GREEN GDP VS. GREEN GROWTH INDEX: COMPARATIVE INSIGHTS FOR SUSTAINABLE DEVELOPMENT METRICS

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Green GDP and the Green growth index have emerged as important indicators for evaluating the alignment of economic progress with environmental sustainability. While Green GDP integrates environmental degradation and resource depletion into traditional GDP calculations, the Green growth index reflects a multidimensional approach, incorporating economic, social, and environmental sustainability criteria. This study provides a comparative analysis of these two metrics, focusing on their temporal dynamics and alignment across European countries. Employing cyclical extraction and cross-correlation analysis, the results uncover significant differences in the dynamics of these two indicators, raising questions about their compatibility and reliability for cross-country analysis of green economic progress. Our findings reveal that both indicators, despite their conceptual and methodological differences on one side and similarity in reflecting consistent global patterns of green economy on the other, in fact have different focus, methodology and application possibilities behind them.

Keywords:
Green GDP,
Green growth index,
sustainability metrics,
cross-country analysis,
cyclical behaviour
European countries

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1 Introduction

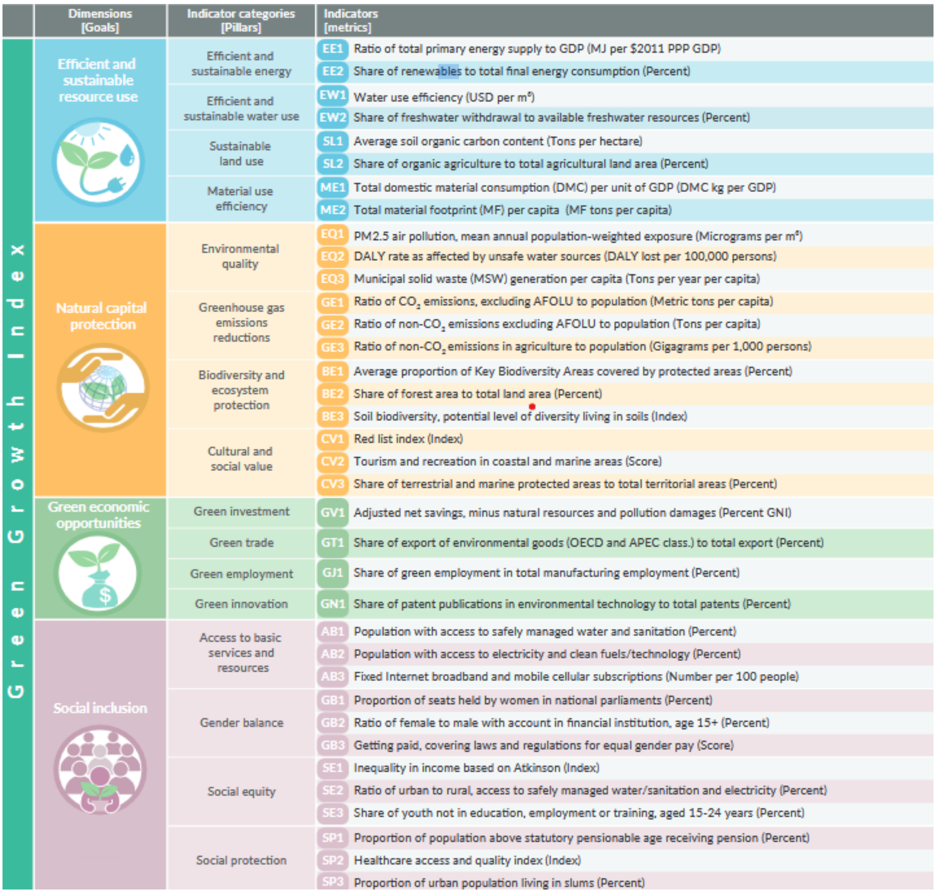
Green GDP and the Green growth index have emerged as important indicators for evaluating the alignment of economic progress with environmental sustainability. While Green GDP integrates environmental degradation and resource depletion into traditional GDP calculations, the Green growth index reflects a multidimensional approach, incorporating economic, social, and environmental sustainability criteria. While not without its shortcomings, Green GDP and Green growth index serve as a pivotal advancement in rethinking how we measure economic progress. By addressing the inherent limitations of traditional indicators, they integrate various important factors into economic analysis. This shift represents a crucial step toward promoting a more sustainable global economy, where long-term ecological health and societal well-being are valued alongside financial growth.

This study provides a comparative analysis of these two metrics, focusing on their temporal dynamics and alignment across European countries. Employing cyclical extraction and cross-correlation analysis, the results uncover significant differences in the dynamics of these two indicators, raising questions about their compatibility and reliability for cross-country analysis of green economic progress. Findings reveal that both indicators, despite their conceptual and methodological differences on one side and similarity in reflecting consistent global patterns of green economy on the other, in fact have different focus, methodology and application possibilities behind them. Nonetheless, our deductions imply their complementary roles in advancing green economic perspectives. Their collective insights contribute not only to economic and environmental discourse, but also to social, political, philosophical, and methodological debates, particularly concerning the integration of sustainability metrics into decision-making frameworks. By highlighting the interplay and versatility of these measures across diverse national contexts, this research emphasizes their utility in monitoring and steering sustainable development goals.

The structure of the paper is as follows. After a brief introduction, Section 2 surveys the main characteristics of two indicators. Section 3 provides a comprehensive perspective on the analytical part by describing the methods and data used, as well as presenting the results, whereas Section 4 explains the research implications. Section 5 offers some concluding remarks.

2 Comparison of Green GDP and GGI indicators

The **Green growth index** or **GGI** provides a robust framework for evaluating a country's progress toward achieving key sustainability objectives, including the Sustainable Development Goals (SDGs), the Paris Climate Agreement, and the Aichi Biodiversity Targets (Global Green Growth Institute, 2024).



Dimensions [Goals]	Indicator categories [Pillars]	Indicators [metrics]
Efficient and sustainable resource use	Efficient and sustainable energy	EE1 Ratio of total primary energy supply to GDP (MJ per $2011 PPP GDP)
		EE2 Share of renewables to total final energy consumption (Percent)
	Efficient and sustainable water use	EW1 Water use efficiency (USD per m³)
		EW2 Share of freshwater withdrawal to available freshwater resources (Percent)
	Sustainable land use	SL1 Average soil organic carbon content (Tons per hectare)
		SL2 Share of organic agriculture to total agricultural land area (Percent)
	Material use efficiency	ME1 Total domestic material consumption (DMC) per unit of GDP (DMC kg per GDP)
		ME2 Total material footprint (MF) per capita (MF tons per capita)
Natural capital protection	Environmental quality	EQ1 PM2.5 air pollution, mean annual population-weighted exposure (Micrograms per m³)
		EQ2 DALY rate as affected by unsafe water sources (DALY lost per 100,000 persons)
		EQ3 Municipal solid waste (MSW) generation per capita (Tons per year per capita)
	Greenhouse gas emissions reductions	GE1 Ratio of CO_2 emissions, excluding AFOLU to population (Metric tons per capita)
		GE2 Ratio of non-CO_2 emissions excluding AFOLU to population (Tons per capita)
		GE3 Ratio of non-CO_2 emissions in agriculture to population (Gigagrams per 1,000 persons)
	Biodiversity and ecosystem protection	BE1 Average proportion of Key Biodiversity Areas covered by protected areas (Percent)
		BE2 Share of forest area to total land area (Percent)
		BE3 Soil biodiversity, potential level of diversity living in soils (Index)
	Cultural and social value	CV1 Red list index (Index)
		CV2 Tourism and recreation in coastal and marine areas (Score)
		CV3 Share of terrestrial and marine protected areas to total territorial areas (Percent)
Green economic opportunities	Green investment	GV1 Adjusted net savings, minus natural resources and pollution damages (Percent GNI)
	Green trade	GT1 Share of export of environmental goods (OECD and APEC class.) to total export (Percent)
	Green employment	GJ1 Share of green employment in total manufacturing employment (Percent)
	Green innovation	GN1 Share of patent publications in environmental technology to total patents (Percent)
Social inclusion	Access to basic services and resources	AB1 Population with access to safely managed water and sanitation (Percent)
		AB2 Population with access to electricity and clean fuels/technology (Percent)
		AB3 Fixed Internet broadband and mobile cellular subscriptions (Number per 100 people)
	Gender balance	GB1 Proportion of seats held by women in national parliaments (Percent)
		GB2 Ratio of female to male with account in financial institution, age 15+ (Percent)
		GB3 Getting paid, covering laws and regulations for equal gender pay (Score)
	Social equity	SE1 Inequality in income based on Atkinson (Index)
		SE2 Ratio of urban to rural, access to safely managed water/sanitation and electricity (Percent)
		SE3 Share of youth not in education, employment or training, aged 15-24 years (Percent)
	Social protection	SP1 Proportion of population above statutory pensionable age receiving pension (Percent)
		SP2 Healthcare access and quality index (Index)
		SP3 Proportion of urban population living in slums (Percent)

Figure 1: Green growth index dimensions, pillars and metrics
Source: Global Green Growth Index, 2024.

It assesses performance across four critical dimensions of green growth: efficient and sustainable resource use, protection of natural capital, promotion of green economic opportunities, and fostering social inclusion (Figure 1). The index is quantified on a scale from 1 to 100, where scores are categorized into five performance levels: very low (1–20), low (21–40), moderate (41–60), high (61–80), and very high (81–100). A score of 100 represents the full attainment of sustainability targets, as the indicators used in the index are benchmarked against these targets.As a composite index, GGI synthesizes diverse indicators spanning economic, environmental, and social dimensions. It integrates both quantitative metrics and qualitative analyses to deliver a broad, comprehensive and 'global' assessment of a country's green growth trajectory. By providing insights into progress and gaps, the index supports the evaluation and refinement of sustainable development policies. Furthermore, it facilitates cross-country comparisons, enabling policymakers to identify best practices, leverage synergies, and address areas requiring additional focus to accelerate green growth (Tomić, 2024).

Further, **Green GDP** or **GGDP** is a refined measure of economic performance that adjusts traditional GDP by incorporating the costs of environmental degradation and the depletion of natural resources. This metric provides a more comprehensive and realistic depiction of economic growth by internalizing ecological costs often overlooked in conventional GDP calculations (Alfsen et al., 2006). The methodological framework for GGDP involves systematically subtracting estimated costs associated with CO_2 emissions, soil erosion, biodiversity loss, and resource depletion from traditional GDP. This approach relies on robust statistical data that integrates both economic and environmental parameters, thereby enhancing its relevance in the context of sustainable development. Research highlights that GGDP serves as a critical indicator of economic sustainability, offering insights into the extent to which environmental costs are embedded within economic activities (Veklych and Shlapak, 2013). By reflecting the ecological consequences of growth, this metric empowers policymakers to formulate strategies that mitigate environmental harm, promote sustainable resource management, and ensure the preservation of natural capital for future generations. Consequently, GGDP aligns economic development with the principles of sustainability, fostering long-term ecological and economic resilience Vimochana (2017).

An indicator that we used within this study is presented by Stjepanović, Tomić, and Škare (2017) in which GGDP = GDP – (CO_2 emissions in kt *x* total CDM in average prices for kt) – (t of waste *x* 74 kWh of electrical energy *x* price for 1 kWh of electrical energy) – (GNI/100 *x* natural resources depletion % of GNI). Basically, this specific indicator is an environmentally adjusted version of conventional GDP, expressed in current U.S. dollars, designed to account for environmental factors. Carbon dioxide (CO_2) emissions, measured in kilotons (*Kt*), encompass all emissions resulting from the combustion of fossil fuels and other energy sources. The term *CDM* refers to the average weighted carbon price expressed in purchasing power parity (*PPP*). Total commercial and industrial waste, measured in tonnes, is denoted as "*Waste*," and kilowatts (*kW*) per ton of waste represent the energy potential recoverable from waste. Research indicates that one ton of waste can generate approximately 74 kilowatt-hours of electricity, illustrating the energy recovery potential of waste management. The price of electricity (*Pelect*), expressed in PPP per kilowatt-hour, is calculated as the average commercial and industrial electricity price within a given country. Gross national income (*GNI*) is defined as the total value added by domestic producers, including taxes on goods (excluding subsidies not included in production valuation), combined with net receipts from primary income (such as employee compensation and property income) from abroad. Natural resource depletion adjusted savings (*NRD*) measures the depletion of natural resources by summing the net depletion of minerals, energy resources, and forests as a percentage of GNI. This indicator provides a comprehensive view of resource sustainability within a nation's economy (Stjepanović, Tomić, and Škare, 2022).

Table 1: Key differences between Green Growth Index and Green GDP

Characteristic	Green Growth Index	Green GDP
Focus	Green growth and sustainable development	Economic growth adjusted for ecological costs
Methodology	Composite index with multiple indicators	Adjusted GDP reduced by ecological costs
Application	Comparative analysis and evaluation of green policies	Analysis of economic growth with ecological adjustments

Source: Tomić (2024).

A comparative analysis of these indicators in 2017 and 2019, as well as longitudinal trends, reveals a substantial similarity in their assessments across countries, reflecting consistent global patterns. Developed nations, particularly those in Europe and North America, exhibit consistently higher performance on both the GGI and GGDP. These countries benefit from greater financial and institutional capacity to invest in clean technologies, enforce rigorous environmental regulations, and promote sustainable practices. In contrast, developing and underdeveloped countries display lower scores on these indicators due to their reliance on natural resource exploitation as a primary driver of economic growth. This reliance often results from limited access to alternative technologies and resources necessary for fostering sustainable development. The disparity highlights a persistent global inequality: affluent nations generally achieve higher levels of environmental sustainability, while less affluent countries grapple with the dual challenges of economic development and ecological preservation (Tomić, 2024). Despite the differences in the focus, methodology and application of GGDP and GGI (Table 1), the global view on environmental focus and sustainability issues seems to be consistent over these two indicators. The difference in the basic methodology on one side and the analogy in portraying the global green situation, gives us reasonable doubt to question the (di)similarity in the dynamics of these two green indicators.

3 Methodology

3.1 Research design and methods

By employing cyclical extraction and cross-correlation analysis, we would like to uncover resemblance or dissimilarity in the behaviour of these two important green economy indicators. In addition, we will obtain bivariate (pairwise) Granger causalities to eliminate any possible doubts on the subject.

Due to its vast utilization we opted to use the Hodrick-Prescott (HP) filter for the extraction of cyclical components of the variables. Many researchers frequently use the HP filter due to its simplicity and ease of interpretation. It provides a straightforward way to decompose a time series into trend and cyclical components, making it accessible for various applications, particularly in macroeconomics. However, it is not the only filter available; alternatives like the Baxter-King filter, Christiano-Fitzgerald filter, or band-pass filters can also be used, each with distinct strengths and weaknesses. The choice of filter often depends on the specific characteristics of the data and the research objectives (Tomić and Demanuele, 2017). The prevalence of the HP filter in detrending time series is undoubtedly due to its simplicity in estimation and comprehension. Hodrick and Prescott's (1997) analysis assumed that time series are consisted of cyclical and growth components, so if growth accounting can provide estimates of growth components with errors that are small relative to the cyclical component, computing the cyclical component is just a matter of calculating the difference between the observed value and the growth component. It resulted in the creation of the filter that became the most popular method for removing long-run movements from the time series within the business cycle analyses. The HP filter focuses on removing a smooth trend τ_t from some given data y_t by solving next equation:

$$\min_t \sum_{t=1} ((y_t - \tau_t)^2 + \lambda((\tau_{t+1} - \tau_t) - (\tau_t - \tau_{t-1}))^2) \quad (1)$$

therefore, the residual $y_t - \tau_t$ is then commonly referred to as the business cycle component. This is actually a linear filter that requires previous specification of a parameter known as lambda (λ). Given the form of the observation this parameter tunes the smoothness of the trend i.e. penalizes the acceleration in the trend component relative to the cycle component. Furthermore, the HP filter's parameter lambda allows users to adjust the sensitivity of the filter to fluctuations, enabling customization for different data frequencies (e.g., quarterly, annual). However, while the HP filter is effective, users must be cautious of potential boundary issues and the choice of lambda , as these can influence the results. Regardless of its simplicity and its methodological constraints, the HP filter has been applied in a number of relevant studies so far.

In order to evaluate the nature of the relationship between the variables, we introduced cross-correlation analysis based on the studies from Stock and Watson (1998) and Napoletano, Roventini and Sapio (2005), who imply that co-movements between variables are revealed through the cross-correlation of the cyclical component of each series with the cyclical component of a benchmark variable. This is the correlation between x_t and y_{t+k}, where x_t is the filtered series and y_{t+k} is the k-quarter lead of the filtered benchmark variable. A large positive correlation at $k = 0$ (i.e. around lag zero) indicates the pro-cyclical behaviour of the series; a large negative correlation at $k = 0$ indicates counter-cyclical behaviour; and no correlation indicates acyclical behaviour of the series. A maximum correlation at, for example, $k = -1$ indicates that the cyclical component of the variable tends to lag the aggregate business cycle by one quarter. In other words, if the absolute maximum (or minimum) is achieved at some benchmark variable lead, then the variable is denoted as *leading*, whereas it is called *lagging* in the opposite case. Finally, *coincident* variables are those displaying the bulk of their cross-correlation with the benchmark variable at lag zero.

For correlation itself does not necessarily imply causation in any meaningful sense, we decided to rafine our study by introducing Granger causality (1969) which questions whether variable x causes variable y, as well as how much of the current y can be explained by past values of y and then to see if adding the lagged values of x can improve conclusions. Thus, y is said to be Granger-caused by x if x can help in predicting y or if coefficients on the lagged x are statistically significant. We have to emphasize that the statement 'Granger-cause' does not imply that one variable is the effect of the result of the other, because Granger causality measures precedence and information content, but does not indicate causality in the more common use. We use bivariate (pairwise) regression of this form to test Granger causality between the observed green variables based on the Granger approach:

$$y_t = a_0 + a_1 y_{t-1} + \dots + a_l y_{t-l} + b_1 x_{t-1} + \dots + b_l x_{-l} + e_t \quad (2)$$

$$x_t = a_0 + a_1 x_{t-1} + \dots + a_l x_{t-l} + b_1 y_{t-1} + \dots + b_l y_{-l} + u_t \quad (3)$$

The null hypothesis is that x does not Granger-cause y in the equation (2) and that y does not Granger-cause x in the equation (3). The F-statistics and supporting probabilities are used for evaluation of joint hypotheses (Benazić and Tomić, 2014).

3.2 Data

This study provides a comparative analysis of two green indicators, namely Green GDP (GGDP) and Green growth index (GGI), focusing on their temporal dynamics and alignment across countries.

Annual data on green variables were collected from the Global Green Growth Institute database for the GGI variable and methodology offered by Stjepanović, Tomić and Škare (2017, 2022: database) for the GGDP variable utilizing the period 2010 – 2022. Our study covers representative sample of 20 European (more precise EU) countries (Austria, Belgium, Bulgaria, Croatia, Cyprus, Czechia, Denmark, Estonia, France, Germany, Greece, Hungary, Ireland, Italy, Lithuania, Luxembourg, Netherlands, Poland, Portugal and Spain); as an initial research platform for more extended study on green metrics across different set of countries. In addition, several other, highly industrialized and green weighted countries are included in the partial analysis as a validation of the results. Green variables for all the countries have been put in their logarithm form in order to stabilize the variance and normalize skewed data. To extract the business cycle component that represents the stationary cycle of the variable, we used the conventional value of 100 for the smoothing parameter, which corresponds to yearly frequencies. To test the integration properties, we analyzed graphical displays of the variables and conducted Augmented Dickey Fuller unit root test (Table 2). Visual introspection and tests (both constant and constant plus trend cases) strongly confirmed the absence of a unit root in the observed variables i.e. countries in their levels, which is an important property of cyclical components. Thus, we obtained the variables; *cycle_GGDP* and *cycle_GGI*.

Table 2: Augmented Dickey-Fuller unit root test (ADF test) in levels

Countries	*Constant Prob.*	*constant + trend Prob.*
Austria	0.00	0.00
Belgium	0.00	0.00
Bulgaria	0.01	0.01
Croatia	0.00	0.00
Cyprus	0.00	0.00
Czechia	0.00	0.00
Denmark	0.02	0.00
Estonia	0.00	0.00
France	0.00	0.00
Germany	0.00	0.00
Greece	0.00	0.00
Hungary	0.00	0.00
Ireland	0.00	0.00
Italy	0.00	0.00
Lithuania	0.01	0.00
Luxembourg	0.00	0.00
Netherlands	0.01	0.01
Poland	0.01	0.02
Portugal	0.00	0.00
Spain	0.00	0.03

Source: Authors' calculation (in EViews 13).

3.3 The results of the study

Cyclical dynamics of the variables, presented through cross-correlation analysis, across all the countries is displayed in Table 3. When we observe cross-correlation coefficients among all European countries, we can notice a relatively weak temporal relationship between these two green indicators. We found for only 4 countries

(Bulgaria, Cyprus, Netherlands and Spain) medium correlation between the green indicators. The other interesting deduction is that most of the higher correlation coefficients (especially those ranging from -0.40 to -0.60.) indicating some kind of weak to medium correlation) are displaying negative sign, suggesting that *cycle_GGI* is countercyclical with mostly leading patterns to *cycle_GGDP* variable in most of the countries involved. Generally, we can reason that correlation coefficients are shown to be relatively low, meaning that this nexus could be economically insignificant.

Table 3: Cross-correlation *cycle_GGDP* and *cycle_GGI* with lags and leads up to 3 periods

Variables	*t-3*	*t-2*	*t-1*	*t-0*	*t+1*	*t+2*	*t+3*
Austria	-0.05	0.48	0.27	-0.36	-0.19	-0.34	-0.07
Belgium	0.01	0.06	-0.10	0.23	0.06	0.14	0.09
Bulgaria	0.52	0.05	0.05	-0.43	-0.60	-0.02	-0.12
Croatia	-0.18	-0.15	-0.22	0.16	0.22	0.32	0.02
Cyprus	0.33	0.33	0.50	0.44	-0.08	-0.46	-0.08
Czechia	-0.19	-0.00	0.34	0.46	-0.09	0.34	-0.17
Denmark	-0.29	0.18	0.31	-0.19	-0.30	-0.05	0.12
Estonia	0.12	0.42	0.22	-0.12	-0.24	-0.18	0.24
France	0.34	0.41	0.21	-0.21	-0.17	0.18	0.08
Germany	0.15	0.02	-0.02	0.04	-0.15	0.40	0.32
Greece	0.05	0.40	0.22	0.30	-0.42	-0.03	0.02
Hungary	-0.04	-0.06	0.03	0.02	-0.09	0.21	0.27
Ireland	-0.15	-0.19	-0.40	-0.23	-0.15	0.16	0.10
Italy	-0.02	-0.16	0.07	-0.10	-0.39	0.11	0.07
Lithuania	0.30	0.33	0.11	-0.27	-0.35	-0.01	0.02
Luxembourg	-0.24	-0.47	-0.24	0.39	-0.07	-0.14	0.06
Netherlands	0.19	-0.36	-0.56	-0.37	-0.01	0.35	0.23
Poland	0.30	0.52	0.33	-0.16	-0.59	-0.23	-0.20
Portugal	0.03	-0.05	-0.30	0.01	-0.08	-0.42	-0.29
Spain	-0.01	-0.03	-0.05	-0.46	-0.46	0.04	0.09

Source: Authors' calculation (in EViews 13).

To confirm of conclusions on the divergent cyclical behaviour of variables *cycle_GGDP* and *cycle_GGI*, we made additional estimations of cross-correlation coefficients with lags and leads for 6 highly industrialized countries (Australia, Brazil, China, India, Japan and USA) with large effect on green economy (through high CO_2 emissions, high energy and carbon intensity, large population, high GDP, intensive enviornmental depletion through resource extraction etc.). The results

(Table 4) are very similar to those of the European countries, however only in the question of the direction of the relationship. For all the countries, except China, we found medium and negative cross-correlations with a leading pattern of *cycle_GGI* variable, indicating again the divergent cyclical behaviour of these two green indicators. These results give us an incentive to carry out more extensive (longitudinal and cross-sectional) research in the future to confirm our hypothesis about the different cyclical behaviour of different green data.

Table 4: Cross-correlation *cycle_GGDP* and *cycle_GGI* with lags and leads up to 3 periods (other countries)

Variables	*t-3*	*t-2*	*t-1*	*t-0*	*t+1*	*t+2*	*t+3*
Australia	0.23	0.10	-0.28	-0.46	-0.56	0.12	0.46
Brazil	-0.16	0.23	0.62	0.50	-0.62	0.22	-0.16
China	-0.34	-0.37	-0.18	-0.21	0.07	0.35	0.28
India	0.30	-0.24	-0.66	-0.40	-0.03	0.21	0.50
Japan	0.26	0.15	-0.40	-0.66	-0.71	-0.02	0.42
USA	-0.03	0.13	-0.26	-0.61	-0.37	0.18	0.18

Source: Authors' calculation (in EViews 13).

While the Granger causality tests (Table 5) do provide additional evidence on the relationship and possible causality between the variables, we found that there exists no mutual causality between the variables *cycle_GGDP* and *cycle_GGI*, across all the observed countries with partial causality just for 4 countries (Bulgaria, Netherlands, Poland and Spain), which does not provide enough evidence on the general Granger causality between these two green indicators.

The majority of correlation coefficients are low to moderate in strength, indicating that the cyclical behaviour of the *cycle_GGI* does not have to be precisely tied to neither current nor to past (lagging) or future (leading) developments of the *cycle_GGDP*. Therefore, the usage of these green indicators does not need to represent the current state of green economy aspirations in the observed countries.

Table 5: Granger causality tests

Variables	*Null hypothesis:*	*F-Stat.*	*Prob.*
Austria	cycle_GGDP does not Granger cause cycle_GGI cycle_GGI does not Granger cause cycle_GGDP	0.80 0.08	0.40 0.79
Belgium	cycle_GGDP does not Granger cause cycle_GGI cycle_GGI does not Granger cause cycle_GGDP	0.12 0.00	0.73 0.97
Bulgaria	cycle_GGDP does not Granger cause cycle_GGI cycle_GGI does not Granger cause cycle_GGDP	0.07 4.63	0.80 0.06
Croatia	cycle_GGDP does not Granger cause cycle_GGI cycle_GGI does not Granger cause cycle_GGDP	0.65 0.81	0.44 0.39
Cyprus	cycle_GGDP does not Granger cause cycle_GGI cycle_GGI does not Granger cause cycle_GGDP	2.61 0.92	0.14 0.36
Czechia	cycle_GGDP does not Granger cause cycle_GGI cycle_GGI does not Granger cause cycle_GGDP	1.23 0.59	0.30 0.46
Denmark	cycle_GGDP does not Granger cause cycle_GGI cycle_GGI does not Granger cause cycle_GGDP	1.02 0.85	0.34 0.38
Estonia	cycle_GGDP does not Granger cause cycle_GGI cycle_GGI does not Granger cause cycle_GGDP	0.64 0.39	0.44 0.85
France	cycle_GGDP does not Granger cause cycle_GGI cycle_GGI does not Granger cause cycle_GGDP	0.48 0.36	0.51 0.56
Germany	cycle_GGDP does not Granger cause cycle_GGI cycle_GGI does not Granger cause cycle_GGDP	0.00 0.25	0.99 0.63
Greece	cycle_GGDP does not Granger cause cycle_GGI cycle_GGI does not Granger cause cycle_GGDP	0.25 1.65	0.63 0.23
Hungary	cycle_GGDP does not Granger cause cycle_GGI cycle_GGI does not Granger cause cycle_GGDP	0.01 0.11	0.92 0.75
Ireland	cycle_GGDP does not Granger cause cycle_GGI cycle_GGI does not Granger cause cycle_GGDP	1.70 0.32	0.22 0.58
Italy	cycle_GGDP does not Granger cause cycle_GGI cycle_GGI does not Granger cause cycle_GGDP	0.04 2.05	0.84 0.19
Lithuania	cycle_GGDP does not Granger cause cycle_GGI cycle_GGI does not Granger cause cycle_GGDP	0.14 0.93	0.72 0.36
Luxembourg	cycle_GGDP does not Granger cause cycle_GGI cycle_GGI does not Granger cause cycle_GGDP	0.22 0.82	0.65 0.39
Netherlands	cycle_GGDP does not Granger cause cycle_GGI cycle_GGI does not Granger cause cycle_GGDP	6.88 1.77	0.03 0.22
Poland	cycle_GGDP does not Granger cause cycle_GGI cycle_GGI does not Granger cause cycle_GGDP	1.09 5.00	0.32 0.05
Portugal	cycle_GGDP does not Granger cause cycle_GGI cycle_GGI does not Granger cause cycle_GGDP	1.47 0.01	0.26 0.94
Spain	cycle_GGDP does not Granger cause cycle_GGI cycle_GGI does not Granger cause cycle_GGDP	0.00 3.66	0.99 0.09

Source: Authors' calculation (in EViews 13).

More interestingly, most of the higher correlation coefficients were of negative sign, indicating that these two green indicators are *de facto* moving and/or fluctuating differently, which is another important deduction on the inconsistency in analogy between these two metrics and its usage for a cross-country comparison.

4 Research implications

The divergence between the GGI and Green GDP can be explained by several factors that influence their dynamics and cyclical fluctuations.

First, there is a difference in measurement components. As we already mentioned, the GGI measures a broader spectrum of sustainable development indicators, including renewable energy, energy efficiency, pollution levels, biodiversity, social inclusion, and policy frameworks that support sustainability; therefore, this index emphasizes qualitative aspects of development and is often independent of total economic output. On the other hand, GGDP is a modification of traditional GDP that subtracts the economic costs of environmental degradation and adds the benefits of conserving natural resources, hence its dynamics are more closely tied to economic activities and their environmental impact. Due to their differing focuses (qualitative vs. quantitative indicators), fluctuations in one metric may not proportionally reflect changes in the other (Tomić, 2024). *Second,* there is a differing time horizon of effects. While the GGI is often based on long-term policies and investments in sustainability, with effects that manifest gradually and are less sensitive to short-term economic shocks, the GGDP can respond more quickly to changes in economic activity, such as recessions or recoveries, since the costs of environmental degradation may rise or fall sharply with shifts in industrial activity. *Third,* there is the influence of external factors. Changes in the prices of oil, gas, or renewable energy resources can directly affect GGDP but have varying effects on the GGI, depending on the share of technologies and resources employed. Extreme weather events or natural disasters can reduce GGDP due to increased restoration costs, while their effects on the GGI may be subtler or negligible in the short term. *Fourth,* there is a question of what happens when we have transitioning economies. In economies transitioning toward greener practices, temporary discrepancies may arise as GGDP may increase if environmental degradation decreases (Rauch and Chi, 2010), while the GGI could stagnate due to slow adoption of innovations and sustainable development policies. Conversely, an increase in the GGI (for example through subsidies for renewable energy) may lead to temporary economic costs, reducing GGDP in the short term. And *fifth,* there is a divergence between short-term economic vs. long-term sustainability goals. Short-term economic stimulus measures (namely subsidies for high-emission industries) may boost GGDP, but reduce the GGI due to increased pollution. Conversely, stricter environmental policies may improve the GGI but temporarily slow GGDP due to the costs of adaptation.

Despite this disparity and nonconformity of these two important green variables, the usage and cross-country comparison of the GGDP and GGI as a vague (and maybe accurate) metrics of welfare with other green metrics and socio-economic indicators could be interesting from the theoretical (economic modelling) and practical (policy) perspective.

5 Beyond conclusion

The findings indicate that the correlation between the cyclical components of the GGDP and GGI for European (20 EU) countries is generally weak to moderate, suggesting limited alignment between these two indicators across different timeframes. This implies that the two metrics may capture distinct aspects of green economic performance, and their usage does not necessarily reflect the present state of green economy aspirations in the analyzed countries. Notably, the predominance of negative correlations highlights that fluctuations between GGDP and GGI often move in opposite directions, reinforcing the notion that these indicators may represent fundamentally different dynamics. This inconsistency raises questions about their comparability and reliability for cross-country analyses of green economic progress. Consequently, policymakers and researchers should exercise caution when interpreting these metrics together and consider their unique methodological and conceptual frameworks.

The lack of correlation between the dynamics of the GGI and GGDP arises from differences in their foundations, methodologies, and temporal sensitivities. While GGDP primarily reflects current economic activities and their direct environmental impacts, the GGI emphasizes structural and qualitative aspects of sustainable development, which are not necessarily tied to cyclical changes in the economy.

There are few shortcomings of this paper that a reader may detect. First is the relatively short time series and second is the generalizability of some conclusions. Both can impose scantiness in economic reasoning, however we find this argument as an incentive for further research that might include more complex methods of analysis and international comparison, especially for the whole EU community and on a larger global cross-country scale. Not being evasive towards limitations, we believe that our conclusions could bear important implications for a reasoning in interpretation of green economy indicators, for economic modelling, as well as for economic policy and environmental programme developments. Furthermore, the perspective that economic development and growth will ultimately result in environmental sustainability, coupled with the observation that developed countries consume more resources per capita than developing countries and that ecological and economic impacts often occur beyond their borders, underscores the potential of GGDP and GGI as a metric for sustainable progress. It can also serve as a tool for assessing the effectiveness of implementation strategies aimed at promoting pro-environmental initiatives (Stjepanović, Tomić, and Škare, 2019).

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