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A new database on Green GDP; 1970–2019: a framework for assessing the green economy

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Abstract

Research background: Numerous modern indicators are attempting to integrate better economic, political, social, and environmental ambitions to uncover potential synergy, trade-offs, and future views that center around the notion of a so-called green economy. As long as the various indicators are not bounded in one comprehensive measurement, utilizing knowledge of relevant information and statistics that are crucial for monitoring the progress will not give us answers on the progress towards green growth either. Without an adequate measurement framework and robust statistics, the evaluation of the green economy is open to subjective reasoning.

Purpose of the article: This paper aims to offer a strong standpoint for green topics by exploring the concept of Green GDP. The paper introduces a new, updated database on Green GDP for the set of 160 countries from 1970–2019.
Methods: This database is distinctive due to its balanced coverage of two components of the green economy: quantitative feature (standard methodological algorithm) and qualitative feature (opportunity costs) within a common Green GDP accounting framework.
Findings & value added: Standardizing new methodologies and procedures for estimating environmental costs with a statistical foundation provides added value, which we hope will support the creation of reliable accounting and valuation systems for the green economy on a developing "green platform."

Introduction

There is generally a high degree of ambition as well as political support for a green economy and green growth policies, especially if it can lead to enhanced social welfare and it does not hamper economic progress. Alone, welfare is a controversial and multidimensional concept (Menegaki, 2021). But now, global economic growth patterns, sustainability issues, stances on the distribution of wealth, questions on the degradation of environmental capital, and the lack of international environmental negotiations are becoming fundamental substances on how policy actors and political community should understand green growth perspective. Over recent years, the concept of green growth, a term rarely heard before, has burst onto the international scene and now occupies an appreciable position in the policy dialogue of global economic and development institutions (Jacobs, 2013, pp. 197–214). After the sustainability outline, not so many concepts have as swiftly entered policy and academic discussions as the term ‘green.’ However, panels on green growth in the context of international experiences reduce concerns about the practical “greening” of national economies and priorities that are agreed upon at the international level (Nowak & Kasztelan, 2022, pp. 379–405). Why? Because any theoretical proclamation of green growth cannot answer the question of whether any green growth strategy or policy will achieve what is claimed for. It becomes an empirical matter also.

How to accurately determine the size of green growth is the current problem of many organizations that are also faced with promoting green growth itself. Today, there are many indicators that aspire to connect economic, political, social, and environmental aspirations to identify possible synergy, trade-offs, and future perspectives that revolve around the green economy and growth. It is well established that single-figure aggregate indicators designed for the international scale are not applicable. Still, as long as various indicators are not bounded in one comprehensive measurement, utilizing knowledge of relevant information and statistics that are crucial for monitoring the progress will not give us answers on the progress towards green growth either. Without an adequate measurement framework and robust statistics, the evaluation of the green economy is open to subjective reasoning. The review of 'green performance' requires reliable statistical data. The task of achieving relevant information critical for monitoring the progress and gauging the results is complicated due to the lack of recognized methodological principles. Instead of waiting indefinitely for statistical designs from important worldwide topics (top-down approach) and accounting contributions (bottom-up approach) that would become universally known and approved techniques, we attempted to harness their full economic potential. Whereas many provide a pessimistic note, suggesting that this challenge may be too great, Boyd (2006, pp. 716–723) argues that the calculation of the green indicator, precisely of green gross domestic product (Green GDP), can and should be attempted.

This paper aims to offer a strong standpoint for green topics by exploring the concept of Green GDP. This paper introduces a new, updated database on Green GDP for the set of 160 countries over the period 1970–2019 based on a novel approach provided by Stjepanović *et al.* (2017, pp. 4–17). In prior studies on green GDP, there is one important constraint or deficiency: all research relevant to the issue of this study was conducted separately over a number of years for a single observed nation or for many countries. There is no single research that had covered all or most of the world's countries over an extended period of time. For that reason, the objective of the study is to consolidate all available historical data for all countries over a lengthy time period. This research deficit is most evident in the literature review section, in which all relevant studies are mentioned. Thus, we find in Chakraborty and Mukhopadhyay's (2014) study for India with just two observed years. Similarly, Kunanuntakij *et al*. (2017) and Sonthi *et al.* (2017) compute Green GDP for Thailand. Other relevant studies on green GDP, mainly for China, are Yu *et al.* (2019), Wu and Han (2020), Liu (2021), Kalantaripor and Alamdario, (2012). The scarceness of relevant literature demonstrates the validity and need for our research. The uniqueness of this database arises from the balanced coverage of two dimensions of the green economy: quantitative feature (standard methodological algorithm) and qualitative feature (opportunity costs). Finally, by offering a more standardized valuation technique for calculating environmental expenses and pollution damage with related statistical coverage, we are trying to encourage a growing 'green platform' to focus on the development of accurate accounting and valuation systems of the green economy.

The remaining sections of the paper are structured as follows. Section 2 examines the conceptual and empirical foundations of the Green GDP notion to justify its computation. The third section provides an overview of the analytical portion by detailing the used technique and data, as well as providing detailed descriptive statistics of the database. Section 4 reviews the paper's findings critically, while Section 5 includes closing observations.

Literature review

Future assessments of economic growth must be accurate, necessitating the development of new, efficient, and more sophisticated indicators for global green growth policies, i.e., indicators that quantify the overall performance of green growth economies. Given the lack of effective indicators and indices to measure sustainable development based on green growth, more precise calculations and progress in the green economy have become of utmost importance. Green GDP measurement, therefore, can be considered a more specific subset of sustainability indicators crucial to inform development planning and sustainable economic progress.

The concept of "green GDP" refers to a large number of adjusted gross domestic product (GDP) indicators that include the costs of environmental pollution and exploitation as well as social costs, which is why green GDP is an alternative way to measure the monetary effect generated by a country's economic growth due to social and environmental damage. In particular, Green GDP, as an advanced measure within growth economics, may provide crucial data that can be used to examine the traditional assumptions regarding the linkages between GDP and sources of growth in classical economics, which are often included in economic growth models (Talberth & Bohara, 2006, pp. 743–758). Since the classic indicator of GDP does not contain a large number of economic quantities that are not evaluated on the market (such as different values of ecosystem services) and overexploitation of natural resources and environmental pollution, the calculation and use of green GDP as a more accurate indicator of natural well-being can be helpful in both theoretical (macroeconomic modelling) and practical (eco-labelling) purposes. Similarly, the general belief in economics that economic development and growth will automatically lead to environmental sustainability, combined with the fact that modern and developed countries consume significantly more resources per capita than developing economies, leads to the conclusion that green GDP has the potential to serve as a metric for evaluating the quality of sustainable development policy (Stjepanović *et al*., 2019, pp. 574–590).

The Green GDP concept's shortcomings explain why it has such a limited "narrative" (expressing environmental damage in monetary terms; calculation problems; pinpointing the exact year in which the damage occurred; underestimation; and data availability).

This significant measurement problem is a great challenge for green GDP accounting. Yet, it should not be an offset but an encouragement for economists to integrate issues from environmental economics into the basic principles of macro-accounting economics (for similar retrospect, see Hoff *et al.*, 2021). As Boyd (2006) suggests, modern societies would have to see the connection and influence of market consumption and the consumption of public goods. Ecologists seek to monitor the future sustainability of nature regardless of whether the government is responsible for it or by comparing one's environmental position to that of other countries. Economists want society to examine different trade-offs, assess performance, and optimize social welfare. To achieve those aspirations, the community needs a good measure of GDP progress, hence a Green GDP indicator. This will enable countries to implement mainstreaming green growth approaches into national planning, select policy instruments that deliver growth in critical sectors and/or resources, and help institutional mechanism link the development factors and support continuous improvement. Without a meaningful methodology, countries would not be aware of whether they are progressing toward green growth. Relevant information and statistics provide the backbone for policies that promote green growth and are critical to monitoring, certification, and labeling schemes of that growth (OECD, 2012).

By creating a database on Green GDP, which, in fact, represents a process of 'greening' of the international system of indicators, we are setting out a supremely ambitious and transformational vision, as we have recognized that baseline data for several of the aspirations mentioned above remains unavailable, calling for increased support for green data collection and green indicator capacity building. This database will provide statistics on the size, activity, and dynamics of the green aspired indicator across a broad spectrum of countries and through time. This database will allow legislators, economists or environmental analysts, and scientists to evaluate socio-economic growth and describe the necessary framework of various factors affecting the environment within the economic abilities of a given country compared to other countries in the region or countries with a comparable GDP or output potential. It will allow credible environmental/ecological comparisons of economic systems for a given year and over time. Ultimately, implementing this measurement framework and related statistics will not increase the burden of statistical exploration for its users.

The notion of green GDP differs from those of other social and environmental accounting systems due to the many issues connected with the computation and assessment of these systems (Stjepanović *et al.*, 2017). Despite various distinct indicators of sustainable socioeconomic growth that evaluate the economic, social, and environmental components of development, there is no agreement on the ideal standard measurement that would permit mutual comparisons of countries and global progress. Certain alternative indicators of socioeconomic well-being that employ national accounts and GDP and then add or delete some key aspects might be seen as measures that partly solve the concerns related to the green economy notion that the Green GDP indicator started to address. The majority of them are designed to reduce the abuse of GDP as a proxy for happiness. These measures carry their limitations (lack of consensus, subjectivity, calculation of depreciation, etc.), yet they are not mutually exclusive and could be used simultaneously (see Rauch & Chi, 2010, pp. 102–116). The historical schematization of several alternative well-being indicators, hence green economy measures (as about GDP), could be seen in Table 1.

These indicators are helpful for policy analysis as it is possible to use them for different interpretation purposes and compare them on different scales; international, national, regional, or even local. Regardless, many calculations of these measures can give a very misleading impression of socioeconomic development and well-being, especially when comparing them at the level of the entire country. Although GDP is a conventional measure of economic progress and does not give a deeper dimension of economic well-being, it is the best starting point for any study since it is the most comprehensive metric.

Green GDP is a measure that shows economic growth, which includes a component of the environmental consequences of such growth. Therefore, it is erroneous to believe that economic development and growth by itself will lead to environmental sustainability, because increased economic growth without significant macro-environmental policy initiatives, the logical fact that advanced economies consume more resources per capita than developing countries, and thus a significant impact and pressure on nature and the environment, demonstrates that green GDP has the potential to serve as a measure for assessing environmental sustainability. The green GDP statistic is derived from the concept of green economy, which focuses on supporting economic growth while ensuring that natural assets continue to supply the resources and ecological services upon which socioeconomic prosperity depends. Many different international platforms built their own indexes to assess the green economy performance in order to help various international green stakeholders, such as policymakers, international organizations, civil societies as well as the private sector, in developing a common understanding of green growth and indicators that can operationalize its concept. Green growth strategy, therefore, provides an important pathway for combating social and environmental issues (Hussain *et al*., 2022).

For example, the Global green economy index (GGEI) is a measurement made by Dual citizen, an international consultancy that stakeholders in the global green economy on communication strategy and associated analysis. This index examines the performance of what are now 130 countries in terms of their green economy and how experts evaluate that success. (GGEI, 2018). It features both perception survey data (from expert practitioners) and performance index data for four key dimensions (leadership and climate change, efficiency sector, market, and investment, and environment), whereas the index weightings result from pooling and a series of interviews with practitioners working in the green economy field. The Global Institute for Green Development has created a composite index that may assist economic decision-makers in making judgments on environmental policy and economic growth. Green growth index (GGI) evaluates the achievements of 115 countries in 4 green growth aspects (efficient and sustainable resource use, natural capital protection, green economic opportunities, and social inclusion) using 36 indicators, all of which are highly relevant metrics for monitoring implementation of the Sustainable development goals, the Paris climate change agreement, and the Aichi biodiversity targets (GGGI, 2019). The OECD's strategy for measuring progress toward green development is centred on the production and consumption of the economy and is reflected in the Green growth indicators. Its calculation procedure identifies 26 indicators to track advancement in four major aspects (environmental and resource productivity of the economy, natural asset base, the environmental dimension of quality of life, economic opportunities, and policy responses) and to capture the key characteristics of green growth (OECD, 2017). Next, United Countries Green economy progress (GEP) measurement framework consists of the GEP index and accompanying indicators of sustainability. The GEP index measures a variety of changes in green economy indicators in accordance with the desired improvements, which have direct or indirect effects on human well-being. It analyses weighted progress for different countries with respect to targets within certain limits and relevant thresholds of several indicators so that the size of the index shows countries the path to greener and more sustainable growth (PAGE, 2017). United Countries Environment Programme also presented a framework with indicators at different stages of green economy policy (indicators for environmental issues and targets, indicators for policy interventions, indicators for policy impacts on wellbeing and equity) that could be customized by all governments to meet their respective needs when embarking on a green economy approach (UNEP, 2012). European Union's European Environment Agency provides an Environmental indicator report (Environmental Indicator Report, 2018) that is based on 29 indicators pointed toward 3 priority objectives (protect nature and strengthen ecological resilience, boost sustainable, resource-efficient and low carbon growth, effectively address environment-related threats to health and well-being). There are some other organizations and interesting indicators that a reader should also scrutinize, such as a global green finance index, Nasdaq OMX green economy index, or some measurements on national (examples of China and Indonesia) or sub-national level (see, for example, Korean Environment Institute).

Methodology and different methodological theories for the analysis of socioeconomic and ecological, i.e., green features are mostly conceptual in nature and used by different countries. However, they are not prescribed by law, do not form policy norms, and are not used (mostly) for international cooperation or negotiation. However, they are commonly used to describe society's perspective on shaping the responses to global environmental problems (Sánchez García & Díez Sanz, 2018, pp. 70–75). Following such logic, our methodology on Green GDP and, thus the results could represent the highest expression of new social benefit.

The number of articles addressing the methodological basis of the Green GDP indicator based on a broad cross-country investigation is rather low. Hence we will focus on studies conceptually linked to our own. Our approach is based on Stjepanović *et al.* (2017) concept, which added social features, i.e., human capital, and various characteristics of the environment, i.e., natural capital that exists according to the volume of production. The authors calculated Green GDP and extracted its average bias to GDP measure for a total of 44 countries for the year 2014, presenting this methodology for the first time. Again, Stjepanović *et al.* (2019) expanded their calculations to the period of 2008–2016 for the same 44 countries providing substantial methodological base for monitoring the Green GDP dynamics. In their research, the authors demonstrated the presence of variances between green GDP growth rates and the conventional GDP measure, even though growth rate dynamics differed little across countries. Qi *et al.* (2001) estimated the value of environmental damage for 103 countries for the period 1980–1997. They concluded that the growth of GDP and Green GDP was nearly identical in all countries, even though the growth rates varied, particularly when comparing developing countries to developed countries. Kalantaripor and Alamdario (2021) investigated the effect of fossil fuel usage on environmental degradation and climatic impact in China using green GDP and green production. The unique aspect of this study is that the authors examined the effect of fossil fuels and renewable energy sources on the global GDP and determined that, although both negatively impact green GDP, the impact of fossil fuels is four times bigger. Wu and Han (2020) investigated the feasibility of computing China's Green GDP by sector over the period 1991–2016, expanding on their prior discussion on green GDP in China. The purpose of this study was to demonstrate which production sectors have the biggest influence on pollution and climate change and have a direct negative effect on Green GDP. For 16 of the 27 investigated sectors, the authors determined that the negative effect has decreased throughout the observation period. In addition, they determined that the gap between the output value and the green output value for the examined sectors continued to decrease throughout that time period. Veklych and Shlapak (2013) attempted to compute green GDP and ecologically modified net domestic product for Ukraine for the period 2001–2010 and found that Ukraine's economic development is reliant on natural capital and has a significant number of environmental policy flaws. Vimochana (2017, pp. 244–251) reviewed different approaches to Green GDP calculations, concluding that many countries still lack general statistical solidity, let alone environmental statistics; thus, without a specific form of environmentally adjusted GDP, the persistence toward sustainable growth will remain an illusion.

Wang *et al.* (2020, pp. 43813–43828) offered measurements of China's Green GDP with respect to its changing trends within the industrial perspective for several years ranging from 2005 to 2017. By evaluating the current situation in China's green aspiration, the authors made a horizontal and vertical comparison of the results by putting forward relevant policy recommendations pointed toward the development of progressive ecological civilization in China. Škare *et al.* (2020, pp. 46–56) used the concept of Green GDP to contrast it with other important economic variables. The authors provided vital evidence to identify energy consumption as a relevant factor influencing the Green GDP development in the European Union. Islam and Asad (2021, pp. 51–57) analysed the patterns of GDP and Green GDP for projecting the sustainable growth of eight South Asian countries for 2001–2011, concluding that a gain in GDP would lead to an increase in Green GDP without causing environmental harm. Qi *et al.* (2021) analysed sustainability based on Green GDP accounting and cloud computing for one of China's provinces providing notable evidence that green accounting can also be evaluated as an assessment indicator for regional sustainable development. In his study, Liu (2021) presented a new level of Green GDP development as a metric applicable at the city level. He argues that the planning and forecasting of the green GDP model at the city level should be based on the analytic hierarchy approach (AHP). Namely, AHP models should be used in computing urban green GDP, which is the next step in the evolution of green GDP as a metric, which was previously exclusively employed at the macrostate level.

Methods and data

Stjepanović *et al.* (2017) proposed a unique way to measure Green GDP, balancing the quantitative (standard methodological algorithm) and qualitative components of the green economy (opportunity costs). Based on the Green GDP and its structure, we have created a more accurate approach for monitoring and measuring the green GDP of various countries, which may be used in other studies. In addition, we generated the green GDP indicator by subtracting from the conventional GDP the expenses associated with environmental depletion and the usage of natural resources. In addition, because this methodology incorporates the observation of critical economic variables that are not adequately represented in traditional national accounts or even in the various green measures currently in place, our evaluation and computation are based on the distinction between the actual costs of environmental damage and the opportunity costs of lost traffic (Stjepanović *et al.*, 2019).

In the initial part of our study, we decided to develop a new technique for estimating and calculating Green GDP based on the following criteria. This decision was prompted by the many demands and deficiencies associated with traditional GDP. The use of natural resources, pollution per ton of waste, and the emission of CO2 into the atmosphere as one of the most influential elements on the global climate are variables that impact GDP and contribute to a green GDP concept i.e. measurement. We selected these factors based on the author's view that they are the most influential in terms of green sustainable development on a country's GDP. By measuring the values of the aforementioned factors and subtracting them from the traditional GDP, we were able to get an estimate of the green GDP, which is a far more accurate depiction of sustainable green development. In the second part of the study, we selected the time period during which we would monitor and compute the green GDP for a number of countries. The observed time period is constrained by the availability of the needed data, and we have chosen 1970 to 2019 based on an examination of the accessible databases. In the third step of the investigation, we depicted countries and available time frame for each county itself. The initial objective was to compute the green GDP for all countries in the globe, however owing it to a lack of data, we were restricted to analyse just 160 countries.

Data (see Tables 2. and 3.) for a sample of 160 countries were collected from Eurostat from the European Union (EU) database, The Organization for Economic Co-operation and Development (OECD) database, the United Countries (UN) database, the International Monetary Fund (IMF) database, and the World Bank's World Development Indicators database; (with some specific indices from other sources such as Capoor and Ambrosi (2007), the Australian Energy Regulator (2015), and the Waste to The research encompasses 160 countries, ranging from developing to developed, spanning the period 1970 to 2019. A general scheme of calculation (presented by Stjepanović *et al.*, 2017) is Green GDP = 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); or expressed simplified as:

$$Green\ GDP = GDP - (KtCO_2 * PCDM) - \\ -(Twaste * 74kWh * Pelect) - (\frac{GNI}{100} * \%NRD) \tag{1}$$

where Green GDP is a green approximation of conventional GDP measurements expressed in current U.S. dollars. Variable GDP in current U.S. dollars is the total of the gross added value of all resident producers in a single economy, to which are added all taxes on goods and removed any subsidies not included in the product's worth. It does not consider depreciation of manufactured assets or depletion of natural resources in its computation (World Development Indicators, 2020). In this model, the first subtraction is the cost of CO2 pollution (CO2 emissions multiplied by the market price of carbon), the second subtraction is the opportunity cost of one ton of waste which could be converted into electricity, and the final subtraction is the saving of natural resources as a percentage of gross national income for each country.

Emissions of carbon dioxide (CO2) expressed in kilotons (Kt) represent all combustion of fossil and other fuels, the result of which is CO2. They contain carbon dioxide generated by the combustion of solid, liquid, and gaseous fuels, as well as gas flaring (World Development Indicators, 2020). PCDM denotes the average weighted carbon price in PPP (Capoor & Ambrosi, 2007). Total commercial and industrial waste (Tonnes) is denoted by the term Waste, with statistics sourced in part from Eurostat and the World Bank database. In order to calculate the costs associated with the waste problem, we recalculated the value of waste through conversion into energy and estimated the value of the energy thus generated. Thus, kilowatts (kW) of electricity in one ton of waste represent the amount of electricity we can get from waste. Numerous studies have indicated that one ton of garbage contains 74 kilowatt-hours of energy, which reflects the amount of power that may be generated from waste (Australian Energy Regulator, 2015; and Waste to Energy in Denmark, 2006). The price (Pelect) in PPP per kilowatt-hour is determined as the average of the commercial and industrial pricing in each nation (Eurostat, 2020). Gross national income, or GNI, is the total of the value added of all domestic producers plus all taxes on goods (excluding subsidies not included in the valuation of production) plus net payments from primary income (employee salary and property income) from outside (in current US dollars) (World Development Indicators, 2020). Natural Resource Depletion Adjusted Savings (NRD) quantifies the depletion of different natural resources as the total of net mineral depletion, energy resource depletion, and forest depletion as a percentage of GNI per nation (World Development Indicators, 2020).

Results

So, here is what the database for a half-century of data on Green GDP suggests. Dynamics of Green GDP, compared to GDP over five decades from Figure 1., indicated balanced growth of both indicators with a relatively small and rather constant difference between them for high-income countries[1]. When observing middle-income countries, we found a strong surge of both indicators, especially after 2000, implying that with greater economic growth, the green aspect of that growth was not lagging behind. On the other side, low-income countries were experiencing a prosperous economic path only through the last decade, with both data and figures, revealing stronger divergence between the Green GDP and GDP over the course of time.

Figure 2. depicts the difference between Green GDP and GDP in terms of GDP movements for the same country's systematization. This graph displays the genuine evolution of the distinction between the two indicators

[1] The classification of high, middle, and low-income countries is based on WB systematization, which uses gross national income (GNI) per capita (in current U.S. dollars) as a benchmark (calculated using the Atlas method). As of the 2021 fiscal year, high-income countries had a GNI per capita of $12.536 or more. Low-income countries are those with GNI per capita was less than $1.026. For example, the UN recognition of the least developed countries is roughly similar to the WB recognition of low-income countries. This analysis recognized 47 high-income countries, 90 middle-income countries, and 23 low-income countries according to WB systematization.

compared to the preceding one. Namely, we found a constant decrease in the difference between the Green GDP and GDP for high and middle-income countries over the five decades, which in fact implies that with greater economic prosperity i.e. GDP growth, the relative gap between the two variables is actually decreasing, indicating that the Environmental Kuznets curve may hold true as environmental quality of life may be increasing as the society leans toward higher income levels. In contrast, data for low-income countries revealed a relatively high (in terms of their growth prospects) and constant (after an initial decline in the 1980s) difference between Green GDP and GDP over time, indicating that with greater economic growth (in terms of GDP dynamics), the difference is not decreasing, but increasing. This could be an argument explaining that most low-income countries sacrificed environmental quality to achieve greater economic growth.

Further systematization will help us comment on some of the previous results. Table 4. introduces average differences in growth between the Green GDP and GDP in regard to GDP dynamics for various groupings of countries. Such systematization is arbitrary and made purely for the purpose of distinct international comparison.

An average difference between the Green GDP and GDP for all 160 countries of 7.23% indicates that over the course of 50 years, GDP growth was, on average, over 7% higher than the Green GDP growth, suggesting that the global economy was indeed implacable over the environmental issues and that ecological aspect of growth was largely ignored within a framework of international preoccupation with economic growth issues. Green perspective, as statistics put forward, still did not change global growth patterns and their far-reaching ramification of 'standard' perception of growth and green growth.

When observing countries by the stage of their development, we notice favorable results for the developed countries as they seem to prove that greater political power can influence the problems of environmental pollution and exploitation to become a topic at the national and international levels. We may infer that economic development is achievable even when the environmental effect is significantly reduced. For instance, the differences between Green GDP and GDP of 2.38 percent for high-income OECD countries, 2.36 percent for high-income WB countries, 2.13 percent for IMF-advanced economies, an impressive 1.60 percent for the first 25 countries by the HDI index, and especially those differences for the most developed countries of the world such as in Northern America, Northern, and Western Europe, and Australia and New Zealand, have shown that, from the green growth viewpoint, the most satisfying outcomes are directly tied to the most developed regions of the globe and, in turn, to the advanced phases of development. This is especially true if we observe just data on the differences in the EU[2], where Euro Area countries with 1.69% and the six countries that founded the EU with 1.16%, displayed impressive dynamics of green growth. The above results show opposite conclusions from the generally accepted opinion that economic progress will automatically lead to sustainable socio-economic progress. However, we can conclude that more advanced and developed countries invest much more and encourage sustainable economic behavior and lifestyle, even though they consume much more resources in total from the environment than other countries.

The classification of countries by their degree of development has revealed that the gap between the Green GDP and GDP growth is greater in countries with lower income levels. High-income countries displayed a 4.78% average difference, middle-income countries an average of 7.66%, and low-income countries a very high average of over 10%. An additional problem for low-income countries is that that difference is actually increasing over time. The conclusion reached by Stjepanović *et al.* (2019) in their study is that the level of environmental quality and economic growth and development vary between development stages, i.e., less developed countries lean toward faster growth rates at the price of sustainable economic development. It also means that all countries are not on the path to greener growth, regardless of whether their economies are growing in terms of real GDP.

The previous conclusion could be validated by observing bias of the Green GDP growth over the world's regions[3]. Africa is a blatant example of a continent that is seriously lagging behind global growth trends. An average bias of the Green GDP of 10.04% over the whole period confirms that. However, the situation across the African continent is not the same as we witnessed below-average differences in Southern, Northern, and Western Africa and above-average differences in backward parts such as the Eastern part and especially in Middle Africa with an astonishing 17.01% average difference between the Green GDP and GDP. The front-runner in America is Northern America, with a relatively low Green GDP growth bias, yet The Caribbean, Central, and South America are all within the continents' average. A larger part of Asia is displaying relatively high differences, yet below the continent's average, whereas the Middle East registered extremely high Green GDP bias, probably due to the reason that many of the economies in this part of the world rely on the extractive industries,

[2] Excluding Latvia and Malta.

[3] Averages are calculated on the basis of the whole sample, therefore there could be differences in aggregating partial averages of the specific regions.

which incline long-term environmental un-sustainability. In Europe, the picture is clearer; advanced Northern and Western Europe showed a very low Green GDP bias that is lower than the averages of developed economies in general, with Eastern and Southern Europe displaying a relatively high bias. Finally, Oceania has an average of 4.87% difference between the Green GDP and GDP, mainly due to countries that are not on the same level of development, like Australia and New Zeeland, which registered a satisfactory 2.30% Green GDP bias.

Figure 3. displays a global map of Green GDP as the percentage difference between GDP and Green GDP across observed countries starting the year 1970 and ending in the year 2019, indicating that the world is indeed becoming greener. In 1970, a large part of the Middle East, Southern Africa, parts of South America, and most of the Asian continent were registering shallow and low values of Green GDP. In contrast, in 2019, most of the world was portrayed with a light green colour indicating the favourable state of national economies with respect to green tendencies. Generally, the world is on a good 'common' green path.

Overall, this database offered some general conclusions. Countries have sacrificed environmental quality to achieve faster development rates and greater socioeconomic advantages. However, countries with higher income levels have better-developed awareness and environmental policy and will therefore care more about the environment and ecology, which they know represents the future. On the other hand, most middle and low-income countries are very far from adequate and efficient environmental policies, considering that the primary goal is economic development regardless of the consequences, i.e., reducing lagging behind developed countries. The analysis also suggested that geographical position is not a determining factor in achieving greener paths but that the stages of economic development strongly condition where would a country be located on a 'global green map'.

Discussion

Although the concepts of green economy and green growth are relatively new, the so-called sustainable and green measurements themselves are not, as we witness a number of indicators that are derived from various economic, social, legal, technological, ecological, and environmental statistics and then compiled on the national or international level. As an example of several approaches to compute green GDP, we can use paper by Sonthi *et al* (2019) study, in which the authors calculate the green GDP for Thailand using Herman E. Daly's method. In the paper by Brilhante and Klass, (2018), we also have the enhancement of the current green GDP metric, and Liu (2021), is provided at the level of smart cities, where the measure of green GDP is utilized at the city level, as opposed to the macro level, where it has been seen in the majority of publications on this issue. The success of all these indicators in achieving sustainable and 'greener' progress depends on the ability of the international community to agree on problems and targets and build the capacity to deploy instruments that will tackle those problems. The biggest problem lies in their capacity to produce a social reaction, because international institutions do not apply them, nor have they been implemented in the laws of individual countries. Evaluation of future growth possibilities requires building relevant, accurate, complete, consistent, reliable, and accessible measurements of Green GDP for global green growth policies. This is exactly why writers such as Nahman *et al.* (2016) recommend a departure from the traditional calculation of GDP and present a solution in the shape of a new approach for evaluating the influence on the direction of the economy toward green sustainable development. Likewise, Boyd (2007) analysed the potential and required characteristics that best characterize a green economy and give the finest cross-section of green GDP. Hence, our Green GDP measurement can be considered a more specific subset of sustainability indicators that are crucial to informing development planning and sustainable economic progress.

This study gives a unique and up-to-date database of green GDP metrics for a vast number of countries across a longer time span for which data is available. Many interested parties will be able to address this intriguing and pertinent issue of the green economy and the economics of development. Similarly, the overview of the database should allow governments, economic or environmental analysts, and academics to analyse and evaluate their own environmental policies for the sake of economic growth, as well as facilitate comparisons across countries. Produced using standard methodologies, i.e., statistical calculation approach, use of variables, and objective comparability with GDP measurement and deficiencies, this database gives information similar to other databases, as it includes a large number of countries and enables comparisons between them. The database provides a very comprehensive time series of green GDP, given the absence of such data series for any single year at the country level. Currently covering 160 countries (from developing to developed) on a yearly basis, the new database is offered in nominal values and may be readily converted to actual values. If we look at everything together, such a database can present a global picture of the world and its aspiration and success in moving towards sustainable and green economic progress. Such methods and measurement frameworks are not standard in the country's statistical calculations; therefore, governments might enhance their standard statistical position, enabling them to manage economic sustainability challenges in a variety of economic and social policies in a dependable, cost-effective, and resource-efficient manner. That database would be consistent and easily accessible to all participants in the analysis and decision-making process. The uniqueness of this database originates from the fact that one of the most important economic growth indicators has been improved by incorporating the components absent from the traditional GDP, making it possible to address the issue of green economies and public policies and management more effectively. This topic demonstrates the necessity for a newly redefined form of GDP estimate that incorporates green sustainable development. As a starting point, we focus on the viewpoint of the policymaker, i.e., the government of a single country, which, based on these facts on green GDP, may establish a far more effective environmental policy and affect both local and global environmental degradation and climate change. This indicator would provide the government with a clearer picture of actual economic development that is not detrimental to ecology and the environment. From the perspective of society and the local community, there is a need to calculate local or regional GDP, there is even a need to calculate live green GDP, so that the local government can react much more quickly and easily to certain segments of its local industry and environmental impact. Green GDP at the global, regional, and local levels would have a significant effect on the person/consumer, if seen from the viewpoint of the individual. The consumer could be aware of the direct effect and magnitude of individual production on the environment, which might affect his choices when purchasing particular goods that contribute more to the environmental impact. Green GDP might serve as a measure of a region's improved quality of life and health, therefore influencing the person choice where to live.

Conclusions

To foster green growth institutional mechanisms towards continuous improvement and possibly reaction, in this paper we have provided a wider audience with substantial data coverage, addressing growth and development challenges that all countries face. Our paper takes an opportunity to explore, both theoretical and empirical, variations in the Green GDP calculations through a novel open-source database that will, hopefully, objectify as a new norm for sustainability issues and 'green dialogue.'

Considering differences in natural resource endowments, economic development, sources of economic growth, and institutional capacity, it is evident that this database cannot entirely dispel all questions regarding the international comparability of growth perspectives. We also recognize the uncertainty in the absolute accuracy of the presented methodology due to various limitations in data management and identification of green growth. The lack of data is the most significant constraint that necessitated compromises in our work over the observed time period, up to the number of countries. A further constraint in the observation and calculation of green GDP is the occurrence of different exogenous shocks in particular countries, which should be addressed in future research. As one of the constraints or possibilities for future study, the issue of how much the environmental policies of a particular nation influence the green GDP emerges, and it would be intriguing to examine changes in environmental policies and their effect at a particular period, if it existed. In this paper, we have identified as the most significant variables the exploitation of natural resources, waste, and release of CO2 into the atmosphere. However, for a more accurate assessment and future research, it will be necessary to include additional variables that affect GDP from the perspective of green sustainable development. Yet, it is the first database that offers broad country coverage and wide-ranging time series. Future endeavours could be pointed to amending imperfections that stem from the boundedness of original data sources. However, by creating such a database on Green GDP, that in fact, represents a process of 'greening' of the international system of indicators, we are setting out a supremely ambitious and transformational vision as we have recognized that baseline data for many aspirations remains unavailable, calling for increased support for green data collection and green indicator capacity building. Ultimately, we hope this paper will raise further discussions on green economy-growth-GDP topics.

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Annex

The database is available on-line: https://data.mendeley.com/datasets/24vbg29y48/1#file-52579afe-2966-4a0c-84b1-af1e48286653.

Table 1. Alternative measures of socio-economic wellbeing

Alternative measures	Reference to GDP
Index of sustainable economic welfare	Corrects GDP
Genuine progress indicator	Adjusts/corrects GDP
Genuine saving indicator	Adjusts/corrects GDP
Environmentally adjusted net domestic product	Adjusts/corrects GDP
Green GDP	Adjusts/corrects GDP
Environmental sustainability index	Substitutes GDP
Environmental performance index	Substitutes GDP
Ecological footprint	Substitutes GDP
Human development index	Substitutes GDP
Happy planet index	Substitutes GDP
Global wellbeing index	Substitutes GDP
Sustainable society index	Substitutes GDP
Development balance index	Substitutes GDP
Living planet index	Substitutes GDP
Better life index	Substitutes GDP
Calvert-Henderson quality life indicator	Substitutes GDP
Millennium development goals and indicators	Substitutes/supplements GDP
Other measures (SNA, SEEA, NAMEA)	Supplements GDP

Note: SNA – Systems of national accounts, SEEA – System of environmental and economic accounts, NAMEA – National accounting matrix including environmental accounts

Table 2. List of 160 countries presented in the database

Afghanistan	Denmark	Lesotho	Sierra Leone
Albania	Djibouti	Liberia	Slovak Republic
Algeria	Dominican Republic	Libya	Slovenia
Angola	Ecuador	Lithuania	Solomon Islands
Argentina	Egypt, Arab Rep.	Luxembourg	South Africa
Armenia	El Salvador	Madagascar	Spain
Aruba	Equatorial Guinea	Malawi	Sri Lanka
Australia	Eritrea	Malaysia	Sudan
Austria	Estonia	Maldives	Suriname
Azerbaijan	Eswatini	Mali	Sweden
Bahrain	Ethiopia	Mauritania	Switzerland
Bangladesh	Fiji	Mexico	Syrian Arab Republic
Barbados	Finland	Moldova	Tanzania
Belarus	France	Mongolia	Thailand
Belgium	Gabon	Montenegro	Togo

Table 2. Continued

Belize	Gambia	Morocco	Tonga
Benin	Georgia	Mozambique	Trinidad & Tobago
Bhutan	Germany	Myanmar	Tunisia
Bolivia	Ghana	Namibia	Turkey
Bosnia & Hercegovina	Greece	Nepal	Uganda
Botswana	Guatemala	Netherlands	Ukraine
Brazil	Guinea	New Zealand	United Arab Emirates
Brunei Darussalam	Guinea-Bissau	Nicaragua	United Kingdom
Bulgaria	Guyana	Niger	United States
Burkina Faso	Haiti	Nigeria	Uruguay
Burundi	Honduras	North Macedonia	Uzbekistan
Cape Verde	Hungary	Norway	Venezuela, RB
Cambodia	India	Oman	Vietnam
Cameroon	Indonesia	Pakistan	Yemen, Rep.
Canada	Iran, Islamic Rep.	Panama	Zambia
Chad	Iraq	Papua New Guinea	Zimbabwe
Chile	Ireland	Paraguay	
China	Israel	Peru	
Colombia	Italy	Philippines	
Comoros	Jamaica	Poland	
Congo, Dem. Rep.	Japan	Portugal	
Congo, Rep.	Jordan	Qatar	
Costa Rica	Kazakhstan	Romania	
Cote d'Ivoire	Kenya	Russian Federation	
Croatia	Korea, Rep.	Rwanda	
Cuba	Kuwait	Saudi Arabia	
Cyprus	Kyrgyz Republic	Senegal	
Czech Republic	Lao PDR	Serbia	

Source: authors' list based on OECD Database (2020).

Table 3. Variables used in calculations with their definitions and sources

Variable	Description	Source
GDP	Obtained as the sum of gross value added by all resident producers in one economy plus any product taxes minus any subsidies not included in the value of the products. It has been calculated without making deductions for depreciation of fabricated assets or depletion and degradation of natural resources. (in PPP)	Word Development Indicators (2020), UN database (2020), OECD database (2020)
CO_2	Carbon dioxide emissions are those stemming from the burning of fossil fuels and the manufacture of cement. They include carbon dioxide produced during consumption of solid, liquid, and gas fuels and gas flaring (expressed as kilotons).	Word Development Indicators (2020), UN database (2020), OECD database (2020)

Table 3. Continued

Variable	Description	Source
CDM	The average volume-weighted price for carbon (in PPP)	Capoor and Ambrosi (2007)
Twaste	Total (commercial and industrial) waste (expressed in tonnes).	Word Development Indicators (2020) and Eurostat (2020), UN database (2020)
74 kWh	Kilowatts of energy in one tonne of waste present an amount of electrical energy that can be obtained from a waste.	Australian Energy Regulator (2015), Waste to energy in Denmark (2006)
Pelect	Price for 1 kilowatt-hour is calculated as a mean of commercial and industrial price for each country. (in PPP)	Eurostat (2020), National statistics
GNI	Gross national income is the sum of value added by all resident producers plus any product taxes (less subsidies) not included in the valuation of output plus net receipts of primary income (compensation of employees and property income) from abroad. (in PPP)	Word Development Indicators (2020), UN database (2020), OECD database (2020)
NRD	Adjusted savings of natural resource depletion as a percentage of the GNI per country, presents natural resource depletion as a sum of net forest depletion, energy depletion, and mineral depletion.	Word Development Indicators (2020), UN database (2020), OECD database (2020), National statistics

Table 4. Average bias of the Green GDP

Average difference in growth rates GDP vs. Green GDP	Difference in %
Average (all countries)	**7.23**
DEVELOPED COUNTRIES	
- High income OECD countries	2.38
- High income WB countries	2.36
- IMF advanced economies	2.13
- HDI Index 25 first countries	1.60
EU COUNTRIES	
- EU 27	2.52
- Euro Area	1.69
- EU 6 Founding countries	1.16
COUNTRIES BY DEVELOPMENT	
- WB High income countries	4.78
- WB Middle income countries	7.66
- WB Low income countries	10.54
COUNTRIES BY REGIONS	
- Africa	10.04
Northern Africa	8.32
Western Africa	8.18

Table 4. Continued

Average difference in growth rates GDP vs. Green GDP	Difference in %
Southern Africa	5.60
Eastern Africa	11.00
Middle Africa	17.01
- The Americas	5.71
Northern America	2.43
Central America	5.09
The Caribbean	5.39
South America	6.86
- Asia	8.51
Middle East	13.95
North, central and east Asia	6.10
- Europe	4.10
Northern Europe	2.08
Western Europe	1.07
Southern Europe	5.49
Eastern Europe	5.78
- Oceania	4.87
Australia and New Zeeland	2.30
The rest of Oceania	6.16

Figure 1. Green GDP vs. GDP for countries by income level.

a) High income countries

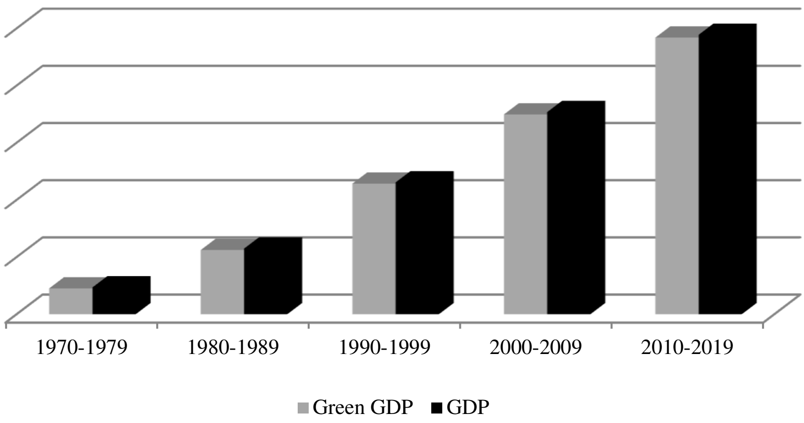
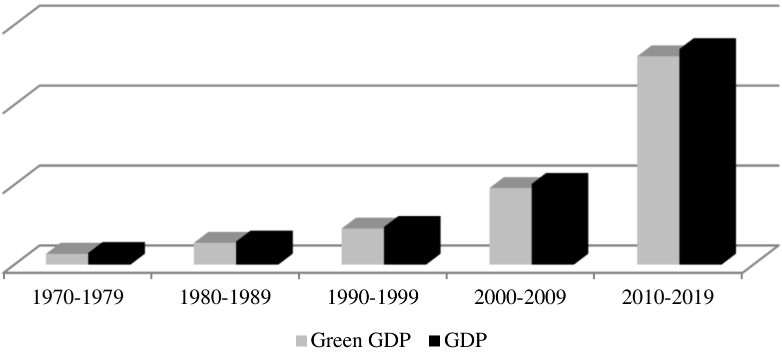


Figure 1. Continued

b) Middle income countries



c) Low income countries

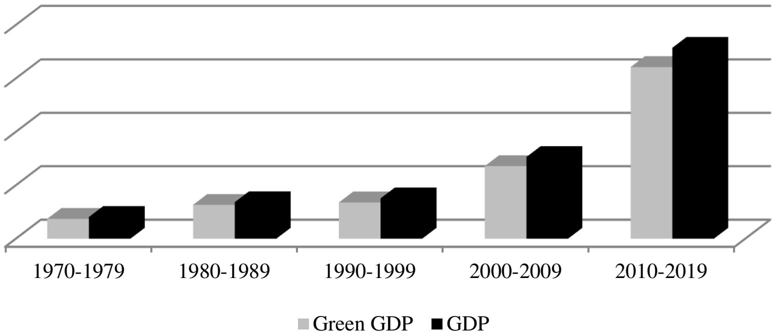


Figure 2. Difference between Green GDP and GDP for countries by income level

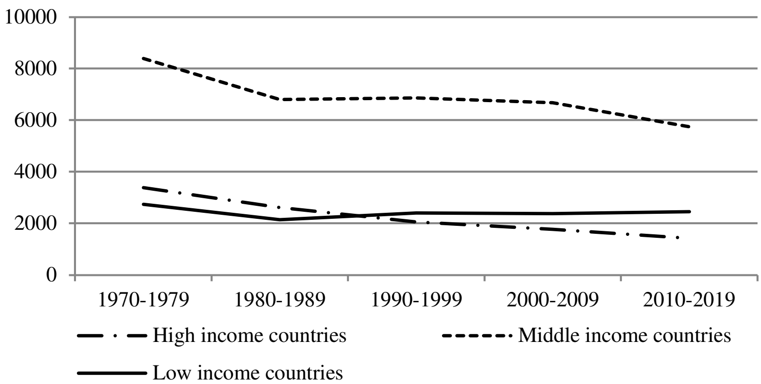


Figure 3. Global map of Green GDP in 1970 vs. 2019