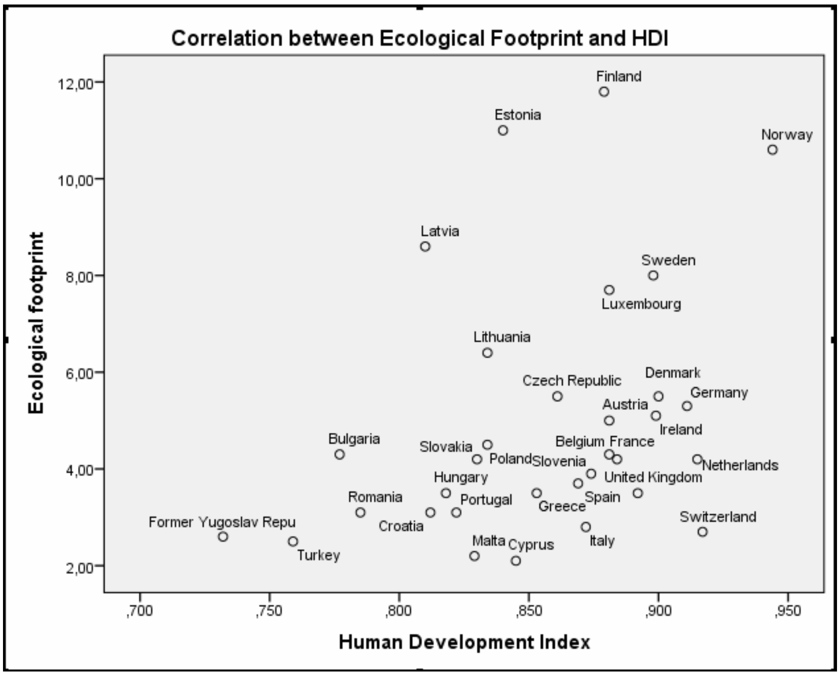


Fig. no. 3. Correlation between the Ecological Footprint and the Human Development Index
Source: performed by the authors, based on data provided by United Nations Development Programm, Human Developments Reports.

The scatter diagram between the Ecological Footprint and the Human Development Index reveal a positive relationship between the two variables; the higher the social development of human resources – the higher the ecological footprint (Fig. no. 3).

Data and methodology. The main results

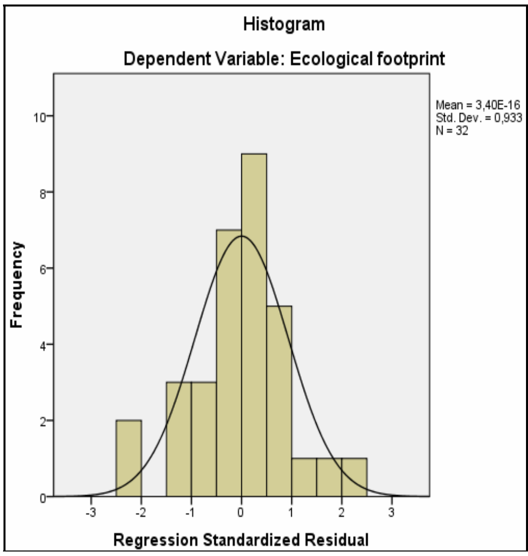
The analysis aims at identifying the most important factors that can explain the variability in the Ecological Footprint, using a multiple regression model, considering the production-based Ecological Footprint. Three pillars were tracked, in order to find the explanatory variables: the human resources (social development), the economic-development level, the environment quality, to which it was added a sustainable component. Thus, the four explanatory variables chosen were as follows (Table no. 1):

Table no. 1. List of variables

Variable	Pillar	Significance	Type of the variable
Gross domestic product per inhabitant at market prices, (current prices, Euro per capita) (*GDP*)	Economic development	Gross domestic product at market prices, (current prices, Euro per capita)	Explanatory variable
Tertiary education (*TERTIARY_ED*)	Social development	% of population with tertiary education in the population aged 15-64 years	Explanatory variable
Greenhouse Gas Emissions (*GGE*)	Environment quality (pollution)	Greenhouse gas emissions per capita (Tonnes of CO_2 equivalent per capita)	Explanatory variable
Renewable energy (*RENEW_EN*)	Sustainability	Share of renewable energy in gross final energy consumption (%)	Explanatory variable
Ecological Footprint of production (*ECOL_FTP*)	-	The area needed to produce goods and services and the area needed to absorb the carbon dioxide emissions.	Explained variable

Source: made by the authors.

The data were provided by the EUROSTAT (Gross domestic product per inhabitant at market prices, Population with tertiary-education, Share of renewable energy in gross final energy consumption, Greenhouse gas emissions per capita) and by the Global Footprint Network - National Footprint Accounts 2017 Edition (Ecological Footprint of Production) and refer to 32 EU and non-EU countries. The correlations between the four independent variables aren't significant, they are low to medium. The data were processed using SPSS. Previously, the main assumptions of the multiple linear regression model were tested: the linear relationship, the residuals' normality, non-auto-correlation of residuals, homoscedasticity, and no or little multicollinearity. The histogram of the Standardized Residuals and the Normal P-P Plot of Regression Standardized Residuals reveal that the errors are approximately normally distributed (Fig. no. 4 and 5).



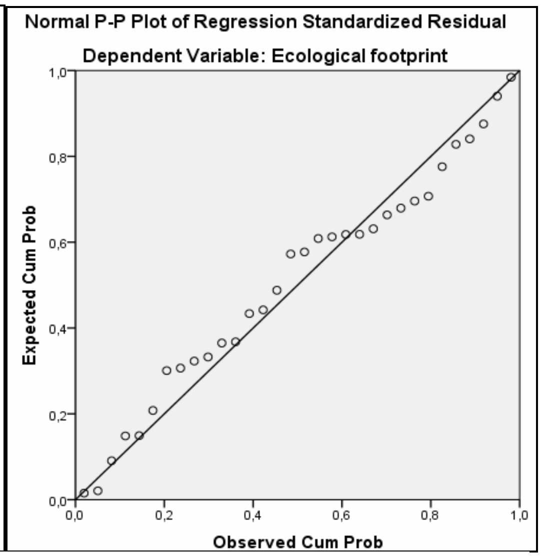


Fig. no. 4. Histogram of the Standardized Residuals. Fig. no. 5. Normal P-P Plot of the Standardized Residuals

Source: authors' processing in SPSS, based on data provided by Global Footprint Network, National Footprint Accounts 2017 Edition and by EUROSTAT.

In testing the multicollinearity between the explanatory variables, the Tollerance values (higher than 0.2) and the Variance Inflation Factor (VIF – lower than 4) reveal that there is no significant collinearity between the independent variables. (Table no. 2)

Table no. 2. Results on model parameters

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients			95,0% Confidence Interval for B		Collinearity Statistics	
		B	Std. Error	Beta	t	Sig.	Lower Bound	Upper Bound	Tolerance	VIF
1	(Constant)	-4,083	1,011		-4,038	,000	-6,158	-2,009		
	Share of renewable energy	,156	,020	,874	7,983	,000	,116	,196	,632	1,581
	Tertiary education	,087	,039	,254	2,215	,035	,006	,167	,575	1,739
	Greenhouse gas emissions	,581	,088	,845	6,613	,000	,400	,761	,465	2,152
	GDP	,000	,000	-,506	-3,748	,001	,000	,000	,415	2,407

a. Dependent Variable: Ecological footprint

Source: authors' processing in SPSS, based on data provided by Global Footprint Network, National Footprint Accounts 2017 Edition and by EUROSTAT.

The homoscedasticity of the residuals was tested by applying the White test, the results revealing that the residuals have a constant variance. Also, the Durbin-Watson test showed that the residuals are not auto-correlated (Table no. 3).

Table no. 3. Model Summary

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	,892[a]	,795	,765	1,25377	1,982

a. Predictors: (Constant), GDP, Share of renewable energy, Tertiary education, Greenhouse gas emissions

b. Dependent Variable: Ecological footprint

Source: authors' processing in SPSS, based on data provided by Global Footprint Network, National Footprint Accounts 2017 Edition and by EUROSTAT.

All the model parameters are statistically significant (using 0.05 significance level). The positive values of the slope-parameters reveal significant positive correlations between the explanatory variables and the explained variable; thus, the direct correlation between the share of tertiary-educated people and the Ecological Footprint of Production can be explained by the fact that employees with tertiary education level develop a more efficient and productive activity, leading to a higher output obtained, and thus an increase in the share of highly educated population implies an increase in the peoples' demand on nature and in a higher Ecological Footprint. The explanation of the she significant positive correlation between the pollution level (quantified through Greenhouse Gas Emissions) and the Ecological Footprint is obvious. Also, the model revealed a similar positive relation between the share of renewable energy and the Ecological Footprint level, which can be explained by the fact that usually, countries with a high Ecological Footprint of Production are developed countries, which benefit to a large extent from high performance technologies, for using and capitalizing the renewable energy sources. According to the model results, the Ecological Footprint of the Production is likely to increase, on average, by 0,156 global hectares per person, as a result of 1% increase in the share of renewable energy, keeping the other explanatory variables unchanged; also, we expect an average increase in the Ecological Footprint of the Production by 0, 087 global hectares per person, as a result of 1% increase in the share of tertiary-educated population, keeping the other explanatory variables unchanged; the explained variable is likely to increase due to 1% increase in the Greenhouse Gas Emissions, maintaining all the other independent variables at the same level.
The statistically significant regression model, through its four independent variables, explains 79,5% of the variability in the Ecological Footprint. There is a strong significant correlation between the combined explanatory variables and the explained variable (Multiple Correlation Ratio 0,982) (Tables no. 3 and 4).

Table no. 4. ANOVA results

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	164,918	4	41,229	26,228	,000[b]
	Residual	42,442	27	1,572		
	Total	207,360	31			

a. Dependent Variable: Ecological footprint

b. Predictors: (Constant), GDP, Share of renewable energy, Tertiary education, Greenhouse gas emissions

Source: authors' processing in SPSS, based on data provided by Global Footprint Network, National Footprint Accounts 2017 Edition and by EUROSTAT.

Based on the previously identified regression model, the predicted Ecological Footprint value for Romania is 3,73 global hectares per person (adjusted predicted value: 3,82 global hectares per person), ranging between 2,86 and 4,61 global hectares per person. The confidence interval is guaranteed with 95% probability level (Table no. 5).

Table no. 5. Predictions – Romania

Ecological Footprint (Production)	Unstandardized Predicted Value	Adjusted Predicted Value	Standardized Predicted Value	95% Lower Confidence Interval for *Ecol_ftp* mean	95% Upper Confidence Interval for *Ecol_ftp* mean
Romania	3,73419	3,81660	-,52848	2,86180	4,60658

Source: authors' processing in SPSS, based on data provided by Global Footprint Network, National Footprint Accounts 2017 Edition and by EUROSTAT.

Conclusions and future work

Over time, the researchers have analyzed the main determinants of Ecological Footprint, and have tried to continuously improve the computing mechanism of Ecological Footprint, taking into account different driving forces and using different models. The difficulty of this process is fueled by the very complexity of the concept. In the present analysis of the Ecological Footprint, three main pillars were outlined: *Economic Development* pillar (through *GDP per capita* variable), *Social Development* pillar (through the *Population with tertiary education%* variable) and *Environmental Quality/ Pollution* Pillar (through the *Greenhouse Gas Emissions* variable), to which was added a variable that characterizes the sustainability of development and which has common points with all three pillars: the *Share of renewable energy* (%).The multiple linear regression model developed brought together the four explanatory variables mentioned above, on one hand, and the Ecological Footprint of Production as the explained variable, on the other hand. The results revealed that the four explanatory variables have a significant direct influence on the dependent variable, the model explaining 79,5% of its variability. The authors aim to improve the predictability of environmental footprint for European countries, taking into account the particularities of the country's economies in this area and to identify new significant elements in the quantification of the Ecological Footprint.

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