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--RESEARCH ARTICLE-

RELATIONSHIP BETWEEN BIOCAPACITY EFFICIENCY AND ECONOMIC GROWTH: SUR MODEL ANALYSIS FOR EUROPE

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Abstract

To investigate the relationship between biocapacity efficiency and economic growth, data from Austria, Belgium, Germany, Spain, the United Kingdom, Greece, Italy, and the Netherlands were used, which are the European countries with the largest deficits in the biocapacity-ecological footprint balance between 1970 and 2014. Biocapacity measures the biosphere's ability to renew itself and supply the resources and services required to sustain life. It expresses overall human demand for natural resources, waste management, and fertile land for urban activities. The phrase "ecological footprint" refers to the quantity of biologically productive land and water that a population must utilize to maintain the urban infrastructure that it inhabits, create all the resources that it consumes, and remove all the garbage that it generates. An ecological deficit exists when a country's ecological footprint exceeds its biocapacity as measured by its population. An ecological deficit suggests that a country's ecosystems are unable to absorb extra carbon dioxide discharged into the atmosphere. When calculating national biocapacity productivity, the relative productivity of an average hectare of a specific land-use type is considered. The biocapacity efficiency factor was used as the dependent variable in this study, which evaluated the eight European nations with the greatest ecological deficit. GDP, the fraction of the total population residing in urban agglomerations with populations greater than one million, and electric energy consumption were the independent variables. Seemingly Unrelated Regression (SUR) model's overall findings reveal that the biocapacity productivity factor and GDP are adversely connected. The biocapacity productivity factor decreased by 0.75% for every 1% rise in GDP. Austria and Belgium had the highest influence on the biocapacity productivity factor, according to country-specific information.

Keywords: *Economic Growth, Biocapacity productivity, Seemingly Unrelated Regression*

JEL Codes: *EO1, Q57, C33*

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BİYOKAPASİTE VERİMLİLİĞİ VE EKONOMİK BÜYÜME ARASINDAKİ İLİŞKİ: AVRUPA İÇİN SUR MODEL ANALİZİ[2]

Öz

Bu çalışmada biyokapasite verimliliği ve ekonomik büyüme arasındaki ilişkiyi incelemek için Biyokapasite-ekolojik ayak izi dengesinde en büyük açıklara sahip Avrupa ülkeleri olan Avusturya, Belçika, Almanya, İspanya, Birleşik Krallık, Yunanistan, İtalya ve Hollanda'nın 1970-2014 yılları arasındaki verileri ele alınmıştır. Biyokapasite, biyosferin kendini ne kadar iyi yenileyebildiğini ve yaşamı desteklemek için gerekli kaynakları ve hizmetleri ne kadar sunabildiğini göstermektedir. Doğal kaynaklar, atık yönetimi ve kentsel faaliyetler için ayrılan verimli araziler üzerindeki insan taleplerinin toplam miktarını yansıtmaktadır. "Ekolojik ayak izi" terimi, bir nüfusun işgal ettiği kentsel altyapıyı desteklemek, tükettiği tüm kaynakları üretmek ve ürettiği tüm atıkları ortadan kaldırmak için kullanması gereken biyolojik olarak verimli arazi ve su miktarını tanımlamaktadır. Bir ülkenin ekolojik ayak izi, nüfusu ile ölçülen biyokapasitesini aşıyorsa o ülke ekolojik açık vermektedir. Bir ülkenin ekolojik açığı varsa, bu durum ekosistemlerinin atmosfere salınan fazla karbondioksiti absorbe edemediğini göstermektedir. Ulusal biyokapasite verimliliği belirlenirken, belirli bir arazi kullanım türünün ortalama bir hektarının göreceli verimliliği değerlendirilmektedir. Biyokapasite verimlilik faktörü, Avrupa'da en büyük ekolojik açığı olan sekiz ülkeyi değerlendiren bu çalışmada bağımlı değişken olarak alınmıştır. Bağımsız değişkenler ise GSYİH, nüfusu bir milyonun üzerinde olan kentsel yığılmalarda yaşayan toplam nüfusun oranı ve Elektrik enerjisi tüketimidir. Görünürde İlişkisisiz Regresyon (SUR) modelinin genel bulguları, Biyokapasite verimlilik faktörü ile GSYH'nin negatif ilişkili olduğunu göstermektedir. GSYH'deki %1'lik bir artış, Biyokapasite verimlilik faktöründe %0.75'lik bir düşüşe neden olmaktadır. Ülke bazlı istatistiklere göre, ekonomik büyümenin Biyokapasite verimlilik faktörü üzerinde en büyük etkiye sahip olduğu ülkeler ise Avusturya ve Belçika'dır.

Anahtar Kelimeler: *Ekonomik Büyüme, Biyokapasite Verimliliği, Görünürde İlişkisisiz Regresyon Modeli*

JEL Kodları: *EO1, Q57, C33*

"Bu çalışma Araştırma ve Yayın Etiğine uygun olarak hazırlanmıştır."

1. INTRODUCTION

All nations exploit their natural resources for rapid economic expansion in a competitive context, regardless of the impact on environmental quality. They are growing at the price of undesirable environmental changes caused by pollution of the air, water, and land. It is morally and ethically obligatory, according to the intergenerational equality concept, to conserve the environment for future generations. Climate change and global warming are at the forefront of environmental discussions worldwide, according to multiple decades. (Nyla, Rahman, and Jun, 2019:1-2). So, it is challenging in this century to sustain high rates of economic expansion while coping with rising levels of environmental degradation and energy use. Different academics have exhaustively investigated the link between economic

[2] Genişletilmiş Türkçe Özet, makalenin sonunda yer almaktadır.

activity, energy use, and environmental damage. These studies had a significant flaw in that they concentrated on a single or limited number of air contaminants as a stand-in for environmental deterioration. There are many aspects of how economic activity affects the environment, and these aspects cannot all be included in one measure of environmental deterioration. In recent years, new research has emerged that considers ecological footprint as a comprehensive and internationally comparable indicator of environmental damage caused by human activities. It is seen as a more realistic picture of environmental degradation than carbon dioxide emissions because it represents the human demand for natural resources and ecosystem services. The ecological footprint, which measures the amount of fertile land and water necessary to support human activities and sequester the rubbish generated, indicates the total amount of natural resources used by a population (Neagu, 2020:1).

To account for nature's contribution to human well-being expressed in global hectares (i.e., surface-equivalent biologically productive hectares), Ecological Footprint Accounting, a tool for environmental accounting, combines two metrics (the Ecological Footprint and the biocapacity). This approach tries to measure, aggregate, and express both human consumption and the biosphere's resource supply in terms of ecosystem services values. The two primary tenets of Ecological Footprint Accounting are additivity and equivalence. We can add up all the biologically productive space needed to satisfy human need using additive reasoning. Equivalence enables the expression of several land kinds, each with a unique production, in a single unit of measurement. Given the prevalent technology and resource management practices of the time, the Ecological Footprint is a measurement of the demand populations and activities placed on the biosphere each year. (Gabbi, Matthias, Patrizi, Pulselli, and Bastianoni, 2021:3). Ecological footprint consists of six elements: carbon footprints, forest land, fisheries, built-up land, grazing land, cropland, and degradation of oil stocks, mining, forestry, and soil. Ecological footprint emphasizes the effects of production and consumption on the environment, both direct and indirect. Ecological footprint is a more thorough way to quantify the environment than the ingrowth-environment nexus. Many nations use their natural resources for rapid economic growth regardless of their negative effects on the environment, such as water pollution, air pollution, and land pollution (Nyla, Rahman, and Jun, 2019: 2).

The entire input on how the ecosystem affects people is reflected in biocapacity. A decline in biocapacity suggests that the ecosystem's stability is being undermined, whereas an increase in biocapacity suggests that the stability of the ecosystem is being strengthened. Biocapacity evaluates the whole ecological land areas of cultivated land, grassland, woodland, forest, fossil fuel, and water to determine the overall feedback of the ecosystem's effect on humans. The ecosystem itself dictates how the ecological footprint affects biocapacity. This influence is a nonlinear process rather than a straightforward linear process because of the complexity of the ecosystem (Shen and Yue, 2023:5).

The Ecological Footprint is a key component of an accounting tool used to promote sustainable consumption of renewable resources. It measures the extent to which humans deplete natural resources faster than they can be replenished. The tool combines elements of sustainable consumption using weighting factors that reflect the planet's regenerative capacity. The Ecological Footprint and Biocapacity, which measure biological production capacity, are sometimes combined. Reserve or deficit refers to the mathematical difference between Ecological Footprint and Biocapacity. (Schaefer, Luksch, Steinbach, Cabeca, and Hanquer, 2006:4). Biocapacity is a way of determining the number of renewable resources that have been made available by the biosphere's regenerative capacity. Most of the biosphere's regenerative ability is represented by biocapacity, which is calculated by combining the outputs of several ecosystems in each region, such as productive sea, pasture, and arable land. It also includes developed or degraded terrain. A more biologically productive region and higher production per unit area both increase the biocapacity of the earth. The country-specific yield factor explains the variations in land type productivity and technical development between nations. There are unique sets of yield parameters for each nation and year. A hectare of a particular land type, such as agriculture, pasture, forestland, marine water, or built-up regions, is converted into a global hectare using the equivalency factor. (Schaefer, Luksch, Steinbach, Cabeca, and Hanquer, 2006: 6-7). When a population's demand for natural resources and services exceeds the capacity of the environment to sustain them, a deficit occurs. This can happen at the national level if a country depletes its ecological assets, outsources its ecological needs through imports, or exceeds the ecosystem's capacity to absorb carbon dioxide. On the other hand, a region is said to have an ecological reserve when its environmental capacity exceeds its demand. (Global Footprint Network, 2023).

2. METHODOLOGY

Rees (1992) makes the case that current economic presumptions about urbanization and the sustainability of cities need to be changed considering overall ecological change using the notions of human carrying capacity and natural capital. He emphasizes that, while we are accustomed to thinking of cities as geographically distinct entities, much of the land occupied by their population extends well beyond their limits. He also points out that the ecological footprint of a metropolitan region is often at least a factor of ten bigger than that of a municipality. Within this framework the ecological footprint concept is based on the notion that a specific area of land in one or more ecosystem types is necessary to provide the consumption-related resource flows and waste sinks for every item of material or energy consumption. Therefore, it is necessary to assess the land-use implications of each important consumption category to establish the overall land area needed to sustain a specific pattern of consumption. Since it is impractical to estimate the amount of land needed for the production, upkeep, and disposal of each of the tens of thousands of consumer goods, the estimates are limited to a few broad categories and specific products (Wackernagel and Rees, Our Ecological Footprint:Reducing Human Impact on the Earth, 1996: 61). Separating consumption into five main categories—food, housing, transportation, consumer goods, and services—has shown to be effective. Any good or service can only be produced and used if diverse forms of ecological productivity are present. These ecological productivities can be translated into equivalents of land area. Calculating the total amount of land needed for all important consumption and waste categories yields an estimate of the reference population's ecological footprint (Wackernagel and Rees, Our Ecological Footprint:Reducing Human Impact on the Earth, 1996:67). The Ecological Footprint assesses the demand side, which is biologically productive land and sea area - the ecological assets - that a population requires to create the renewable resources and ecological services it consumes. Biocapacity monitors the availability of ecological resources in nations, regions, or on a worldwide scale, as well as their ability to create renewable resources and ecological services (Galli, Wackernagel, Iha, and Lazarus, 2014:122).

2.1. Theorical Literature

An economy's ecological footprint is calculated by keeping track of the resources needed to manufacture all the goods it generates, absorb its trash, and generate all its imports minus exports. Equation 1 illustrates how to compute it (Galli, Wackernagel, Iha, and Lazarus, 2014:122).

$$EF_c = EF_P + EF_I - EF_E \quad (1)$$

EF_c =ecological footprint of consumption

EF_P =ecological footprint of production

EF_I =ecological footprint of imported commodity flows

EF_E = ecological footprint of exported commodity flows

The Ecological Footprint (EF) of every single product i, regardless of whether it is produced locally, imported, or exported, is computed as in because ecological footprints are measured in global hectares (Galli, Wackernagel, Iha, and Lazarus, 2014:122):

$$EF = \frac{P_i}{Y_{w,i}} . EQF_i \quad (2)$$

$Y_{w,i}$ is the annual world-average yield to produce commodity i (or its capacity to absorb carbon dioxide in cases where P is CO2); and EQF_i is the equivalence factor for the land use type producing product i. Where P is the amount of each primary product i that is harvested (or carbon dioxide emitted) in the country (Galli, Wackernagel, Iha, and Lazarus, 2014:122).

Biocapacity serves as an ecological standard and measures nature's capacity to satisfy this need, whereas the Ecological Footprint quantifies human demand. The concept of biocapacity is used in Equation (3) to quantify the capacity of each nation's ecological assets to produce renewable resources and ecological services. $YF_{N,i}$ is the yield factor particular to the nation for the land generating goods i, and EQF_i is the equivalency factor for the land use type producing each product i. Where $A_{N,i}$ is the bioproductive area that is accessible to produce each product i at the country level (Galli, Wackernagel, Iha, and Lazarus, 2014:123).

$$BC = \sum_i A_{N,i} . YF_{N,i} . EQF_i \quad (3)$$

The biocapacity of a surface assesses how effectively it can restore the specific requirements of users. As follows, biocapacity refers to an ecosystem's potential to generate biological resources that humans consume and absorb waste materials produced by people, given current management practices and extraction technology. Biocapacity may fluctuate from year to year according to climate, management techniques, and the quantity of biocapacity seen as a desirable input into the human economy. In the National Footprint and Biocapacity Accounts, the yield factor and appropriate equivalence factor are multiplied by the actual physical area to estimate a region's biocapacity. Biocapacity is frequently expressed in global hectares (Global Footprint Network, 2023). Therefore, biocapacity is a significant indicator in terms of realizing sustainable growth for today's economies where climate change is accepted as one of the most significant problems.

2.2. Empirical Literature

In the empirical literature, it is common for carbon emissions to represent environmental destruction and be used in past and present models. However, biocapacity and ecological footprint data as a more comprehensive and complex measure have recently become more common, as it reflects environmental destruction and provides limited information regarding shedding light on climate crises. We can state that the effects of the COVID-19 pandemic and global warming have started to be observed intensively in the empirical literature.

The study by Nathaniel (2021) examined how biocapacity, human capital, and urbanization affected the EF using a sophisticated approach that tackles fundamental panel data concerns and can display results for individual countries. According to the research, human capital decreases the EF whereas biocapacity, economic expansion, and urbanization all enhance it. Additionally, the interaction coefficient between urbanization and economic growth is negative, indicating that if economic growth continues, urbanization will reach the necessary level to lower the EF. Except for Canada, all nations see a rise in EF due to biocapacity (Nathaniel, 2021:435).

Sarkodie (2021) maps nations' ecological performance, biocapacity, and carbon footprint. Using cutting-edge cross-country time series approaches, he evaluates the socioeconomic factors that influence environmental performance and convergence. He discovers that improving nations' biocapacity results in improved ecological performance. The top-performing nations in terms of the environment are Australia, Brazil, China, Germany, India, Japan, Russia, and the United States. He affirms that there is environmental convergence among nations, suggesting that over time, the differences in the ecological footprint and carbon emissions between higher-income and lower-income countries will disappear (Sarkodie, 2021).

Javed et. al. (2023) intended to explore the link between environmental rationality and economic actions that increase environmental indicators in Asia. The goal of the study is to establish a connection between economic development, globalization, biocapacity, energy intensity, and renewable energy sources, as well as their effects on the ecological footprint in Asian nations between 1990 and 2017. The findings demonstrate that environmental quality is enhanced by increasing the proportion of renewable energy in overall energy consumption. The findings indicate that the ecological footprint rises by 0.55%, 0.08%, 0.06%, and 0.03% for each 1% increase in economic growth, globalization, biocapacity, and population density, respectively. Renewable energy does, however, help the environment by 0.04% (Javeed, Siddique, and Javed, 2023:77006)

Shen and Yue (2023) examined the nonlinear relationship between the ecological footprint and biocapacity from the perspective of the ecosystem's ability to self-regulate, providing a new perspective for measuring a country's sustainability. Using panel data from the G20 nations, this study developed a panel smooth transition model with a continuous transition process, overcoming the limits of linear models and agreeing with the progressive aspects of ecosystem change. According to the study's findings, the link between ecological footprint and biocapacity for the G20 nations has an inverted "U" shape. In terms of a country's degree of development, a rise in a developing nation's ecological footprint reduces its biocapacity, whereas an increase in a developed nation's ecological footprint increases it. Economic expansion reduces biocapacity, and excessive economic growth may irreversibly destroy the ecosystem. Because of technological advancements and population growth, biocapacity will expand. (Shen and Yue, 2023:1-2).

As the efforts of countries to balance economic growth and sustainable environmental conditions vary depending on the level of development, we can foresee that studies within this scope will gain more diversity in the future.

2.2.1. Ampirical Analysis

This study aims to analyze the relationship between the biocapacity productivity factor and economic growth in Austria, Belgium, Germany, Spain, United Kingdom, Greece, Italy, and Netherlands, which have an ecological footprint larger than their biocapacity. The countries considered in the study are the European countries with the highest deficit in terms of biocapacity ecological footprint. Accordingly, the biocapacity productivity factor (yield factor) reflecting the ecological footprint is used in the econometric analysis. The relative productivity of hectares with a certain land use type at the national and global levels is reflected in yield factors. For each sort of land use, there is a yield factor for each nation and each year.

The era of econometric analysis in Austria, Belgium, Germany, Spain, the United Kingdom, Greece, Italy, and the Netherlands is 1970-2014. The analysis relied on annual data. The World Bank's World Development Indicators database was used to acquire data for the econometric analysis period. The worldwide footprint network provided data on the yield factor variable, which was chosen to reflect biocapacity.

The quantity of regenerated primary products that humans can harvest per square unit of biologically productive land or water is referred to as yield. The yield factor accounts for variances in the productivity of a particular land type between countries.

The determinants of cropland, grazing land, woodland, and fishery production differ by nation and year (Global Footprint Network, 2023).

Seemingly Unrelated Regression (SUR) models have been used for this study. When the error terms of seemingly independent equations with no covariates are correlated, these systems of equations are apparently uncorrelated regression models (Eren, Yerdelen Tatoğlu ve Akarsu, 2022:873).

$$Y_t = \beta_1 + \beta_2 L_t + u_t$$

$$X_t = \alpha_1 + \alpha_2 K_t + v_t \qquad (4)$$

In the system of equations as specified by equation 4, Y and X are interdependent, while L and K are independent variables of the respective models. The constants α_1 and β_1 are independent variables of the models to which they are related. In this equation system, there are no covariates, but it is assumed that the error terms u_t and v_t are correlated with each other. If this correlation does not exist, the two equations estimated by the least-squares method will be independent. A seemingly uncorrelated regression model can be estimated using the generalized least-squares method. In the first stage of estimation, the system of equations both models are estimated by the least squares method and residuals were obtained. After estimating the variance covariance matrix, generalized least squares forecasts are made.

$$\beta = (X'\Omega^{-1}X)^{-1}X'\Omega^{-1}Y \qquad (5)$$

Whether the equations have apparently uncorrelated regressions, the Breusch Pagan LM (1980) test determines the significance of the correlation between error terms. If the calculated value is greater than the table value, the null hypothesis is rejected, indicating that the error terms are correlated with each other. Therefore, it is concluded that estimation methods for apparently uncorrelated regression should be used.

The summary statistics for the data set used in the study are shown in Table 1 below.

Table 1. Summary Statistics

Variable	Abr.	Obs	Mean	Std.Dev.	Min.	Max.
Yield Factor	yldf	360	1.426967	.4498351	.574246	2.5188
GDP (constant 2015 US$)	gdp	360	9.84e+11	8.59e+11	9.43e+10	3.31e+12
Population in urban agglomerations of more than 1 million (% of total population)	pop	360	20.6367	6.587933	8.795635	31.12659
Electric power consumption (kWh per capita)	eltrc	360	5134.152	1715.596	1023.792	8683.671

Due to the difference in scale between the data in the study, it was decided that the functional form of the data should be logarithmic except yield factor.

$yldf_{it} = \beta_0 + \beta_1\ lgdp_{it} + \beta_2\ lpop_{it} + \beta_3\ leltrc_{it} + \varepsilon_t$

Table 2. Correlation Matrix

Variable	ylfd	lgdp	lpop	leltrc
yldf	1.000			
lgdp	0.3544 0.0000	1.000		
lpop	-0.3659 0.0000	-0.4805 0.0000	1.000	
leltrc	0.3154 0.0000	0.3319 0.0000	-0.2751 0.0000	1.000

According to the correlation matrix in Table 2, all variables in the model are significant.

Table 3. VIF Values

Variable	VIF	1/VIF
lgdp	1.38	0.725946
lpop	1.33	0.754055
leltrc	1.15	0.872484
Mean VIF	1.28	

The average of the vif values in Table 3 is below 5. According to this result, there is no multicollinearity problem between the variables. For the condition of normal distribution, the Jarque-Bera value should be less than 5 and the probability value should be higher than 0.05. The calculated Jarque-Bera value is 3.97 and the probability value is 0.1374. There is no normal distribution problem in the model.

3. RESULTS

According to the swamy, pesaran and yamagata test results in table 4, the parameters are heterogeneous. According to the results of the Breusch-Pagan test (chi2(28) =4015.31, pr=0.0000) for inter-unit correlation, there is an inter-unit correlation. Since the time is 31 years and the number of countries is 8, it is appropriate to use SUR estimator.

Table 4. Test results of Swamy, Pesaran and Yamagata for slope heterogeneity

Swamy	Test of parameter constancy		Chi2(28) =4015.31 Prob>chi2=0.0000	H_0 = rejected
Pesaran and Yamagata	Delta 21.859 Adj. 23.185	p-value 0.000 0.000	Ho: slope coefficients are homogenous	$H_0 = rejected$

According to the SUR estimator results in Table 5, the results for 8 countries are significant. However, the r-squared values vary between approximately 20% and 91%, indicating a heterogeneous structure.

Table 5. Seemingly Unrelated Regression

Equation	R-sq	Chi2	P
yldf1	0.7617	138.33	0.0000
yldf2	0.4477	36.03	0.0000
yldf3	0.5065	44.33	0.0000
yldf4	0.2090	12.96	0.0047
yldf5	0.5507	43.74	0.0000
yldf6	0.4127	36.17	0.0000
yldf7	0.7572	157.97	0.0000
yldf8	0.9169	512.05	0.0000

Breusch-Pagan test of independence: chi2(28) = 87.975, Pr = 0.0000 (there is correlation between units)

According to the results in Table 5, the proportion of variations explained by the dependent variables is 76% for Austria, 44% for Belgium, 50% for Germany, 20% for Spain, 55% for United Kingdom, 41% for Greece, 75% for Italy, and 91% for Netherlands.

Table 6 presents the SUR estimator results for 8 countries. Country number 1 in Austria. According to the SUR estimator results, all parameters are significant. A 1% increase in Austria's GDP decreases yield factor by approximately 2.21%. A 1% increase in Austria's population in urban agglomerations of more than 1 million (% of total population) decreases yield factor by approximately 1.13%. A 1% increase in Austria's electric power consumption increases yield factor by approximately 1.81%.

Table 6. Seemingly Unrelated Regression for Each Country

	Coef.	Std. Err.	P>z
lgdp1	-2.213947	0.3407661	0.000
lpop1	-1.131572	0.5256173	0.031
leltrc1	1.813766	0.3608344	0.000
cons	47.21117	5.44846	0.000
lgdp2	-1.134157	0.2088412	0.000
lpop2	10.07292	2.135945	0.000
leltrc2	0.2715878	0.1763935	0.124
cons	-3.898471	5.048417	0.440
lgdp3	0.3499488	0.1386072	0.012
lpop3	-4.290517	0.7554567	0.000
leltrc3	-0.6931367	0.2072558	0.001
cons	7.509123	2.279237	0.001
lgdp4	-0.4021266	0.2835059	0.156
lpop4	-1.305223	1.044045	0.211
leltrc4	0.5432901	0.2255167	0.016
cons	11.39656	5.624827	0.043
lgdp5	-0.3551858	0.148572	0.017
lpop5	-5.497204	1.113122	0.000
leltrc5	0.6701385	0.3913734	0.087
cons	24.29173	5.298374	0.000
lgdp6	-0.5424141	0.17981	0.003
lpop6	2.778352	0.6151632	0.000
leltrc6	0.2819781	0.1037198	0.007
cons	3.435394	4.56419	0.452
lgdp7	-0.7037867	0.4747244	0.138
lpop7	10.66448	1.290633	0.000
leltrc7	0.3336428	0.3927092	0.396
cons	-13.20833	9.06397	0.145
lgdp8	-1.023772	0.2201307	0.000
lpop8	1.099087	0.5207246	0.035
leltrc8	0.4576026	0.3232183	0.157
cons	22.37409	3.222911	0.000

Country 2 in the model is Belgium. According to SUR results, GDP, and population in urban agglomerations of more than 1 million (% of total population) parameters for Belgium are significant. A 1% increase in Belgium's GDP decreases yield factor by approximately 1.13%. A 1% increase in Austria's population in urban agglomerations of more than 1 million (% of total population) increases yield factor by approximately 10.07%.

The third country in the model is Germany. According to SUR results, all parameters for Germany are significant. A 1% increase in Germany's GDP increases yield factor by approximately 0.34%. A 1% increase in Germany's population in urban agglomerations of more than 1 million (% of total population) reduces yield factor by about 4.29%. A 1% increase in Germany's electric power consumption reduces yield factor by 0.69%.

The 4th country in the model is Spain. According to SUR results, electric power consumption and constant parameters for Spain are significant. A 1% increase in Spain's electric power consumption increases yield factor by approximately 0.54%.

The 5th country in the model is United Kingdom. According to SUR results, all parameters for United Kingdom are significant except electric power consumption. A 1% increase in United Kingdom's GDP decreases yield factor by approximately 0.35%. A 1% increase in United Kingdom 's population in urban agglomerations of more than 1 million (% of total population) decreases yield factor by approximately 5.49%.

The 6th country in the model is Greece. According to SUR results, all parameters for Greece is significant except constant parameter. A 1% increase in Greece's GDP decreases yield factor by approximately 0.54%. A 1% increase in Greece's population in urban agglomerations of more than 1 million (% of total population) increases yield factor by approximately 2.77%. A 1% increase in Greece's electric power consumption increases yield factor by about 0.28%.

The 7th country in the model is Italy. According to SUR results, only population in urban agglomerations of more than 1 million (% of total population) parameter is significant for Italy. A 1% increase in Italy's population increases yield factor by about 10%.

The 8th country in the model is Netherlands. According to SUR results, the GDP, population in urban agglomerations of more than 1 million (% of total population), and constant parameters for Netherlands are insignificant. A 1% increase in Netherlands's GDP reduces yield factor by about 1.02%. A 1% increase in Netherlands's population in urban agglomerations of more than 1 million (% of total population) increases yield factor by about 1.09%.

According to the results of the SUR model on a country-by-country basis, Germany seems to be more oriented towards a sustainable economic growth model and has been more successful in this area. However, agglomeration in the urban population and the use of electric power have negative impacts on the biocapacity productivity factor. Austria has the most negative impact on the biocapacity productivity factor. The urban population agglomeration in Austria has a negative impact on the biocapacity productivity factor. Similarly, economic growth in Belgium had a negative impact on the biocapacity productivity factor. However, in contrast to growth, the positive effect of urban agglomeration on biocapacity productivity was quite high.

4. DISCUSSION

Table 7 presents the overall results of the SUR model. The calculated value of all parameters is greater than the table value (t_table=1.96665), so all parameters are significant. If we make a comment for all 8 countries in the model, a 1% increase in the GDP of all these 8 countries decreases yield factor by approximately 0.75%. A 1% increase in the population in urban agglomerations of more than 1 million (% of total population) of all these 8 countries increases yield factor by approximately 1.54%. A 1% increase in the electric power consumption of all these 8 countries increases yield factor by approximately 0.45%.

According to the general results of the SUR model, economic growth in the countries considered in this study cannot be realized at the desired level of sustainability. We can state that supporting economic growth models that support a sustainable environment is important in this context. However, we can state that the urban population has a high sensitivity towards the environment, which is supported by the finding that an increase in population density positively affects the productivity factor. Similarly, the orientation towards renewable energy throughout Europe is also reflected in the results of the model.

Table 7. General results of the SUR model

	Beta	Standart Error	$t_{calculated}$
lgdp	-0.7531801	0.09577646	7.863937548
lpop	1.54879038	0.39634331	3.90769906
leltrc	0.45985865	0.10290699	4.46868235
_cons	12.3889083	15.279173	0.810836

CONCLUSION

It is extremely typical in the environmental economics literature to refer to carbon emissions as a single environmental contaminant. However, we can conclude that ecological footprint is now widely used in environmental economics research as a more accurate representation of environmental harm. To provide the renewable resources and ecological services that a community consumes, a population needs biologically productive ecological assets. These assets are evaluated by the ecological footprint. Biocapacity, on the other hand, monitors the availability of ecological resources on a global, regional, or national scale as well as their capacity to provide renewable resources and ecological services. Put differently, a surface's biocapacity refers to its capacity to both create the biological resources humans require and absorb the waste products they make. It serves as a gauge of how effectively a surface can accommodate its users. When a population's ecological footprint exceeds the biocapacity of the region they may access, an ecological deficit result. An ecological reserve, on the other hand, is present when a region's biocapacity surpasses its ecological footprint.

Among the eight countries included in the study, Austria and the Netherlands are the countries where the negative effect of growth rate on biocapacity is observed the most. Unlike these countries, Germany represents a unique country where economic growth causes a positive effect on biocapacity. While the effect of economic growth on biocapacity in Italy is statistically insignificant, the effect of economic growth on biocapacity is negative in Belgium, Spain, and Greece. The positive effect of population in urban agglomerations of more than 1 million (% of total population) in large cities on biocapacity is high in Belgium and Italy, while the positive effect in Greece and the Netherlands is relatively small. In Austria, Germany, and Spain, population in urban agglomerations of more than 1 million (% of total population) has a negative impact on biocapacity. Electric power consumption has a positive effect on biocapacity in Austria and Greece, but a negative effect in Germany.

If we make a remark for all eight nations in the model, a 1% increase in GDP reduces the yield factor by approximately 0.75%. A 1% increase in the population of urban agglomerations of more than one million people (% of the total population) in all eight nations raises the yield factor by approximately 1.54%. A 1% increase in electric power usage across all eight nations increased the yield factor by approximately 0.45%.

Finding a balance between economic growth and environmental sustainability has become a top priority aim at the global level in the modern world, where the issues of global warming and climate change are growing. World economies now strive to expand economically while minimizing their environmental impact. However, because there is a complicated relationship between economic development, biodiversity, ecosystem services, and human well-being, the ecological footprint is still not a significant component in political decision-making. The fact that the results of sustainable growth efforts are insufficient even in European countries can be considered an indicator that we are progressing very slowly in taking measures against the global climate crisis, considering that these countries are more sensitive to the sustainable environment. In the fight against the climate crisis, on which many international organizations have emphasized and announced action plans, it is seen that it is not enough for individuals to change their daily behavioral patterns. There is a need to create an agenda to hold economic actors responsible in parallel with their pollution rates, and to design a consistent and decisive sanction mechanism. While it is of great importance to harmonize the industrial structure and energy use with sustainable growth and to be determined in this direction, the resistance of economies that contribute the most to environmental problems at the global level to such transformations will hinder a comprehensive action plan to be implemented against the global climate crisis.

BİYOKAPASİTE VERİMLİLİĞİ VE EKONOMİK BÜYÜME ARASINDAKİ İLİŞKİ: AVRUPA İÇİN SUR MODEL ANALİZİ

1. GİRİŞ

Küresel piyasaların rekabetçi ortamında, ekonomik aktörlerin çevre üzerindeki etkisine bakmaksızın doğal kaynakları yüksek büyüme oranları için hızla tüketme eğiliminde olduğunu söyleyebiliriz. Bu durumda nesiller arası eşitlik ilkesi göz ardı edilmekte ve çevresel bozulma pahasına büyüme odaklı politikalar sürdürülmektedir. Ancak artık daha da görünür hale gelmiş olan iklim değişikliği ve küresel ısınma günümüzde çevre tartışmalarının giderek daha da alevlenmesine yol açmaktadır. Sürdürülebilir büyüme odaklı araştırmaların artması ile çevresel bozulma için bir vekil olarak tek veya az sayıda hava kirleticisine odaklanılması giderek artan düzeyde eleştirilmeye başlanmıştır. Ekonomik faaliyetlerin çevreyi etkilemesinin çeşitli yolları mevcut olduğundan çevresel zararın tek bir ölçüt ile değerlendirilmesi yeterli görülmemektedir. Son yıllarda ekolojik ayak izini insan faaliyetlerinin neden olduğu çevresel zararın kapsamlı ve uluslararası karşılaştırılabilir bir göstergesi olarak gören yeni araştırmalar ortaya çıkmıştır. İnsan faaliyetlerini desteklemek ve atıkları tutmak için gereken verimli toprak ve su miktarını hesaplayan ekolojik ayak izi, bir nüfus tarafından tüketilen doğal kaynakların toplam miktarını temsil etmektedir. Dolayısıyla yeşil büyüme odaklı modellerin oluşturulabilmesi için önemli bir ölçüt olma niteliği taşıdığı kabul edilmektedir.

2. YÖNTEM

Bu çalışmada biyokapasite verimliliği ve ekonomik büyüme arasındaki ilişkiyi incelemek için Biyokapasite-ekolojik ayak izi dengesinde en büyük açıklara sahip Avrupa ülkeleri olan Avusturya, Belçika, Almanya, İspanya, Birleşik Krallık, Yunanistan, İtalya ve Hollanda'nın 1970-2014 yılları arasındaki verileri ele alınmıştır. Biyokapasite, biyosferin kendini ne kadar iyi yenileyebildiğini ve yaşamı desteklemek için gerekli kaynakları ve hizmetleri ne kadar sunabildiğini göstermektedir. "Ekolojik ayak izi" terimi, bir nüfusun işgal ettiği kentsel altyapıyı desteklemek, tükettiği tüm kaynakları üretmek ve ürettiği tüm atıkları ortadan kaldırmak için kullanması gereken biyolojik olarak verimli arazi ve su miktarını tanımlamaktadır. Bir ülkenin ekolojik ayak izi, nüfusu ile ölçülen biyokapasitesini aşıyorsa o ülke ekolojik açık vermektedir. Bir ülkenin ekolojik açığı varsa, bu durum ekosistemlerinin atmosfere salınan fazla karbondioksiti absorbe edemediğini göstermektedir. Avrupa'da en büyük ekolojik açığı olan sekiz ülkeyi değerlendiren bu çalışmada Biyokapasite verimlilik faktörü, bağımlı değişken, GSYİH, nüfusu bir milyonun üzerinde olan kentsel yığılmalarda yaşayan toplam nüfusun oranı ve Elektrik enerjisi tüketiminin bağımsız değişken olarak alındığı görünürde ilişkisiz regresyon modeli (SUR) kullanılmıştır.

3. BULGULAR

Ülkeler bazında elde edilen SUR modeli sonuçlarına göre, Almanya'nın sürdürülebilir bir ekonomik büyüme modeline daha fazla yöneldiği ve bu modelde daha başarılı olduğu görülmektedir. Bununla birlikte, Almanya'da kentsel nüfus yığılması ve elektrik enerjisi kullanımı biyokapasite üretkenlik faktörü üzerinde negatif bir etkiye sahiptir. Biyokapasite verimliliği üzerinde en olumsuz etkiye sahip ülke Avusturya'dır. Avusturya'da kentsel nüfus yığılması biyokapasite üretkenlik faktörü üzerinde olumsuz bir etkiye sahiptir. Benzer şekilde, Belçika'da ekonomik büyüme biyokapasite üretkenlik faktörü üzerinde olumsuz bir etki yaratmaktadır. Ancak ekonomik büyümenin aksine Belçika'da kentsel yığılma biyokapasite üretimi üzerinde önemli bir pozitif etkiye sahiptir.

4. TARTIŞMA

Avusturya ve Hollanda, incelenen sekiz ülke arasında büyüme oranının biyokapasite üzerindeki olumsuz etkisinin en yüksek olduğu ülkelerdir. Bu ülkelerin aksine, ekonomik büyümenin biyokapasite üzerinde olumlu bir etkiye sahip olduğu tek ülke Almanya'dır. İtalya'da ekonomik büyümenin biyokapasite üzerindeki etkisi istatistiksel olarak ihmal edilebilir düzeydeyken, Belçika, İspanya ve Yunanistan'da biyokapasite üzerindeki etki negatiftir. Büyük şehirlerde nüfus yoğunlaşmasının biyokapasite üzerindeki olumlu etkisi en fazla Belçika ve İtalya'da görülürken, Yunanistan ve Hollanda'da minimum düzeydedir. Avusturya, Almanya ve İspanya'da bir milyondan fazla kişinin yaşadığı kentsel yığılmalarda nüfus artışı (toplam nüfusun yüzdesi olarak) biyokapasite üzerinde olumsuz bir etkiye sahiptir. Elektrik enerjisi kullanımı Avusturya ve Yunanistan'da biyokapasiteyi artırırken Almanya'da azaltmaktadır. GSYH'deki %1'lik bir artış, modeldeki sekiz ülkenin tamamı için verim faktörünü yaklaşık %0,75 oranında azaltmaktadır. GSYH'deki %1'lik bir artış, modeldeki sekiz ülkenin tamamında verim faktörünü yaklaşık %0,75 oranında azaltmaktadır. Sekiz ülkenin tamamında, bir milyondan fazla kişinin yaşadığı kentsel yığılmaların nüfusundaki %1'lik artış (toplam nüfusun %'si) verim faktörünü yaklaşık %1,54 oranında iyileştirmektedir. Sekiz ülkenin tamamında elektrik enerjisi tüketimindeki %1'lik artış, verim faktörünü yaklaşık %0,45 oranında arttırmaktadır.

SONUÇ

Karbon emisyonları, çevre ekonomisi literatüründe sıklıkla tek bir çevresel kirletici olarak anılmaktadır. Bununla birlikte, ekolojik ayak izinin artık çevre ekonomisi araştırmalarında çevresel zararın daha gerçekçi bir ölçüsü olarak yaygın bir şekilde kullanıldığı söyleyebiliriz. Bir toplumun tükettiği yenilenebilir kaynakları ve ekolojik hizmetleri sunabilmesi için biyolojik olarak aktif ekolojik varlıklara ihtiyacı vardır. Ekolojik ayak izi bu varlıkları değerlendirmek için kullanılır. Öte yandan biyokapasite, ekolojik kaynakların küresel, bölgesel veya ulusal mevcudiyetinin yanı sıra yenilenebilir kaynaklar ve ekolojik hizmetler sunma kapasitelerini de izler. Küresel ısınma ve iklim değişikliğinin giderek yaygınlaştığı günümüzde ekonomik büyüme ile çevresel sürdürülebilirlik arasında bir denge kurmak öncelikli bir hedef haline gelmiştir. Dünya ekonomileri şu anda çevresel etkilerini azaltırken ekonomik olarak büyümeye çalışmaktadır. Ancak ekonomik kalkınma, biyoçeşitlilik, ekosistem hizmetleri ve insan refahı arasındaki karmaşık etkileşim nedeniyle ekolojik ayak izi, siyasi karar alma süreçlerinde çoğu zaman göz ardı edilmektedir. Sürdürülebilir büyüme çabalarının sonuçlarının Avrupa ülkelerinde bile yetersiz olması, bu ülkelerin sürdürülebilir çevre konusunda daha duyarlı olmalarına rağmen küresel iklim kriziyle mücadelede yavaş ilerleme kaydettiğimizin bir göstergesi olarak yorumlanabilir. Birçok uluslararası kuruluşun dile getirdiği eylem planları ve bireylerin günlük davranış kalıplarını değiştirmeleri gibi önlemler iklim felaketiyle mücadele için yetersiz kalmaktadır. Ekonomik aktörlerin kirlilik oranlarıyla orantılı olarak hesap vermelerini sağlayacak bir strateji geliştirmenin yanı sıra tutarlı ve kararlı bir yaptırım mekanizması inşa edilmesi gerekmektedir. Sanayi yapısı ve enerji kullanımının sürdürülebilir büyüme ile uyumlu hale getirilmesi ve bu yönde kararlı olunması kritik önem taşırken, küresel çevre sorunlarına en fazla katkıda bulunan ekonomilerin bu tür dönüşümlere direnç göstermesi, küresel iklim krizi ile mücadele için kapsamlı bir eylem planının hayata geçirilmesini sekteye uğratmaktadır.

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Tasarım / *Design*	Yöntemi, ölçeği ve deseni tasarlamak / *Designing method, scale and pattern*	Aslı OKAY TOPRAK
Veri Toplama ve İşleme / *Data Collecting and Processing*	Verileri toplamak, düzenlenmek ve raporlamak / *Collecting, organizing and reporting data*	Aslı OKAY TOPRAK
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