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GREEN ECONOMY IN NATURAL CAPITAL MANAGEMENT: IMPLICATIONS FOR SUSTAINABLE DEVELOPMENT

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Abstract

Building a green economy is a complex process whose dynamics, among other things, are directly related to the application of many traditional and new concepts within the framework of natural capital management. In this paper, the essence of numerous concepts widely applied in the management of natural capital and the construction of a green economy, as well as the achievement of sustainable development goals, is explained by means of descriptive analysis. Using panel regression analysis, a model was created to determine the impact of changes in the use of natural resources, the state of the environment and gross national income on the sustainable development index of 166 countries in the period between 1990 and 2019. Research has confirmed the finding that the growth of the material footprint, gross national income per inhabitant, and CO2 emissions per inhabitant have a negative impact on the index of sustainable development. The obtained results speak of the necessity of building a green economy in order to stop the further growth of the ecological footprint and reduce CO2 emissions per inhabitant. The results also implicitly point to the imperative of increasing efficiency and improving the effectiveness of natural capital management in order to build a green economy and achieve the goals of sustainable development.

Key words: green economy, natural capital management, sustainable development, sustainable development index.

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ЗЕЛЕНА ЕКОНОМИЈА У МЕНАЏМЕНТУ ПРИРОДНОГ КАПИТАЛА: ИМПЛИКАЦИЈЕ ЗА ОДРЖИВИ РАЗВОЈ

Апстракт

Изградња зелене економије је сложен процес чија је динамика, поред осталог, директно повезана са применом многих традиционалних и нових концепата у оквиру менаџмента природним капиталом. У раду је помоћу дескриптивне анализе објашњена суштина бројних концепата широко примењених у менаџменту природног капитала и изградњи зелене економије, као и постизању циљева одрживог развоја. Помоћу панел регресионе анализе креиран је модел за утврђивање утицаја промена употребе природних ресурса, стања животне средине и бруто националног дохотка на индекс одрживог развоја 166 земаља у временском периоду од 1990. до 2019. године. Истраживања су потврдила констатацију да раст материјалног отиска, бруто националног дохотка по становнику, и емисије CO2 по становнику имају негативан утицај на индекс одрживог развоја. Добијени резултати говоре о неопходности изградње зелене економије у циљу заустављања даљег раста еколошког отиска и смањења емисије CO2 по становнику. Резултати такође, имплиците указују на императив раста ефикасности и унапређења ефективности управљања природним капиталом у циљу изградње зелене економије и постизања циљева одрживог развоја.

Кључне речи: зелена економија, управљање природним капиталом, одрживи развој, индекс одрживог развоја.

INTRODUCTION

Continually endangering the biophysical capacity of the geographical space, first on a local and regional, and then on a global level, humanity has for a long period of time been acting in a way that contradicts the basic laws of nature (Rockström et al., 2009; Steffen et al., 2015; Wiedmann et al., 2020). The question of human existence, among other things, is increasingly viewed in the light of numerous problems associated with limited natural resources and the limits of the ecological capacity of the planet Earth to absorb waste as a consequence of growing production and consumption (Lenzen, et al, 2022). It is possible to see numerous specificities in the domain of economics and management of modern companies and countries by identifying the content coverage of natural resources and the environment in the category of natural capital (Harris, & Rouch, 2021).

At the end of the previous century, it became evident that the existing model of growth and development of industrial companies and countries is based on the premise of the practically unlimited use of natural and energy resources. It is also based on the almost uncontrolled emission of polluting substances into the environment since the time of the first Industrial Revolution at the end of the 18th century and, as the ruling mode of economic value creation, it lost its relevance (Malaval, 2008). This is evidenced by the fact that the framework for shaping strategies and policies for the growth and development of companies and countries over the last thirty years has been the paradigm of sustainable development (SD).

One of the main challenges facing the modern world is the SD challenge. It is becoming more obvious that humanity is still very far from fulfilling the goals of SD. Namely, there are too many problems related to sustainability, among which many of them are increasing every day. One of the acute issues of sustainable development is related to the growing exploitation of natural resources and the increasing CO2 emissions.

According to the usual and often cited definition of SD, it is about development that meets the needs of the present without jeopardising the ability of future generations to meet their own needs (Our Common Future, 1987). The concept aroused a much greater interest of researchers and development policy makers after the Earth Summit in Rio de Janeiro in 1992, at which a program for the implementation of sustainable development in the twenty-first century known as Agenda 21 was adopted (Agenda 21, 1992). Quickly after this event, the SD paradigm became a generally accepted principle of ecological, economic and social development of the largest number of companies and countries in the world. At the same time, one should keep in mind the necessity of distinguishing between two forms of the SD paradigm, the form of weak and the form of strong sustainability. At the base of weak sustainability is the attitude that 'anthropological' capital, i.e. capital that is the result of human work and natural capital, are interchangeable and that, accordingly, in order to achieve sustainability, a complete change of the existing mode of production is not required (Neumaier, 2013). Strong sustainability, on the contrary, implies that natural capital and complementary drivers of economic activities are created by human labor.

Issues related to the imperative of the industrial transition to a green economy (GE) have recently taken a prominent place in discussions about sustainable business models and strategies of SD countries. The transition from a carbon-based, CO2-heavy industrial economy to a very low-CO2 GE is capturing the attention of policymakers in economically developed countries and, more recently, in emerging economies. It turned out that most countries plan the development of GE with clearly defined priorities and activities. The transition to GE is a complex process that is directly related to many traditional and new production concepts, widely applied in natural resource management and environmental management, i.e. in natural capital management (NCM).

The aim of this work is to present a new insight into the interdependence of material footprint (MF) and CO2 emissions per inhabitant on the sustainable development index (SDI) at the global level. It should be noted that the largest number of reference studies of this interdependence provide insight at the national or regional level. In this context, the paper apostrophises traditional and new concepts important for the GE construction process related to the reduction of MF and CO2 emissions per inhabitant in light of SD challenges at the global level. By using the methods of qualitative economic analysis, the essence of the concepts relevant to the construction of GE and the improvement of the effectiveness of NCM in light of their contribution to the realisation of weak or strong sustainability is explained. The panel data analysis methodology was used to assess the impact of changes in MF and CO2 emissions per inhabitant on the sustainable development index (SDI).

Structurally, the paper consists of eight sections. After the introduction, section two re-views the concepts of GE and GG with special reference to the imperative of resource decoupling and decoupling impact. In the next section, the most important concepts on which the transition to GE is based are described, and their role in the realisation of paradigms is considered. In section four, a research model was constructed with the aim of determining the relationship between the use of natural resources, the state of the environment and sustainable development on the example of a group of 166 countries in the period between 1990 and 2019. The following sections of the paper are dedicated to the explanation of the research methodology, to the interpretation of the obtained results, and to the discussion of the obtained results. The final sections of the paper consist of concluding remarks and a list of used references.

GREEN ECONOMICS AND GREEN GROWTH

The development of GE represents one of the key instruments for achieving SD, for the protection and preservation of natural resources, for ensuring the economic valuation of the ecosystem of services and goods, reducing poverty, creating opportunities for the creation of new jobs for decent work, and moving the world in the direction of development with a reduced level of carbon dioxide emissions. In other words, the movement towards GE protects the planet, current and future generations and serves the purpose of achieving SD goals (Denona Bogović, & Grdić, 2020). Thus, green economy is becoming an increasingly interesting area of research, while green projects are gaining importance (Stojković et al, 2021).

The transition to GE was in the spotlight at the United Nations conference in Rio de Janeiro in 2012. The final document of the conference points out that each country should determine the transition to GE in accordance with its national SD plans, strategies and priorities. Although it has recently been led by environmentalists and green parties, GE is now a concept equally advocated by the EU, OECD, the World Bank, the United Nations Environment Program UNEP), the United Nations Conference on Trade and Development (UNCTAD), and a whole range of other global organisations.

In recent times, GE has stoods out as a generally accepted concept, way of thinking and business model. The concept is by its very nature extremely complex. It is made up of various initiatives and, as such, occurs at all political, managerial and entrepreneurial levels. It includes the research and development of new technologies, new policies and schools of thought, and the creation of new concepts, as well as lifestyles and habits. There is still no single and generally accepted definition of GE in the available literature. In the simplest terms, GE is seen as a low-carbon, resource-efficient and socially inclusive economy (UNEP, 2011).

In addition to the GE coin, the term green growth (GG) is also used in professional and everyday life. GG is an important premise of SD, and in the most elementary sense it means economic growth based on resource-efficient, cleaner and more resilient production. At the basis of the idea of GG is the attitude that a growing economy is possible with a stagnant and preferably declining trend in the exploitation of natural capital. GG is a way to solve economic and environmental problems that have been present for years, as well as to devise new ways of growth by stimulating production based on lower consumption of natural and energy resources, and lower pollution per unit of final production. GG implicitly implies the existence of effective NCM (Dietz, & Neumaier, 2007; Neumaier, 2013); Loiseau et al., 2016).

The basic analytical starting point of GG is the idea of decoupling economic activities from the exploitation of renewable and non-renewable natural resources and environmental pollution (Graph 1). In the analysis of decoupling and the success of the transition from the traditional production model to GE, in addition to the indicators of the rate of economic growth, the indicators of the use of material resources and emissions of polluting substances per inhabitant are extremely important. The most widespread indicator of resource use in economic research is the material footprint (MF), and the level of environmental pollution is CO2 emissions per inhabitant[1].

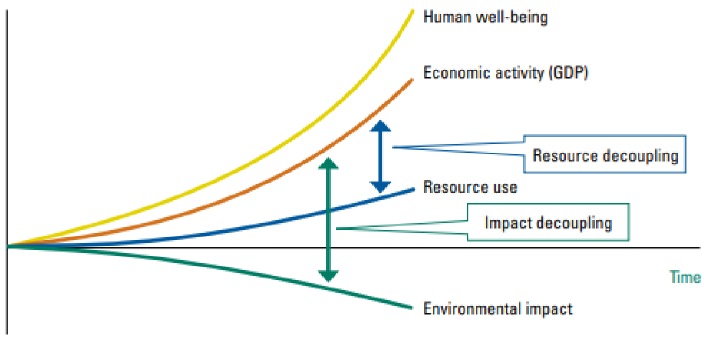

Figure 1. Resource decoupling and Impact decoupling

Source: UNEP, 2011.

[1] Indicators MF, CO2, GNI are always used in per capita terms.

Resource decoupling exists when economic activity and human well-being increase at a higher rate than resource use, and decoupling impact is present when the economy grows while simultaneously reducing its negative impact on the environment. Separation is very important, because humanity aspires to intensify economic growth and improve human well-being, and today, per se, it implies the growing consumption of natural resources whose extraction, processing and use have serious negative consequences for the environment and human health. Decoupling can reduce resource use and, more importantly, reduce environmental degradation caused by increasing resource use (Umpfenbach, 2016). Resource decoupling and impact decoupling could reduce resource use and, at the same time, reduce environmental degradation. This could affect the growth of human well-being under other unchanged conditions (Wood et al, 2018; Charlier, & Fizaine, 2023).

Critics of the GE approach and green growth point out that the thesis of decoupling resource and impact decoupling is completely unrealistic. In addition, critics of GE believe that its representatives do not fully take into account the very demanding changes in the economic system that are necessary to solve global environmental problems such as climate change, or the biodiversity crisis. Therefore, some of them propose degrowth as the only realistic option (Kallis, 2018; Schmelzer et al, 2020).

CONCEPTS RELEVANT TO THE GREEN TRANSITION

Many already well-established and some new concepts have a prominent place in the construction of GE and the realisation of the decoupling resource and impact decoupling vision. Among the concepts whose application in modern production is very important in the process of designing GE and improving the effectiveness of NCM, cleaner production and resource efficiency, waste hierarchy, industrial ecology, circular economy, bioeconomy, nature-based solutions, and product-service system stand out (Loiseau et al, 2016: 368).

Cleaner production and resource efficiency represents the continuous application of an integrated environmental protection strategy to processes, products and services in order to increase efficiency and reduce risks for people and the environment. This is of particular importance considering the fact that the issues of the protection and improvement of environmental quality in today's economic conditions represent one of the central elements of economic development strategies of countries around the world (Đurović Todorović et al, 2023). This approach points out that it is more appropriate to try to prevent pollution, rather than to treat it by so-called techniques 'at the end of the pipe' (El Kholi, 2002). Cleaner production and resource efficiency includes the issue of resource efficiency, which is undeniably one of the key elements of the transition to GE (UNEP, 2016). Accordingly, emphasis is placed on the development of cleaner technologies that generate less pollution and waste, and that use natural resources more efficiently.

The focus of cleaner production and resource efficiency management is on prevention and avoidance, not on remediation of environmental problems. At the same time, it should be known that there is no universal form of cleaner production management, since different industries and different countries have specific obstacles that need to be overcome. Generally speaking, many factors still hinder effective management with cleaner production. Lack of workforce training, insufficient investments financed from public sources, lack of adequate foresight by top management and interested parties have caused the management with cleaner production in different fields and areas to look very heterogeneous (Tschiggerl & Topic, 2019).

Waste hierarchy: reuse, repairing, recovery and recycling with waste prevention are important elements of GE whose impact on improving the efficiency of resources and reducing their consumption is very pronounced. The stages of waste hierarchy are prevention, reuse, recycling, recovery and final disposal. The starting point of NCM in the waste management segment is the treatment of waste materials as production resources. The general principles are avoiding, reduce, reuse, recycle, redesign and remanufacture (Ghisellini & Ulgiati, 2020; Kaza et al, 2018; Zaman, 2015). Waste management approaches should be chosen based on waste form, composition, quantity and local needs and conditions (Marshall & Farahbakhsh, 2013). Globally, the generation and structure of waste is influenced by industrialisation, urbanisation, population size, education level, public habits and intentions (Zaikova et al, 2022), household attitudes, age groups, local climate, consumption, behavior and culture (Moh, 2017), land size, household location (rural/urban), economic status and monthly household income (Triguero et al, 2016; Zaman, 2015). In general, higher economic status corresponds to higher disposable income, higher consumption and higher waste generation (Roi & Tarafdar, 2022). The waste hierarchy approach is mainly focused on reducing material and energy flows, and therefore environmental pollution caused by the nature of production processes. As such, it aims to increase resource efficiency similar to the cleaner production approach (Bartl, 2014). It differs from the latter in its stronger emphasis on waste reduction and control of harmful substances. Emphasising the importance of protecting the planetary ecological boundaries, this concept corresponds with the vision of strong sustainability.

Industrial ecology is a research field interested in integrating sustainability concepts into ecological and economic systems. Energy and material use is optimised, waste generation is minimised to move from linear permeability to closed loop materials and energy use (Ehrenfeld &

Gertler, 1997). The basic elements of industrial ecology are the use of biological analogy, systemic perspective, introduction of technological changes, and the dematerialisation of production (Lifset & Graedel, 2002; Aires & Aires, 2002). The primary goal of industrial ecology is the promotion and improvement of sustainable industrial development at global, regional and local levels (Guinée, 2017).

The circular economy represents a regenerative economic system in which resources, waste emissions and energy inefficiencies are significantly reduced due to slowing down, rounding off and extending energy and material cycles in production (Ekins et al, 2019). This is achieved, first of all, by designing and creating products that extend their life as much as possible, but also by maintaining, servicing and recycling. The circular economy model is in complete contrast to the currently dominant model of the linear economy, which promotes the concept of production based on the principle of take (from nature), make (in the production process), use, throw away (Potting, 2017). It is a concept characterised by a holistic approach to SD, which aims to minimise waste and maximise the use of resources (What is a Circular Economy?, 2020; *Universal Circular Economy Policy Goals,* 2021). The concept of circular economy implies the adoption of cleaner production patterns in companies, increasing the responsibility and awareness of producers and consumers, the use of renewable technologies and materials wherever possible, as well as the adoption of appropriate, clear and stable policies and implementation tools. By promoting the adoption of closed-loop production patterns within the economic system, the concept of the circular economy aims to increase the efficiency of resource use, with a special focus on urban and industrial waste, in order to achieve a better balance and harmony between the economy, the environment and society (Ramos, 2024).

Bioeconomy offers broad perspectives for progress in primary production (e.g. plant and animal breeding), health (pharmacogenetics) and industry, while reducing dependence on non-renewable resources and ensuring food, environmental, social and economic security through job creation and competitive position. Also, bioeconomy covers the use of processes based on biological development in green industries. This is mostly a micro approach since it aims to change the behavior of the firm. Exceeding planetary boundaries, and especially climate change, requires economies around the world to decarbonise production and respect the principles and goals of sustainable development as much as possible. The transformation of the traditional economy into a sustainable bioeconomy by replacing fossil resources with renewable biogenic resources offers a solution to these goals (Hinderer et al, 2021).

Nature-based solutions are defined as actions for the protection, sustainable management and restoration of natural or modified ecosystems that solve social challenges in an effective and adaptive way, while providing benefits for human well-being and the sustainability of biodiversity. Nature-based solutions provide benefits to both natural ecosystems and human-managed systems, ensuring a healthier and better quality of life for people at the same time. They must be able to adapt to changed conditions of production and consumption, and provide long-term positive results. In simple terms, nature-based solutions are built on the use of natural processes to combat the destabilisation and degradation of living conditions on Earth. The result is the search for innovative solutions for the management of natural systems that can achieve benefits for both nature and society in a balanced way. In other words, by working with nature, not against it, human communities can develop and implement solutions that lead to a more resource efficient and environmentally sound economy (Seddon et al, 2020). Applying nature-based solutions requires designing multifunctional environments that contribute to sustainable resource management systems that induce the development of a green economy. The application of nature-based solutions is aligned with the criteria of strong sustainability (Mazza et al, 2011).

The concept of product-service system was defined in Europe in the 1990s as a combination of tangible products and intangible services designed to meet the needs of end customers (Tukker & Tischner, 2006). Products are owned by companies throughout their life cycle, and the use of the service is what the consumer pays for. That is why companies have a strong economic interest in extending the life of their products, in order to ensure that they are intensively used, that is, to make them as attractive as possible in terms of price and quality. The concept of product-service systems generally remains at the micro level and does not aim at systematic changes in the overall patterns of resource consumption (Mont & Tukker, 2006). They are one of the pillars of improving energy efficiency, because the focus is on the production of physical goods in a rational way. Due to the fact that they speak to the sustainability of the entire production chain, product-service systems also deal with the maintenance of these products-services, recycling and, if necessary, product replacement. In this way, the negative impact on the environment of the entire cycle is reduced. The concept of product-service system is a paradigm shift to the entire logic of designing new products and services, which leads to the conclusion that its application implies strong sustainability (Roman et al, 2015). For example, IBM decided to rent servers instead of selling units directly to companies. Philips, on the other hand, has a service where customers buy a promised level of lighting for a given building. The British company Drover is in the business of renting cars instead of selling them.

Figure 2 presents the previously analysed concepts important for building GE and improving the efficiency and effectiveness of NCM depending on two characteristics of sustainability: the degree of substitution of environmental and economic benefits, and the required level of changes in the production system. The picture shows that, depending on which of the considered concepts dominates NCM, it is possible to distinguish their connections with visions of weak or strong sustainability.

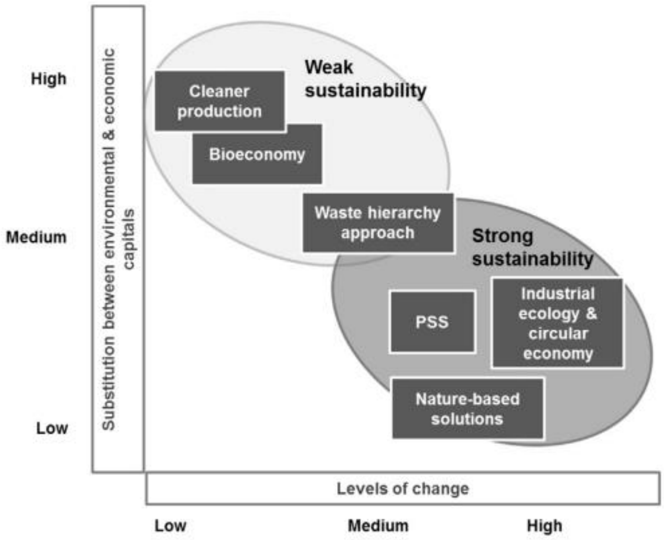

Figure 2. Concepts present in GE and NCM depending on the two visions of sustainability
Authors based on: Loiseau et al, 2016: 368

RESEARCH MODEL: THE IMPACT OF CHANGE IN GNI, MF AND CO2 EMISION ON SD

For this study, annual data spanning from 1990 to 2019 was utilised for 166 countries worldwide. All the data for the SDI, GNI per capita at constant 2017 US dollars adjusted for Purchasing Power Parity (GNI), Carbon Dioxide emissions per capita, measured in tonnes (CO_2), and MF per capita, measured in tonnes (MF) was collected from SDI (2020). The exclusion of 2020, 2021, and 2022 is based on data availability considerations, with the last documented year in the database being 2019. The decision to end the dataset with 2019 is also based on recognising potential outliers or anomalies due to global events, notably the COVID-19 pandemic and the Russia-Ukraine conflict. It is assumed that the inclusion of these years would lead to significant distortions in the data patterns, so deliberate exclusion is necessary to ensure the integrity and reliability of the analysed data set.

The SDI serves as an overarching measure that combines multiple dimensions of development and considers economic, social, and environmental factors. It provides a holistic assessment of a country's development and aligns with the principles of sustainable development, which aim to reconcile economic progress with environmental and social well-being.

Specifically, the SDI is an innovative paradigm to quantify the complex balance between human development and ecological preservation. Unlike its predecessor, the Human Development Index (HDI), the SDI represents a groundbreaking innovation in contemporary environmental discourse, developed specifically to address the complex challenges of our time of primarily anthropogenic environmental degradation. As such, the SDI goes beyond the conventional HDI framework in which life expectancy, education, and income serve as the established trinity of human development metrics. The decisive factor lies in the inventive integration of an ecological dimension into the SDI. In other words, the index recognises prosperity and requires a harmonious alignment between human well-being and environmental protection. The SDI appeals to and guides policymakers, researchers, and practitioners into a new era of refined sustainability metrics, forcing them to re-evaluate the fundamental principles of progress in an age where balance is proving to be the prerequisite for a prosperous future. For a comprehensive exposition of the SDI methodology and its underlying rationale, please refer to Hickel (2020).

GNI per capita is an important economic indicator that is adjusted for inflation and purchasing power parities, and provides insights into the economic prosperity of a country's residents. Using constant 2017 US dollars and adjusting for PPP facilitates cross-country comparisons and, thus, contributes to a crucial economic perspective in assessing sustainable development.

CO_2 emissions per capita measure a country's carbon footprint and reflect its contribution to greenhouse gas emissions. Monitoring this variable is critical to understanding the environmental impact of economic activities, and a country's commitment to mitigating climate change, an essential aspect of sustainable development.

The material footprint per capita measures the amount of raw materials and resources consumed by each individual in a country. This metric sheds light on the environmental impact of consumption patterns and provides insights into resource efficiency and potential environmental impacts. The assessment of material consumption is in line with the Sustainable Development Goals and emphasises the responsible management of resources.

The following research hypotheses were formulated:

H1 – An increase in MF has a negative impact on the Sustainable Development Index.

H2 – An increase in Gross National Income has a negative impact on the Sustainable Development Index.

H3 – An increase in CO2 emissions has a negative impact on the Sustainable Development Index.

METHODOLOGY

The methodology framework in this paper relies on panel regression modelling (Cameron et al, 2005; Wooldridge, 2013). The general form of the panel model is represented by the equation:

$$y_{it} = \alpha_{it} + x_{it}'\beta_{it} + u_{it},\ i = 1, \dots , N,\ t = 1, \dots , T,$$

where y_{it} is the dependent variable (scalar), x_{it} is the vector of independent variables, u_{it} is the stochastic error (noise), N is the number of countries, and T is the number of time periods observed (number of years). The general form of the model allows the dependence of both parameters, the intercept α_{it} and the slope β_{it} of the regression, on both the individual and time. However, such a model has more unknown parameters than the sample size, making model estimation impossible. For this reason, various assumptions should be made about the dependence of parameters on i and t, as well as on the noise, in order to obtain parameter estimates. In panel data analysis, the fixed and random effects panel models are two distinct, but most commonly used approaches designed to address unobserved heterogeneity among individual units within a dataset, such as countries.

The fixed effects panel model incorporates individual-specific effects α_i into the model. These fixed effects capture unobservable characteristics unique to each unit that remain constant over time, representing time-invariant individual heterogeneity. On the other hand, the random effects panel model treats individual-specific effects as random variables, assuming they follow a specific distribution. These random effects encompass both time-invariant and time-varying unobserved heterogeneity. The model is estimated using Generalized Least Squares or Maximum Likelihood Estimation, considering the assumed distribution of the random effects.

In mathematical terms, we look at the model in the form:

$$y_{it} = \alpha_i + x_{it}'\beta + \varepsilon_{it},$$

where ε_{it} are i.i.d. If α_i and x_{iT} are correlated, then the model is a fixed effect panel model. Otherwise, if they are independent, the model is a random effect model. In both models, we assume:

$$E[\varepsilon_{it}|\alpha_i, x_{i1}, \dots , x_{iT}] = 0,\ t = 1, \dots ,T.$$

To determine the appropriate model to utilise, we conducted the Hausman test. The null hypothesis states that random effects characterise the optimal model, while the alternative hypothesis suggests a fixed effects model. The test examines whether a correlation between the distinctive errors and the regressors within the model exists. The null hypothesis asserts the absence of such a correlation between the two.

RESULTS

The Hausman test is designed to guide the choice between fixed-effects and random-effects models. The results of the Hausman test (chi-square (3) = 64.34, $p<0.01$) give evidence to reject the null hypothesis, suggesting that GLS estimates are consistent with the fixed-effects model. That is, the implication is that fixed effects are preferred over random effects.

Hence, we built the fixed-effects panel model in this paper, which incorporates t=4677 observations with N=166 cross-sectional units.

The results are given in Table 1. The gross national income is negatively associated with SDI, with a coefficient of -2.68499e-06 and a significant t-ratio of -11.27 ($p<0.01$). The SDI is expected to decrease by 2.68499e-06 units for a one-unit increase in gross national income. Similarly, the variables CO_2 and Material Footprint exhibit negative associations with SDI, with coefficients of -0.00328723 and -0.00795721, respectively. Both predictors are statistically significant, supported by t-ratios of -4.293 and -25.32 and very low p-values ($p<0.01$). For a one-unit increase in CO_2, the SDI is expected to decrease by 0.00328723 units. The SDI is expected to decrease by 0.00795721 units for a one-unit increase in material footprint. The model provides insights into the relationships between these variables and the SDI, suggesting that gross national income, CO_2, and material footprint significantly impact sustainable development outcomes.

Table 1. Fixed effect panel model

Variable	Coefficient	Std. Error	t-ratio	p-value
Constant	0.729348	0.00475590	153.4	0.0000
GNI	−2.68499e-06	2.38280e-07	−11.27	<0.01
CO2	−0.00328723	0.000765704	−4.293	<0.01
MF	−0.00795721	0.000314292	−25.32	<0.01

The summary of the estimated model given in Table 2 provides key insights from the regression analysis. The mean of the dependent variable is 0.572383, with a standard deviation of 0.166024, suggesting variability around the mean. The sum squared residual of 19.94464, and a low standard error of the regression (0.066515) indicate a well-fitted model. The LSDV R-squared of 0.845257 suggests that the model explains a substantial portion of the total variation. The within R-squared of 0.256646 indicates that a considerable portion of the variability is attributed to individual-specific effects. The high LSDV F-statistic (146.5728) with an extremely low p-value (0.000000) implies overall model significance. The log-likelihood of 6125.875 and associated criteria (Akaike, Schwarz, Hannan-Quinn) provide measures of model fit, with lower values being preferable.

Table 2. Model summary

Measure	Value	Measure	Value
Mean dependent var	0.572383	S.D. dependent var	0.166024
Sum squared resid	19.94464	S.E. of regression	0.066515
LSDV R-squared	0.845257	Within R-squared	0.256646
LSDV F(168, 4508)	146.5728	P-value(F)	0.000000
Log-likelihood	6125.875	Akaike criterion	−11913.75
Schwarz criterion	−10823.63	Hannan-Quinn	−11530.39

We also performed two additional tests. The joint test on named regressors, with a test statistic of F(3, 4508) = 518.801 and an extremely low p-value (1.28579e-289), indicates that at least one of the regressors is significant. The test for differing group intercepts rejects the null hypothesis of common intercepts (F(165, 4508) = 110.866, p-value = 0), suggesting heterogeneity among groups. Overall, the findings highlight the significance of the model, the explanatory power of the regressors, and potential serial correlation and group heterogeneity.

DISCUSSION

The obtained results confirm the existence of a statistically significant long-term co-integrating relationship between changes in GNI pc, MF and CO2 emissions, and FDI in 166 countries of the world in the period between 1990 and 2019. Specifically, for a unit increase in GNI, the expected decrease in FDI is 2.68499e-06 units. Similarly, for a one-unit increase in MF, the expected decrease in FDI is 0.00795721 units, while the expected decrease in FDI is 0.00328723 units for a one-unit increase in CO2. With this, the research results confirmed hypotheses H1, H2 and H3. In other words, the constructed model provides a respectable insight into the relationships between independent variables and FDI as a dependent variable at the global level. In light of the defined research objectives, these results speak of the expressed need for the transition of business models and national development strategies to the GE concept. They also talk about the importance of NCM for the development of GE.

It should be emphasised that the constructed model fully abstracts the numerous factors behind the observed relationship. Namely, it is evident that a whole series of factors have an influence on the relationship between changes in GNI, MP and CO2 emissions on FDI. First of all, the inadequate use of natural resources in many world economies, especially in less developed economies, results in an increase in pollution and the manifestation of negative externalities in the production process. The share of consumed energy from green sources in the total energy consumption is still the predominant characteristic of economically developed economies. The insufficient effectiveness of natural capital management at all levels is also a factor that contributes to the increase of MF, which implicitly implies growing CO2 emissions. Outdated technology is associated with high consumption of natural resources per unit of final production, which, as a rule, means growing CO2 emissions. In this context, the purpose of NCM is to point out the importance of investing in equipment that implies resource-saving production with lower CO2 emissions. In the discussion about the place of MF, CO2 emissions in the GE, the NCM concept and their implications for SD, it is necessary to point out the importance of improving general environmental awareness in order to reduce CO2 emissions.

Less developed economies on the NCM plan should follow the recommendations of the global environmental policy, such as the recommendations of the conference of the parties (COP), making maximum efforts in order to achieve the goals set by these and other international agreements (Mitić et al, 2017). Also, economies at a lower level of economic development can consider the implementation of CO2 storage technologies, where the limiting factor of such policies is certainly the high cost of that procedure.

Green taxes can significantly contribute to the reduction of CO2 emissions, especially if tax revenues are focused on solving current issues related to the use of natural capital. Taxes on environmentally harmful behavior have the potential to increase the amount of public revenue. On the other hand, CO2 emission trading schemes mean that increases in pollutant emissions from one source must be accompanied by an equivalent decrease in pollution from other sources. Developed countries have these programs to limit pollutant emissions and to stimulate businesses that choose to pollute the environment less.

Many studies confirm the negative relationship between GDP and domestic material consumption, as well as harmful emissions, which cannot be said for the relationship between GDP and the material footprint (MF). The primary reason for this discrepancy is that the former pertains exclusively to local consumption, while the MF indicator encompasses the consumption of material resources throughout the entire production and consumption chain (Razzaq et al., 2021). Due to this fact, most economically developed countries characterised by outsourcing products with high material demands have not achieved the desired outcomes in terms of resource decoupling. Hence, sustainability policies related to MF are incomparably more complex than those addressing GDP decoupling from domestic natural resource consumption, and can significantly contribute to achieving the Sustainable Development Goals (SDGs).

In recent years, numerous studies have emerged analysing MF trends to investigate the achievement of SDGs. Some of the more notable ones have focused on examining the role of ecological factors in achieving SDGs (Adebayo et al, 2022; Adebayo et al, 2023; Zhang et al, 2023; Akadiri et al, 2022; Wu et al, 2022), while others have concentrated on identifying the nature of interactions between economic growth and environmental conditions by testing the validity of the Environmental Kuznets Curve hypothesis (Wang et al, 2023; Naveed et al, 2022; Kilinc-Ata et al, 2022).

Vavrek and Chovancová (2016) noted the existence of absolute decoupling between economic growth and greenhouse gas emissions in the Visegrad Group countries (Czech Republic, Hungary, Slovakia, and Poland). However, despite this finding, the authors emphasise the necessity for these countries to develop new and rapidly applicable energy policies to reduce greenhouse gas emissions and achieve sustainable development goals by 2050. Wang et al. (2018) found that resource decoupling is more pronounced in developing countries than in economically advanced ones. These results are valid for three BRICS countries (China, India, and Brazil) and three OECD countries (the USA, Australia, and Japan).

Bithas and Kalimeris (2018) concluded that the global economy's dependence on natural resources increased by over 60% during the period between 1900 and 2009. They assert that the effects of resource decoupling achieved in post-industrial economies during the 1970s were entirely negated by the intensified use of natural resources in several developing countries. Accordingly, the authors believe that the dematerialisation of production is one of the prerequisites for achieving sustainable development. For this reason, they stress that managing economic development requires much clearer definitions of policies regarding natural resource exploitation and environmental protection than is generally the case in most global economies.

Kjaer et al. (2019) analysed product-service systems as tools for achieving a circular economy and green growth. They concluded that even a widespread implementation of such systems does not guarantee absolute resource decoupling. The authors recommend a sequence of specific measures for policymakers aimed at supporting the broad adoption of product-service systems to achieve absolute resource decoupling and green transformation.

Lonca et al. (2019) examined the issue of resource decoupling within the development of circular economy models in EU countries. They concluded that three types of circularity measures must be implemented to reduce greenhouse gas emissions in the steel, plastic products, aluminium, and cement industries by 2050. These measures include material circulation, material efficiency, and new circular business models.

Haberl et al. (2020) conducted an extensive review of the literature on resource decoupling and impact decoupling as key premises for green transformation. They noted that absolute decoupling is a rare phenomenon, and that only a few industrialised countries have managed to decouple GDP from CO2 emissions. This achievement has primarily been attributed to changes in production models and fundamental consumption patterns.

Hickel and Kallis (2020) concluded that it is unrealistic to discuss the existence of resource decoupling on a global scale. They highlighted that even under the assumption of limiting global warming to 1.5 °C or 2 °C annually, impact decoupling is nearly unattainable. Therefore, they argue that the concept of green growth is highly debatable, necessitating the consideration of alternative development strategies.

Frodyma et al. (2020) investigated the decoupling between GDP and fossil fuel consumption in 141 countries by analysing trends in domestic material consumption and the material footprint (MF). Their findings revealed that relative decoupling of domestic material consumption and GDP exists in a small number of economies, while there is no evidence of any decoupling between GDP and MF in the majority of the analysed countries.

Charlier and Fizaine (2023), based on panel analyses using extensive datasets and diverse methodologies, found no evidence of resource decoupling in a sample of 163 countries over the period between 1990 and 2015.

Using Brazil, one of the largest developing economies globally, as an example, Rovere et al. (2018) expressed the view that, under the assumption of implementing appropriate economic development policy instruments, it is possible to achieve both resource decoupling and impact decoupling in Brazil.

The previous literature review indicates that the findings of numerous studies focused on the existence of resource decoupling and impact decoupling vary, but largely align with the results and confirmation of the hypotheses presented in this paper. Additionally, it has becomes evident that, while the phenomenon of decoupling is a frequent research topic, the same cannot be said for studies examining the relationship between the material footprint (MF) and sustainable development. In this context, assessing the impact of GDP growth, MF, and CO2 emissions on the Sustainable Development Index (SDI) posed a significant research challenge in itself.

The results of this study can provide policymakers with insights into the challenges posed by economic growth, unsustainable natural resource consumption, and high environmental pollution. These findings can undoubtedly assist macro-level managers in designing measures and instruments aimed at reducing natural resource consumption and per capita CO2 emissions while achieving a satisfactory GDP growth rate.

It is crucial for future research to evaluate the impact of rising natural resource prices on their use in the production and consumption processes, as well as the associated CO2 emissions. In addition to the methods used thus far, other econometric techniques and evaluation tools could be employed to assess this impact. Moreover, research must go beyond advocating for continued GDP growth or its deceleration. It is essential to rigorously investigate the relationship between natural resource consumption and social well-being, a topic that was robustly debated over a decade ago by Steinberger and Roberts (2010), as well as Roberts et al. (2012).

CONCLUSION

The links between the growth of GNI pc, MF pc and CO2 pc, on the one hand, and sustainable development, on the other hand, are of essential importance for understanding the essence and scope of GE, the phenomenon of resource and impact decoupling, and NCM. In the 1980s, this relationship was the focal point of theoretical and many empirical studies, because the direct consequences of inadequate NCM were manifested in the emergence of global problems such as climate change, global warming and many others.

Bearing in mind the results of the created research model of the change impact in GNI, MF and CO2 emission on SDI on a sample of 166 countries, the transition process of the existing model of industrial production to the GE model, which is based on the idea of resource decoupling and impact decoupling, is imposed as essential. This, in turn, logically implies an increase in the efficiency and effectiveness of NCM.

There are also numerous limitations of the model created here, starting from the inappropriate and basically excessive use of natural resources in many national environments, low technological innovation in the field of exploitation of natural resources and environmental pollution control instruments, insufficient efficiency and, especially, inadequate effectiveness of NCM. In this sense, including some of these variables in the research model would undoubtedly be very useful. Here, variables that are especially taken into account, are related to the achieved level of ecological innovation, consumption of electricity from green sources and others for whose values arranged statistical data can be found.

In perspective, NCM must become a management infrastructure and a trial test of the success of every management practice without exception. Curbing the consumption of not only non-renewable but also renewable natural resources represents the modus vivendi of human survival. In this context, it can be concluded that NCM is a process that promotes the sustainable use of natural resources and the emission of polluting substances without jeopardising the sustainability of vital ecosystems. This management approach should integrate research on different types of natural resources in a process of adaptive management and stakeholder-driven innovation, in order to improve lifestyles, increase ecosystem resilience, and increase the productivity of resources and environmental services at the local, regional and global level.

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ЗЕЛЕНА ЕКОНОМИЈА У МЕНАЏМЕНТУ ПРИРОДНОГ КАПИТАЛА: ИМПЛИКАЦИЈЕ ЗА ОДРЖИВИ РАЗВОЈ

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Резиме

Непрестано угрожавајући биофизичке капацитете географског простора, најпре на локалном и регионалном, а затим и на глобалном плану, човечанство се већ дужи временски период понаша на начин који је у супротности са основним законима природе. Питање људске егзистенције, између осталог, све више се посматра у светлу бројних проблема повезаних са расположивим природним ресурсима и ограничењима капацитета Земље да апсорбује отпад као последице растуће производње и потрошње. Идентификујући категорију природног капитала садржајем природних ресурса и животне средине, могуће је говорити о ефикасности и ефективности управљања тим фактором производње на нивоу различитих економских ентитета у светлу многих изазова одрживог развоја са којима се суочава савремени свет.

Питања која се односе на императив транзиције постојећег облика производње на модел зелене економије заузимају све истакнутије место у конципирању одрживих пословних модела и стратегија одрживог развоја земаља. У раду је коришћењем панел регресионог модела сагледаван утицај промена материјалног отиска, промена бруто националног дохотка по становнику и емисије CO2 по становнику на индекс одрживог развоја за групу од 166 земаља света у периоду од 1990. до 2019. године. Резултати модела указују да за јединични пораст бруто националног дохотка по становнику, очекивано смањење индекса одрживог развоја износи 2,68499e-06 јединица. Слично, за повећање материјалног отиска за јединицу, очекивано смањење индекса одрживог развоја износи 0,00795721 јединица, док је за повећање емисије CO2 по становнику од једне јединице, очекивано смањење индекса одрживог развоја 0,00328723 јединица. Ови резултати упућују на потребу успостављања пословних модела и националних стратегија развоја на принципима озелењавања економије. Они такође указују на важност постојања ефикасног и ефективног менаџмента природног капитала који промовише одрживо коришћење природних ресурса и регулише емисију загађујућих материја без угрожавања одрживости виталних екосистема. У перспективи, обуздавање потрошње не само необновљивих, већ и обновљивих природних ресурса, као и смањење загађења животне средине представљају важан услов људског опстанка.