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CONDITIONS OF THE GREEN TRANSFORMATION. THE CASE OF THE EUROPEAN UNION

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Abstract. The main purpose of the paper is to identify the factors that determine the course of green transformation and to assess the current stage and possible directions of change in subsequent years in EU countries. The literature lacks comprehensive studies that show the impact of diverse types of factors on the course of green transformation. For this purpose, two perspectives of the research – economic and environmental – are usually taken into account. This paper also proposes to take social factors into account. The empirical verification was conducted using green growth indicators that are published by the OECD that were compared with factors identified from the literature review. Taxonomic (synthetic) measure of development applying the Weber median and correlation coefficient were used for searching for relationships between the identified groups of indicators described both the changes in the dimension of green growth (internal factors of green transformation) and changes in the dimension of contextual indicators (so-called external factors). The proposed way of combining the results obtained from these two methods of data analysis is also new to research in this field. Its aim is an in-depth exploration of the issue, which enables a 2-step verification of the results obtained.

Keywords: green growth, green economy, green transformation, Weber median.

JEL Classification: C38, C43, Q43, Q48, Q57.

Introduction

Green transformation is now one of the most frequently discussed topics in both political debates and academic works. The increased interest in research in this dimension, concerning mostly the last 10 years (see: Duarte & Cruz-Machado, 2013; Brown & McGranahan, 2016; Cheba & Bąk, 2021) is a result of the current global metamorphoses of the environment

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associated with climate change and biodiversity loss, among other things. Growing public awareness and the certainty that an incremental change is not enough to combat climate change, have led to a growing interest in green transformation. That results, inter alia, in many different proposals for defining the term. Although there is still no complete consensus in the literature on how to describe green transformation, it is not and should not be the only line of research. It should be emphasised, however, that the scope of the adopted definition also determines several subsequent decisions related to, for example, the introduction of legal regulations or measures that enable greater social acceptance of implemented changes. Green transformation is described in the literature both as a gradual improvement of existing activities (Gibbs & O'Neill, 2015; Kemp & Never, 2017), as well as the implementation of significant changes that drastically alter the existing way of doing business (Gea-Bermúdez et al., 2021). Regardless of the definition adopted, the very course of green transformation is conditioned by many different factors. Some of them, such as society wealth level, economic activity, or technological advancement level, clearly determine the current stage of this process in individual economies. Some other have yet to be conceptualised and precisely defined.

This study aims to identify the factors that determine the course of green transformation and to assess the current stage of this transformation and possible directions of change in this respect in subsequent years.

The starting point for the considerations presented in this paper is a review of the literature on green transformation, the aim of which is to identify differences in terms of the conceptualisation of the term in different economies. Feola (2015) claims that currently "little consensus exists regarding the conceptual basis of transformation," which necessitates more empirical studies that can help to specify the term. The considerations presented in this paper and the attempts made to show differences in defining the term depending on, for example, the level of public acceptability of changes related to green transformation are a response to the growing needs in this respect.

This paper assumes that both different approaches to defining the term and different current stages of economies of the world's countries are the result of many various factors that are directly and indirectly related to the transformation process itself. These include, for example, society wealth level, technological advancement level of the economy, cultural differences or even geographic location. The identification of these factors and then the assessment of their impact on current processes of green transformation in individual EU countries is the next stage of the research conducted in this paper.

The following research questions were formulated in this paper to detail the scope of the considerations concerned:

1. How is the green transformation defined in the literature and which factors are indicated as important determinants of this process?
2. Which of these factors do have a significant impact on green transformation?
3. Can correlations be established between the factors identified and the current stage of the transformation process in the EU countries?

The approach proposed in this paper based on, on the one hand, the systematisation of knowledge in the field of defining the term green transformation and identification of determinants of this transformation, and, on the other hand, on the empirical verification of the results of this review, constitutes the added value of this paper. In fact, the literature lacks comprehensive studies that show the impact of diverse types of factors on the course of green transformation. For this purpose, two perspectives of the research – economic and environmental – are usually taken into account. This paper also proposes to take social factors into account. This type of approach is in line with recent proposals for defining green transformation that is referred to, for example, as sustainable transformation. Differences in terms of the course of this process resulting from the availability of specific natural resources in individual countries and from human activities, such as environmental or technological innovations, were also taken into consideration.

The empirical verification was conducted using green growth indicators that are published periodically by the OECD and they were juxtaposed with information regarding factors identified from the literature review, which determine the course of green transformation in individual economies.

Taxonomic (synthetic) measure of development applying the Weber median and correlation coefficients were used for searching for relationships between the changes in the dimension of green growth (internal factors of green transformation) as well as the changes in the dimension of contextual indicators (so called external factors). The proposed way of combining the results obtained from these two methods of data analysis is also new to research in this field. Its aim is an in-depth exploration of the issue, which enables a 2-step verification of the results obtained.

1. From green growth and green economy to green transformation – literature review

In the past, economic growth was considered to be a process that is strongly dependent on the availability and consumption of natural resources. The consequence of this sort of thinking that assumes unlimited access to deposits of resources, mainly energy resources, is the current crisis that is related to a shortage of raw materials and constantly rising energy prices. This crisis should result in a fundamental change in the approach to managing the economy with a view to its green transformation that until recently has only been treated as an alternative. To fully understand the importance of green transformation for the modern world, it is crucial, among other things, to define the framework for defining this term and indicate the factors that significantly affect the course of green transformation.

The basis for defining the term green transformation is an explanation of the concepts that are directly related to it, i.e. green economy and green growth.

Although attempts to describe these concepts have been made in the literature for many years, they have not been clearly defined to date. A review of publications indexed, for example, in the Web of Science (WoS) database reveals that there are currently (as of the end of December 2021) over 5,000 papers including references to the terms such as green economy or green growth, while the oldest paper presenting these terms in the context of economic growth dates back to 1983 (Shearer, 1983). A systematic increase in publications in this field has been observed since 2010. A total of 4,956 papers were published in 2010–2021, with the highest number, 691, in 2021.

At the global level, the term "green economy" was first used in a pioneering 1989 report "Blueprint for a Green Economy" (Barbier et al., 1990) prepared by a group of leading environmental economists for the government of the United Kingdom. However, apart from the title of this report, there are no further references to green economy. In the following years: 1991 and 1994, the authors published the second part of the first report entitled "Blueprint 2: Greening the world economy" and "Blueprint 3: Measuring Sustainable Development" (Pearce, 2014). Only these reports attempted to explain the problem more broadly in the context of the global economy. The definitions of green economy emerged later, especially after 2008, in many documents elaborated by the European Commission, international organisations (UN and OECD agencies) or national agencies and research teams. For example, UNEP defines green economy as "one that results in improved human well-being and social equity, while significantly reducing environmental risks and ecological scarcities. In its simplest expression, a green economy can be thought of as one which is low carbon, resource efficient and socially inclusive" (UNEP, 2011).

The term "green growth" first emerged in the context of intergovernmental discussions at the Fifth Ministerial Conference on Environment and Development (MCED) in Asia and the Pacific held in 2005 in Seoul, the Republic of Korea. The green growth, or environmentally sustainable economic growth, was defined as "a strategy of sustaining economic growth and job creation necessary to reduce poverty in the face of worsening resource constraints and climate crisis" (United Nations Environment Programme & International Resource Panel, 2011).

Currently, there are many different definitions of these concepts in the literature (see: Jacobs, 2012; Bowen & Hepburn, 2014). Merino-Saum et al. (2020) identified as many as 95 definitions of green economy and 45 definitions of green growth. They also note that these terms focus on "potential trade-offs and synergies between economic and environmental dimensions (without ignoring social issues)". In contrast, recent proposals to define both green economy and green growth have also increasingly emphasised the importance of social capital and social determinants. For example, inclusive green growth (IGG) "combines economic, social and environmental dimensions, which increases the complexity of measurement and monitoring. IGG is a multi-faceted concept covering multiple interlinked dimensions – economic, social and environmental. IGG requires a transformation of economies and a transition towards cleaner, low-carbon, resource efficient and resilient economic systems in the long-run" (Narloch & Bangalore, 2016).

The desire to emphasise social aspects in created definitions is also linked to recent proposals to explain the term "green transformation". The literature pays a lot of attention to the issue of green transformation. Green transformation is now one of the most frequently discussed topics in both political debates and academic works. The WoS database identifies more than 65,000 publications that refer to the green growth context or terms such as transition or transformation in green economy. The increased interest in research in this dimension, primarily concerning the last 10 years (see: Guo et al., 2017; Hallegate & Rozenberg, 2017; Amudsen & Hermansen, 2021) is a result of the current unfavourable global metamorphoses of the environment associated with, for example, climate change and biodiversity loss.

The literature defines green transformation in many different ways. Some authors (see Borel-Saladin & Turok, 2013; Georgeson et al., 2017) claim that this term should be associated primarily with environmental change, for example, as “the process of structural change which brings the economy within the planetary boundaries” or as “a system (of decisions, policies, and directions of development) that emphasises the use of renewable energy sources and economical management of green dimensions for a sustainable future”. In contrast to definitions that focus on the need to comply with environmental restrictions, other authors (see: Hermwille et al., 2015; Barbier, 2020) closely link “regreening” to multiple dimensions of sustainability – environmental, economic, social and institutional-political. By prefixing the term “transformation” with the word “green”, our intention is to focus on environmental dimensions of the changes; however, these almost inevitably give rise to questions concerning social issues and environmental justice (see: Schmitz, 2015; Crespi et al., 2016; Keeys & Huemann, 2017; Cui & Lui, 2021).

With the development of research in the field of green economy and green growth and, as a consequence, green transformation, there are also changes in defining these terms. There is an increasing number of determinants that are taken into account. Definitions that refer to economic aspects complemented by environmental factors also include social factors. Currently, the literature (Scoones et al., 2015) is increasingly drawing attention to the fact that green transformation has no chance of success without social acceptability of this process.

Table 1 shows an overview of various definitions that directly or indirectly identify references to terms that are related to green transformation of the economy, including starting terms that include green economy and green growth.

2. Green transition factors

The current state of knowledge on the existing progress in the implementation of assumptions of green transformation clearly indicates that this process is affected by a wide variety of factors. Some of these factors, such as society wealth level, economic activity or technological advancement level, certainly determine the current stage of this process in individual economies. Other factors, on the other hand, have yet to be conceptualised and precisely defined. The structure of green transformations varies depending on the environment in which they are carried out (Perez-Valls et al., 2016). Pitkänen et al. (2016) point that “the practical implementation of green economy is related to a multiplicity of factors and causalities depending on the context, and transition to green economies requires negotiation between potential trade-offs among multiple goals, and interests of various stakeholders”.

Speck and Zoboli (2017) state that “major economic transformations in the EU economies, are not leading to a green economy transition”. The main factors that promote green transformation include eco-innovation, the open circulation of green knowledge, availability of financial resources for investing in the long-term transition and fiscal reforms, in particular economic instruments, such as carbon pricing schemes.

On the other hand, Wang et al. (2018) examine the relationships between technological innovation capability, which is divided into two dimensions such as research and development capability and result transform capability, and green economic growth in China.

In contrast, Chen and Lin’s article (2021) aims to explore the relationship between the development of infrastructure investment and the pace of green transformation in manufac-

Table 1. Green transition and green transformation – a various proposal of definition

Year	Author(s)/Institution	Definition
2011	OECD (The Organisation for Economic Co-operation and Development)	Green growth is defined as being "about fostering economic growth and development while ensuring that natural assets continue to provide the resources and environmental services on which our well-being re-lies. It is also about fostering investment and innovation, which will underpin sustained growth and give rise to new economic opportunities".
2011	UNEP (The United Nations Environmental Program)	UNEP propose s definition of green economy that it is presented as one of that results in "improved human well-being and social equity, while significantly reducing environmental risks and ecological scarcities". A green economy is low carbon, resource-efficient, and socially inclusive". According to UNEP: "In a green economy, growth in income and employment should be driven by public and private investments that reduce carbon emissions and pollution, enhance energy and resource efficiency, and prevent the loss of biodiversity and ecosystem services".
2012	World Bank	"Green growth is growth that is efficient in its use of natural resources, clean in that it minimizes pollution and environmental impacts, and resilient in that it accounts for natural hazards".
2012	ESCAP (Economic and Social Commission for Asia and the Pacific)	"Green growth, or environmentally sustainable economic growth is a strategy of sustaining economic growth and job creation necessary to reduce poverty in the face of worsening resource constraints and climate crisis".
2014	Olsson, Galaz, & Boonstra	Sustainability transformations is shifts that fundamentally alter human and environmental interactions and feedbacks.
2015	International Labour Organization	In term "transition" means "just transition to environmentally sustainable economies and societies".
2016	EC (European Commission)	"The aim (of green growth) is to create more value while using fewer resources, and substituting them with more environmentally favorable choices wherever possible".
2018	UNRISD (United Nations Research Institute for Social Development)	A Just Transition means greening the economy in a way that is as fair and inclusive as possible to everyone concerned, creating decent work opportunities and leaving no one behind.
2020	Melnyk, Reznikova, & Ivashchenko	"Green economics is the economics leading to the increased welfare of people and the assured social justice along with the reduced environmental risks due to the sustainable economic growth, which includes elaboration of political decisions on the implementation of energy-saving technologies and "clean production" methods.
2021	Nordic Council of Ministers	Green transition is "the gradual and full transition to a fossil-fuel-free, low-carbon society". Digital green transition, defined as "a comprehensive societal transformation in which all sectors adopt relevant technologies that contribute to a low-carbon society".

turing industry. According to their research, completed infrastructure investments help to create an environmentally friendly development model; however, new infrastructure investments can also have a negative impact on the environment.

A 2017 study conducted by Zhai and An (2020) in 500 Chinese enterprises found that "human capital, financing ability, technology innovation, and government behavior all exerted significant positive impact on green transformation performance in the manufacturing industry". On the other hand, environmental regulations are, according to the authors of this study, a factor that positively affects the scope of technological innovation but at the same time limits the speed of the entire process of green transformation.

Comparable results were obtained by Hou et al. (2018), who point out that if environmental regulations exceed a critical level, their role in the CO2 transformation and CO2 reduction is weakened, resulting in the inability to decarbonise.

Martinez-Zarzoso, Bengochea-Morancho, and Morales-Lage (2019), who used data obtained from 14 OECD countries to examine the impact of stringent environmental policies on national total factor productivity (TFP), have an opposite opinion. Their research reveals that stricter environmental regulations may promote cleaner production and accelerate green transformation.

A different approach to this issue was taken by Declich, Quinti, and Signore (2020), who analysed the impact of non-economic factors related to the materials used during production on the course of green transformation in small and medium-sized enterprises.

A far more comprehensive study of the factors that affect the pace and course of green transformation is proposed by Rudneva, Pchelintseva, and Guryeva (2016). These authors divide the factors that affect the development of the region on the way of "greening" into eight groups:

- biological (i.e. nature of the landscape, soil and land cover, climate characteristics and biological resources),
- industrial (i.e. industrial strategy, infrared parameters of production networks, hierarchy in the management systems),
- resource (i.e. fuel and energy resources, water, forest and labour resources),
- investment and innovation (i.e. investment attractiveness, structure of the investment and degree of the innovation),
- social environmental and economic (i.e. social service infrastructure, demographic situation, conditions and safety of work, environmentally friendly production and safety parameters),
- financial (i.e. availability of major enterprises, availability and effectiveness of major financial and credit institutions),
- structural (i.e. branch, territorial and social structure),
- technological (i.e. knowledge-based production, labour resource structure).

The comprehensive literature research in this dimension can also be found in Zhang, Song, and Zou's study (2020). These authors emphasise that "there is little research into the factors that influence green total factor productivity and this has become an obstacle in the transition to a greener economy". Their study shows that factors that are most frequently analysed in various types of papers concerning green transformation include:

- economic factors: industrial structure (intra-industry competition), economic development level (financial development), production factors (physical and human capital), market factors (degree of marketisation and market potential),
- technical factors: technological progress (technological innovation), technological efficiency,
- government factors: environmental regulations (tools and policy), intellectual property protection, infrastructure level (transport infrastructure), fiscal decentralisation (degree of pollution control).

These factors cannot, according to the authors of the aforementioned study, be analysed separately because each of them is in close relationship with others.

Research by various international organisations is also a comprehensive source of information regarding factors that may determine the current state and course of green transformation. Certainly, it would be useful to indicate the green growth indicators, which were published by the OECD and divided into four main groups that include environmental and resource productivity, natural asset base, environmental dimensions of quality of life, economic opportunities and policy responses, as well as into an additional group of explanatory indicators; socio-economic context. The OECD publishes information on nearly 100 different green growth indicators.

An interesting example is also the indicators that are used for constructing the Green Growth Index (GGI) developed by The Global Green Growth Institute, which are divided into 4 groups such as efficient and sustainable resource, green economic opportunities, social inclusion and natural protection. In total, sixteen indicators make up this index.

The Global Green Economy Index (GGEI) should also be noted. GGEI was launched in 2010 by Dual Citizen LLC and which is defined by twenty indicators within one of the four main dimensions such as leadership and climate change, efficiency sectors, markets and investment, the environment.

Almost all studies concerning determinants that are relevant to green transformation of the economy use quantitative techniques, including parametric and non-parametric methods. However, the use of non-parametric methods and methods of the multivariate statistical analysis is far more common, especially for the construction of synthetic indices (GGI and GGEI). For example, Männasoo, Hein, and Ruubel (2018) used the Solow residual method, control function method, stochastic frontier analysis (SFA) and non-parametric data envelopment analysis (DEA) to investigate the factors that affect green transformation. Feng and Chen (2018) also used DEA and the green growth (performance) index to analyse panel data from 165 countries to estimate green growth performance from a global perspective.

The analysis also reveals that although there is some (fragmented) research on the factors that affect the achievement of green growth, most of it focuses primarily on examining the impact of single factors or possible groups of factors on the course of green transformation. Only a few papers also broaden the traditional view of economic growth by building models that take environmental problems and social determinants into account. Such proposals for green transformation models can be found, for example, in papers by Marsiglio and La Torre (2018), Privileggi and Marsiglio (2013). In fact, there are no comprehensive studies in the literature that analyse green transformation considering many different perspectives.

Due to the growing importance of environmental considerations for economic development involving green transformation, this article aims to contribute to research in this dimension by analysing models of green transformation in EU countries. This article proposes to divide the factors of green transformation into several groups that include environmental, social and economic-technological determinants. It is also important for us to study specific natural determinants found in individual countries and the effects of human activity on green transformation. All these group will presented in the paper as internal factors of green transformation.

To this end, the indicators published by the OECD for the study of green growth will be used later in this paper to describe green transformation models (based on internal factors) that are used by these countries. The OECD is currently one of the most comprehensive databases of this kind, which includes indicators in different spatial and temporal profiles. These factors will be compared in the study with socio-economic variables (external factors) which, according to the presented literature review, may determine the course of this process.

3. Research methodology

3.1. Stages of the applied research procedure

This paper uses a 3-step research process to identify green transformation models in EU countries, the successive steps of which are shown in Figure 1. In the first step, the identification of factors that are used in the literature to study green transformation was intended to be conducted. The results of this stage of the study are presented in Chapter 2.1. The literature review reveals that increasingly diverse factors are currently being used in research on green transformation. Their scope is not limited to exploring the relationship between economic and environmental determinants. Numerous factors that describe the social situation in individual countries are also increasingly gaining in importance.

In the next step, rankings were constructed for each of the identified groups of factors, showing how individual EU countries implement green transformation. The results obtained by the studied economies for each of the distinguished groups were analysed separately, and the relationships between the individual groups of factors were also considered.

The relationships identified in this way were used for building green transformation heuristic models of EU countries. The model developed in this way provides a tool for improving this process and enables the identification of recommendations for improvement in economies performing below the leaders in this dimension.

3.2. Statistical data

To achieve the research objectives stated in the introduction (objectives no. 2 and no. 3), statistical data concerning fifty-six (56) indicators were collected and divided into five dimensions. Four of them are related to the green economy in EU countries (internal factors of green transformation) and the fifth dimension describes the socio-economic situation in individual member states (external factors of green transformation). The choice of features was determined by the availability of data. Most of the information was obtained from 2019.

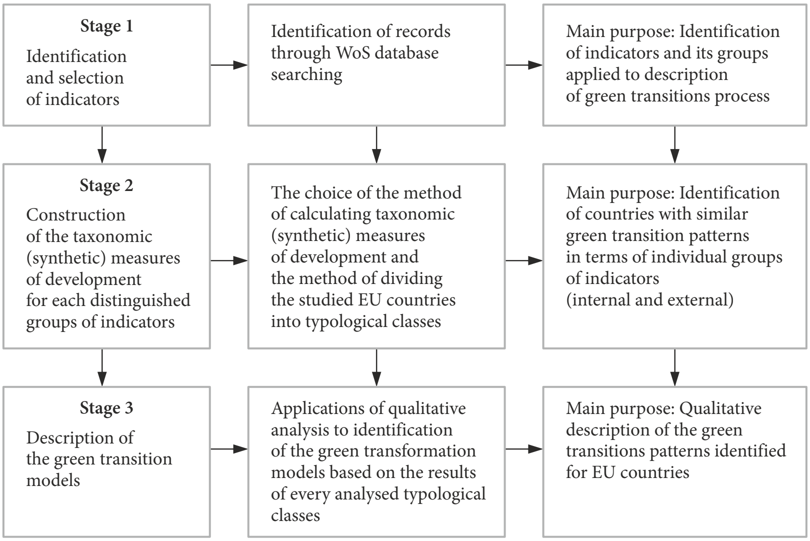

Figure 1. Research procedure chart

Only in a few cases, due to lack of data, earlier years were chosen. The study included 27 countries plus the UK, which was part of the EU in 2019. Each of the analysed indicators (diagnostic features) was assigned the symbol $Y_{i,j}$, where i stands for the number of the diemnsion where a feature is located, while j means the number of this feature. The impact of each of these features on the analysed phenomenon was also identified by classifying it into a set of indicators that stimulate development in a given dimension (symbol *S*) or destimulate (symbol *D*). The list of indicators used in this research, including a division into all identified diemensions, is presented in Tables 2–6.

The state of green economy was monitored through indicators grouped into four thematic dimensions: natural asset base, environmental and resource productivity, environmental dimensions of quality of life, economic opportunities and policy responses. Given human activity, these indicators can be further divided into two groups. The first group includes indicators that describe the state of natural environment, i.e. the natural resources possessed (Table 2). These indicators point to the potential for increased risk of a declining natural resource base. The second group includes the other three green economy dimensions (Tables 3–6) and indicators whose value is determined by human activity and its interference with the natural environment. This interference results in activities that affect both nature and humans themselves. It should be noted that most indicators of green economy are destimulants, i.e. features that negatively affect the phenomenon under study. These features represent 65.2% of all the indicators adopted for the study, the majority of which can be found in dimensions such as environmental dimensions of quality of life (80% of features from this dimension) and natural asset base (69.2% of features from this dimension). The distributions of the indicators adopted for the study will be described below.

The Natural asset base (dimension 1) indicators presented in Table 2 relate to three categories of diagnostic characteristics. In the first one, the share of the following selected elements of the natural environment was considered, in total dimension: Natural and semi-natural vegetated land, bare land, cropland, artificial surfaces, water. In the second category, attention was focused on the loss, gain and level of conversion of natural and semi-natural land to other elements of the natural environment. The third category concerns matters related to the built up dimension management processes.

The diagnostic features that describe natural capital show the highest variation among all the dimensions studied. The coefficient of variation ranges from 25.10% ($X_{1.12D}$ – built up dimension *per capita*) to 244.34% ($X_{1.2S}$ – proportion of uncultivated dimensions in total dimension, %), with variation exceeding 50% for most features. A consequence of the high dispersion of features is also their high asymmetry. It should be noted that the dominant asymmetry is right-skewed, which means that the values of features for most of the EU countries are below the EU average, which is a negative situation for features that have a positive impact on the studied phenomenon and a positive situation for destimulants.

Indicators characterising environmental and resource productivity (dimension II) were defined by four categories of diagnostic characteristics. The first takes into account CO2 emissions from energy production and a country's GDP. The second concerns energy intensity, where TPES per capita and total primary energy supply are taken into consideration. The third category involves the contribution of renewable energy sources to TPES capacity building and electricity generation. The last one takes into account energy consumption in agriculture, industry and transport that was compared to the total energy consumption.

Table 2. Natural asset base (dimension I)

Description	Symbol	Descriptive statistics		
		$\overline{x}$	V_s (%)	As
Natural and semi-natural vegetated land, % total	$X_{1.1S}$	50.50	36.96	–0.17
Bare land, % total	$X_{1.2S}$	1.18	244.34	3.58
Cropland, % total	$X_{1.3D}$	41.89	39.43	–0.50
Artificial surfaces, % total	$X_{1.4D}$	4.25	114.59	3.19
Water, % total	$X_{1.5S}$	2.18	114.82	2.17
Loss of natural and semi-natural vegetated land, % since 1992	$X_{1.6D}$	4.74	77.75	3.58
Gain of natural and semi-natural vegetated land, % since 1992	$X_{1.7S}$	4.46	72.11	0.62
Conversion from natural and semi-natural land to cropland, % since 1992	$X_{1.8D}$	3.24	58.83	0.79
Conversion from natural and semi-natural land to artificial surfaces, % since 1992	$X_{1.9D}$	3.39	56.78	0.76
Conversion from natural and semi-natural land to artificial surfaces, % since 1992	$X_{1.10D}$	3.17	78.15	1.30
Built up dimension, % total land	$X_{1.11D}$	4.45	110.26	2.41
Built up dimension per capita	$X_{1.12D}$	263.86	25.10	0.57
New built up dimension, % since 1990	$X_{1.13D}$	33.38	31.74	0.73

Note: $\overline{x}$ – mean, V_S – coefficient of variation, A_s – asymmetry, S – stimulants and D – destimulants.

The descriptive parameters determined for the individual indicators suggest that, in terms of environmental and resource productivity, there are also large disparities between the analysed countries (Table 3). This is indicated by high values of the coefficient of variation (V_s) and coefficient of asymmetry (As). The coefficient of variation ranges from 19.84% ($X_{2.3S}$) to 131.78% ($X_{2.6D}$); however, it exceeds 30% for most features. All indicators, excluding demand-based CO2 productivity and GDP per unit of energy-related CO2 emissions ($X_{2.3S}$), have high right-skewed asymmetry, which means that the indicators adopted for the study in this dimension are below the average for most countries. Certainly, this is a favourable situation for most features that are destimulants. The situation is different for features for which a higher level is demanded (stimulants) and a distribution with strong right-handed asymmetry is unfavourable. These features include production-based CO2 productivity, GDP per unit of energy-related CO2 emissions ($X_{2.1S}$); energy intensity, TPES per capita ($X_{2.5S}$); renewable energy supply, % TPES ($X_{2.7S}$) and renewable electricity, % total electricity generation ($X_{2.8S}$).

Three categories of diagnostic characteristics were used to describe the dimension of the environmental dimensions of quality of life (dimension III). The first one is related to the exposure of the public to harmful factors. The second category takes into account the cost of healthcare related to the morbidity rate of the population, where the main cause of a disease was the impact of harmful factors. The third category, on the other hand, concerns the public's access to clean water and good sanitation, the quality of which has a significant impact on the health of citizens. A total of 10 indicators qualified for the study, among which there were only two stimulants (Table 4). These both indicators ($X_{3.9S}$ and $X_{3.10S}$) have low variation, 4.28% and 11.34% respectively, and strong right-skewed asymmetry. This means that for most EU countries, population with access to improved drinking water sources, % total population and population with access to improved sanitation, % total population represent values above the average for all member states. This is a positive situation from the perspective of the studied dimension. However, the distribution of percentage of population exposed to more than 10 micrograms/m^3 ($X_{3.2D}$) is unfavourable, which means that exposure to pollutants is above the average for most EU countries.

The indicators given in Table 5 are related to economic opportunities and policy responses (dimension IV). Three categories of diagnostic features were considered when describing this dimension. The first category concerns the level of development of environment-related technologies that translate in a positive way into sustainable transition processes. The second category takes into account the problem of the scale of taxes related to environmental, energy and transport matters. The last category concerns petrol and diesel prices. Five stimulants and seven destimulants were identified among them. Their level of variation is high and ranges from 16.50% ($X_{4.8D}$ – energy-related tax revenue, % total environmental tax revenue) to 222.57% ($X_{4.3S}$ – development of environment-related technologies, % inventions worldwide). $X_{4.3\ S}$ also has the highest asymmetry value (3.95), which shows a strong prevalence of EU countries with below average indicator values Only seven countries had indicator values above the average. The highest indicator value was observed in Germany (10.76), which was more than 1,000 times the average for the EU countries. A weak and moderate left-skewed asymmetry was found for four indicators that are destimulants ($X_{4.6D}$ – environmentally-related taxes, % GDP; $X_{4.7D}$ – environmentally-related taxes, % total tax revenue; $X_{4.8D}$ – energy-related tax revenue, % total environmental tax revenue and $X_{4.11D}$ – diesel tax, USD

Table 3. Environmental and resource productivity (dimension II)

Description	Symbol	Descriptive statistics		
		$\bar{x}$	*Vs* (%)	As
Production-based CO2 productivity, GDP per unit of energy-related CO2 emissions	$X_{2.1S}$	7.48	37.05	1.28
Production-based CO2 intensity, energy-related CO2 per capita	$X_{2.2D}$	6.03	39.97	1.84
Demand-based CO2 productivity, GDP per unit of energy-related CO2 emissions	$X_{2.3S}$	4.55	19.84	–0.16
Demand-based CO2 intensity, energy-related CO2 per capita	$X_{2.4D}$	7.61	35.62	1.01
Energy intensity, TPES per capita	$X_{2.5S}$	3.19	37.57	1.17
Total primary energy supply	$X_{2.6D}$	56.46	131.78	2.02
Renewable energy supply, % TPES	$X_{2.7S}$	17.66	58.52	1.08
Renewable electricity, % total electricity generation	$X_{2.8S}$	37.88	56.16	0.56
Energy consumption in agriculture, % total energy consumption	$X_{2.9D}$	2.65	50.98	1.15
Energy consumption in industry, % total energy consumption	$X_{2.10D}$	22.93	29.48	0.87
Energy consumption in transport, % total energy consumption	$X_{2.11D}$	30.94	26.70	0.90

Note: $\bar{x}$ – mean, V_S – coefficient of variation, A_s – asymmetry, S – stimulants and D – destimulants.

Table 4. Environmental dimensions of quality of life (dimension III)

Description	Symbol	Descriptive statistics		
		$\bar{x}$	*Vs* (%)	As
Mean population exposure to PM2.5	$X_{3.1D}$	12.89	33.55	0.22
Percentage of population exposed to more than 10 micrograms/m3	$X_{3.2D}$	69.93	45.48	–1.17
Mortality from exposure to ambient PM2.5	$X_{3.3D}$	401.66	68.15	1.31
Welfare costs of premature mortalities from exposure to ambient PM2.5, GDP equivalent	$X_{3.4D}$	4.15	72.42	1.32
Mortality from exposure to lead	$X_{3.5D}$	25.06	62.97	0.55
Welfare costs of premature deaths from exposure to lead, GDP equivalent	$X_{3.6D}$	0.25	64.70	0.61
Mortality from exposure to lead	$X_{3.7D}$	85.51	69.75	1.50
Welfare costs of premature deaths from exposure to lead, GDP equivalent	$X_{3.8D}$	0.87	72.49	1.50
Population with access to improved drinking water sources, % total population	$X_{3.9S}$	96.84	4.28	–2.07
Population with access to improved sanitation, % total population	$X_{3.10S}$	89.30	11.34	–1.62

Note: $\bar{x}$ – mean, V_S – coefficient of variation, A_s – asymmetry, S – stimulants and D – destimulants.

per litre). This means a negative situation from the prespective of the phenomenon under study (more countries with indicators above the average).

Information concerning individual dimensions of green economy is complemented by contextual indicators that provide data on the general socio-economic situation of EU countries (Table 6).

Table 5. Economic opportunities and policy responses (dimension IV)

Description	Symbol	Descriptive statistics		
		$\overline{x}$	*Vs* (%)	As
Development of environment-related technologies, % all technologies	$X_{4.1S}$	10.82	51.61	0.78
Relative advantage in environment-related technology	$X_{4.2S}$	1.19	51.72	0.80
Development of environment-related technologies, % inventions worldwide	$X_{4.3S}$	0.94	222.57	3.95
Development of environment-related technologies, inventions per capita	$X_{4.4S}$	13.49	116.23	1.79
Net ODA provided, % GNI	$X_{4.5S}$	0.33	82.39	1.33
Environmentally related taxes, % GDP	$X_{4.6D}$	2.47	33.08	–0.13
Environmentally related taxes, % total tax revenue	$X_{4.7D}$	6.87	32.64	–0.26
Energy related tax revenue, % total environmental tax revenue	$X_{4.8D}$	75.03	16.50	–0.70
Road transport-related tax revenue, % total environmental tax revenue	$X_{4.9D}$	22.82	74.52	1.53
Petrol end-user price, USD per litre	$X_{4.10D}$	2.14	21.52	0.25
Diesel tax, USD per litre	$X_{4.11D}$	0.67	20.27	–0.45
Diesel end-user price, USD per litre	$X_{4.12D}$	2.03	24.57	0.51

Note: $\overline{x}$ – mean, V_S – coefficient of variation, A_s – asymmetry, S – stimulants and D – destimulants.

Table 6. Socio-economic context

Description	Symbol	Descriptive statistics		
		$\overline{x}$	*Vs* (%)	As
Real GDP per capita, USD Dollar	$X_{5.1S}$	42697.57	41.43	2.21
Value added in industry % of total value added	$X_{5.2S}$	24.83	25.77	–0.12
Total fertility rate, children per woman	$X_{5.3S}$	1.57	10.57	–0.06
Life expectancy at birth	$X_{5.4S}$	80.39	3.20	–0.82
Population, ages 0–14, % total	$X_{5.5S}$	15.61	10.39	1.25
Population, ages 65 and above, % total	$X_{5.6S}$	19.51	11.72	–1.16
People at risk of poverty or social exclusion, %	$X_{5.7D}$	21.20	23.94	0.60
Severely materially deprived people, %	$X_{5.8D}$	6.08	75.31	1.75
People living in households with very low work intensity, percentage of total population aged less than 60	$X_{5.9D}$	8.04	31.32	0.64
Population unable to keep home adequately warm by poverty status, %	$X_{5.10D}$	8.09	93.81	1.68
Tertiary educational attainment by sex, from 25 to 34 years, %	$X_{5.11D}$	42.79	20.10	–0.07
Employment rate by sex, from 20 to 64 years, % of total population	$X_{5.12S}$	74.61	6.69	–1.03
Purchasing power adjusted GDP per capita, %	$X_{5.13S}$	31867.86	40.49	2.32

Note: $\overline{x}$ – mean, V_S – coefficient of variation, A_s – asymmetry, S – stimulants and D – destimulants.

The study included thirteen such indicators, while 8 indicators had a positive impact on the studied dimension (stimulants) and 5 had a negative impact (destimulants). In terms of indicators that are stimulants, both the highest variation and very high positive asymmetry apply to two features such as real GDP per capita, US dollar ($X_{5.1S}$) and purchasing power adjusted GDP per capita, % ($X_{5.13S}$). Therefore, for most EU countries, the economic situation in view of these indicators is below the average for all EU countries. The demographic situation regarding the percentage of children aged 0–14 years ($X_{5.5S}$) and the labour market situation regarding the employment rate by sex ($X_{5.12S}$) are also unfavourable. In terms of indicators that are destimulants, unfavourable values concern the indicator representing the proportion of people aged 65 and older in the total population. The strong left-skewed asymmetry shows that a high proportion of this age group applies to most EU countries.

3.3. Research method

To study the relationships between analysed dimensions of green growth and contextual indicators of green transformation, the taxonomic measure of development applying the Weber median vector was used. In the literature (Młodak, 2014; Adam & Kroupa, 2017; Szopik-Depczyńska et al., 2018) one may indicate many examples of the application of this synthetic measure to calculate rankings comprising many various dimensions of the socio-economic development of the countries, regions or cities etc. The Weber median is presented in the literature as a multi-dimensional generalization of the classical notion of the median (Szopik-Depczyńska et al., 2018). The median Weber vector is estimated on the basis of indicators by transforming destimulants into stimulants using the following formula:

$$x'_{ij} = \frac{1}{x_{ij}},\ i = 1,2,\ldots,n,\ j = 1,2,\ldots,n. \quad (1)$$

The positional option of the linear object assignment is calculated based on a quotient of the indicators value deviation from the proper coordinate of the Weber median and a weighed absolute median deviation, applying the Weber median (Młodak, 2014):

$$z_{ij} = \frac{x_{ij} - \theta_{0j}}{1,4826 \cdot \tilde{\mathrm{mad}}(X_j)}, \quad (2)$$

where: $\theta_0 = (\theta_{01}, \theta_{02}, \ldots, \theta_{0m})$ is the Weber median, $\tilde{\mathrm{mad}}(X_j)$ is the absolute median deviation, in which the distance from the features to the Weber vector is measured, i.e.: $\tilde{\mathrm{mad}}(X_j) = \underset{i=1,2,\ldots,n}{\mathrm{med}} \left| x_{ij} - \theta_{0j} \right|$ (j = 1, 2, …, m).

The synthetic measure μ_i is calculated on the basis of maximum values of normalized features:

$$\phi_j = \max_{i=1,2,\ldots,n} z_{ij}, \quad (3)$$

with applications of the following formula:

$$\mu_i = 1 - \frac{d_i}{d\_}, \quad (4)$$

where: $d\_$ = med (**d**) + 2.5mad (**d**), where **d** = (d_1, d_2,…,d_n) is a distance vector calculated using the formula: $d_i = \underset{j=1,2,\ldots,m}{\mathrm{med}} \left| z_{ij} - \phi_j \right|$ i = 1, 2, …, n, ϕ_j – the i-th coordinate of the development pattern vector, which form the maximum values of the normalized indicators.

The objects ranked according to the taxonomic measure are the basis for a division of objects (in this case: countries) into four classes. For this purpose the three medians method can be applied that involves indicating a median of vector coordinates $\mu = (\mu_1, \mu_2, ..., \mu_n)$, which is denoted $\mathrm{med}(\mu)$. Based on this vector the population of countries is divided into two groups Ω_k: those, for which the measure values exceed the median (are higher than it – Ω_1 : classes A and B) and those, for which the measure values do not exceed the median (are equal or lower than it – Ω_2 : classes C and D). On this basis, in the next step, the indirect medians are defined as: $\mathrm{med}_k(\mu) = \underset{i:\Gamma_i \in \Omega_k}{\mathrm{med}}(\mu_i)$, where k = 1, 2. This way the following classes of objects are created:

- Class A: $\mu_i > \mathrm{med}_1(\mu)$,
- Class B: $\mathrm{med}(\mu) < \mu_i \leq \mathrm{med}_1(\mu)$,
- Class C: $\mathrm{med}_2(\mu) < \mu_i \leq \mathrm{med}(\mu)$,
- Class D: $\mu_i \leq \mathrm{med}_2(\mu)$.

The first and the second classes include countries with higher level of development than countries assigned as classes three and four.

4. Results

The indicators described in the previous section were used, in accordance with the described methodology of the study, to determine taxonomic measures of development. Synthetic measures were determined separately for each of the four analysed dimensions of green growth. On their basis, the EU countries under study were ordered according to the decreasing values of individual synthetic measures (formula 3) and they were classified (divided into typological classes) based on a similar level of development. The synthetic results of the ordering and classification of EU countries are presented in Table 7.

The positions taken by individual EU countries in all dimensions of green growth vary considerably. The selected descriptive characteristics (Table 8), estimated for the synthetic measures of development, estimated on the basis of the diagnostic characteristics adopted for the study, also point to the same conclusion. The largest variation could be observed in the first dimension of green growth concerning the countries' natural resources (V_s = 27.290) and the smallest in the second dimension involving environmental and resource productivity indicators (V_s = 19.665). Consideration should also be given to the strength and sign of the asymmetry coefficients. Left-skewed asymmetry was identified in the first and third dimension of green growth (respectively: natural asset base and environmental dimension of quality of life). In both cases the asymmetry is very strong, meaning that in 2019, a greater number of countries achieved values of the taxonomic measures above the mean. The opposite situation can be observed for the second dimension (environmental and resource productivity) and the fourth dimension (economic opportunities and policy responses), with the strength of this asymmetry also being high. This means that for these dimensions the values of the synthetic measures were below mean for most EU countries.

Table 7. Comparison of the results of the ordering of EU countries in 2019

Country	Dimension I		Dimension II		Dimension III		Dimension IV	
	μ_i	rank	μ_i	rank	μ_i	rank	μ_i	rank
Austria	0.716	8	0.663	8	0.843	8	0.561	7
Belgium	0.191	27	0.557	16	0.788	12	0.592	3
Bulgaria	0.815	4	0.471	25	0.264	28	0.527	12
Croatia	0.579	21	0.755	6	0.527	26	0.272	28
Cyprus	0.666	13	0.423	28	0.704	19	0.557	9
Czechia	0.671	11	0.525	22	0.760	15	0.376	26
Denmark	0.650	18	0.632	10	0.833	9	0.716	2
Estonia	0.687	10	0.502	24	0.960	3	0.571	6
Finland	0.882	2	0.631	11	0.998	1	0.495	15
France	0.482	26	0.529	21	0.826	11	0.447	22
Germany	0.517	24	0.551	17	0.830	10	0.560	8
Greece	0.754	6	0.502	23	0.606	25	0.477	18
Hungary	0.704	9	0.626	12	0.613	24	0.547	11
Ireland	0.917	1	0.601	14	0.937	4	0.553	10
Italy	0.663	14	0.603	13	0.650	22	0.577	5
Latvia	0.655	16	0.708	7	0.700	20	0.482	17
Lithuania	0.744	7	0.800	4	0.765	14	0.591	4
Luxembourg	0.526	23	0.808	3	0.921	6	0.462	19
Malta	0.100	28	0.839	2	0.719	18	0.890	1
Netherlands	0.544	22	0.542	19	0.872	7	0.390	25
Poland	0.760	5	0.459	27	0.646	23	0.457	20
Portugal	0.498	25	0.543	18	0.758	16	0.484	16
Romania	0.640	19	0.647	9	0.431	27	0.518	13
Slovak Republic	0.603	20	0.768	5	0.682	21	0.448	21
Slovenia	0.660	15	0.470	26	0.772	13	0.282	27
Spain	0.666	12	0.530	20	0.758	17	0.407	24
Sweden	0.843	3	0.847	1	0.970	2	0.498	14
United Kingdom	0.654	17	0.563	15	0.924	5	0.411	23

Table 8. Descriptive characteristics of the taxonomic measures in the dimensions of green economy and in 2019

Summary statistics of synthetic measure μ_i	Dimension I	Dimension II	Dimension III	Dimension IV
Mean value	0.635	0.610	0.752	0.505
Coefficient of variation (Vs, %)	27.290	19.665	21.795	23.541
Minimum	0.100	0.423	0.264	0.272
Maximum	0.917	0.847	0.998	0.890
Asymmetry	–1.397	0.585	–0.989	0.876

The best situation, considering the results obtained in all analysed dimensions of green growth, was observed in Sweden, which ranked 3rd in the first three dimensions. The country's situation was worse in terms of the fourth dimension concerning policies and their consequences (rank 14th). This is mainly due to high values of indicators that have a negative impact on this dimension (destimulants), such as: $X_{4.7D}$ (environmentally related taxes, % total tax revenue), $X_{4.10D}$ (petrol end-user price, USD per litre), $X_{4.12D}$ (diesel tax, USD per litre).

Finland also ranked high in the constructed rankings, coming top twice, i.e. for the first and third dimension of green growth. Such a high rank for the first dimension resulted from the lowest values, among the EU countries, of the characteristics affecting it negatively, such as $X_{1.4D}$ (artificial surfaces, % total) and $X_{1.10D}$ (conversion from cropland to artificial surfaces, % since 1992), as well as the highest value of the indicator stimulating the development of the EU countries – $X_{1.5S}$ (water, % total), among others. For the third dimension, Finland had the lowest values for the following indicators among the member countries: $X_{3.1D}$ (mean population exposure to PM2.5) and $X_{3.7D}$ (mortality from exposure to lead) and the highest value for the $X_{3.10S}$ indicator (population with access to improved sanitation, % total population).

It is worth noting that, apart from Sweden and Finland, no country was identified as being in the top three for more than one dimension of green growth.

Observing the positions of the countries at the bottom of the rankings also reveals no countries that are the weakest in terms of several different dimensions of green growth. Slovenia and Croatia are the exceptions. The former was ranked 26th for dimension two and 27th for dimension four. The vast majority of indicators for these dimensions had unfavourable values from the point of view of the examined phenomena, i.e. low values for characteristics that are stimulants and high values for destimulants. Croatia was in a similar situation, ranking 26th for dimension three and last for dimension four.

In the literature (see Hu et al., 2021) as well as in earlier studies by the authors of this paper (see: Cheba & Bąk, 2021), geographical proximity of individual countries is identified among the factors that may affect the performance of EU countries in terms of the various analysed dimensions. This kind of influence can also be observed for some of the results obtained in this study. Table 9 presents the division of EU countries into typological classes that takes into account their geographical distribution in different parts of Europe (the division of Europe proposed by the World Bank was used).

Geographical proximity and, related to it, cultural proximity are particularly evident in the results obtained by most countries located in Western Europe. This applies especially to the first analysed dimension – the natural asset base. The results obtained by five out of the six countries from this part of Europe influenced their classification into Typological Class IV.

Similarity of results can also be observed for some countries located in Eastern Europe. This applies primarily to the third analysed dimension – environmental dimensions of quality of life – in the case of which the countries were classified into classes III and IV (i.e. classes in which synthetic measures were below average). In contrast, their results for the second dimension – environmental and resource productivity – are much more varied. Bulgaria, Czechia and Poland were classified in this dimension into the fourth typological class and the remaining countries into the first (Slovak Republic) or second (Romania and Hungary) class.

Table 9. The results of division of EU countries into typological classes

Country	Dimension I	Dimension II	Dimension III	Dimension IV
Northern Europe				
Denmark	C	B	B	A
Estonia	B	D	A	A
Finland	A	B	A	C
Ireland	A	B	A	B
Latvia	C	A	C	C
Lithuania	B	A	B	A
Sweden	A	A	A	B
United Kingdom	C	C	A	D
Western Europe				
Austria	B	B	B	A
Belgium	D	C	B	A
France	D	C	B	D
Luxembourg	D	A	A	C
Netherlands	D	C	A	D
Germany	D	C	B	B
Southern Europe				
Croatia	C	A	D	D
Cyprus	B	D	C	B
Greece	A	D	D	C
Italy	B	B	D	A
Malta	D	A	C	A
Slovenia	C	D	B	D
Spain	B	C	C	D
Portugal	D	C	C	C
Eastern Europe				
Bulgaria	A	D	D	B
Czechia	B	D	C	D
Poland	A	D	D	C
Romania	C	B	D	B
Slovak Republic	C	A	C	C
Hungary	B	B	D	B

Similar differences can also be observed in relation to other countries in the south or north of Europe.

The literature (see: Cheba et al., 2020) also emphasises that southern European countries are currently still more strongly affected than e.g. eastern European countries by the economic downturn of 2007–2008. The result is less activity in the dimension of environmental quality of life and slower economic and technological development. Symptoms of this type of response to the economic crisis are also evident in the described results. The results of Greece, Spain and Portugal are particularly worth noting here. These countries, apart from the indicators related to natural resources, were classified into class three or four. The results of countries from this part of Europe are most often similar to those of Eastern European countries, which joined the EU much later and have had less time to catch up with the more developed countries from other parts of Europe.

The results of the selected countries that ranked highest and lowest are shown in Figure 1. Sweden with the highest scores in the first three dimensions and Belgium with by far the highest score in the last dimension were selected for comparison (Figure 2).

The very diverse results of the EU countries observed so far confirm that there is a need, already mentioned at the beginning of this paper, for identifying factors that may have an impact on the results of the ordering of the countries and their classification in an analysed dimension. For this purpose, in accordance with the methodology described for this study, 13 indicators that may determine the performance of EU countries were identified based on a literature review. Some of them are also used by the OECD, as contextual indicators, when analysing the changes taking place in the dimension of green growth. They can be divided into two groups that include indicators describing the economic development of individual EU countries ($X_{5.1S}$, $X_{5.2S}$, $X_{5.3S}$) and social development indicators ($X_{5.4S}$ – $X_{5.13S}$). The next step of the research involved determining whether relationships between contextual indicators and dimensions of green growth could be observed. For this purpose, the relationships between the synthetic measures determined for each dimension of green growth and all the contextual indicators adopted for this study were examined using the Pearson linear correlation coefficient (Table 10). The table shows the highest correlation coefficient scores.

The presented information shows that high correlation coefficient scores are mostly found between part of the analysed contextual indicators and dimension three: environmental dimensions of quality of life. High correlation coefficient scores include, for example: $X_{5.1S}$ – real GDP per capita (USD dolar): 0.615. This means that for some EU countries, as GDP per capita increases, so does the value of the synthetic measure determined for dimension three. This relationship is also presented in Figure 3.

The highest but negative correlation coefficient score was identified for indicator $X_{5.8D}$ – people at risk of poverty or social exclusion: –0.825, which means that as the value of this indicator increases, an average decrease in the synthetic measure is observed. Poverty is therefore one of the factors that have a strong negative impact on the value of the synthetic measure in the dimension of environmental dimensions of quality of life. This is also supported by the slightly lower, but also negative, correlation coefficient values for: $X_{5.10D}$ – percentage of people living in households with very low work intensity in total population aged less than 60 (–0.592). In turn, relatively strong positive correlations were identified for: $X_{5.12S}$ – tertiary educational attainment by sex, from 25 to 34 years and $X_{5.13S}$ – employment rate (from 20 to 64 years, % of total population). This confirms the regularities observed also by Hallegate et al. (2012), which show that as the level of education and affluence increases, actions for the improvement of the quality of life in terms of environmental protection are taken more frequently, as evidenced by contemporary world problems, important for people's lives, but still viewed as optional.

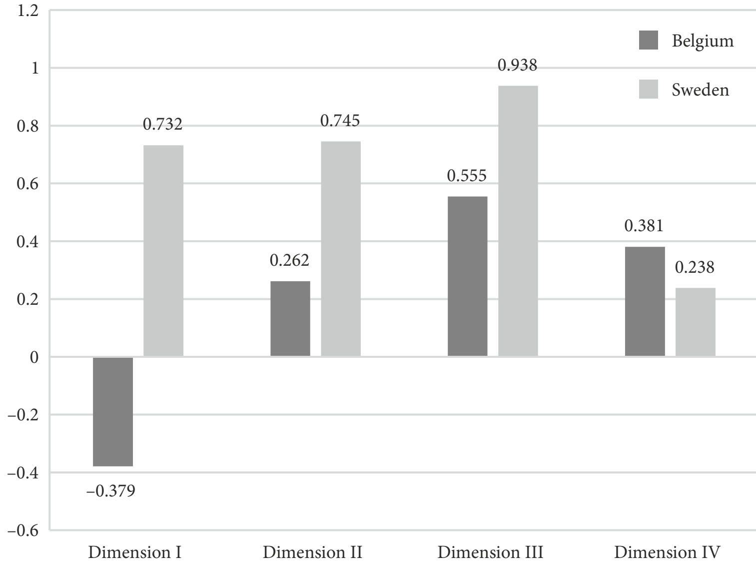

Figure 2. Results of Belgium and Sweden

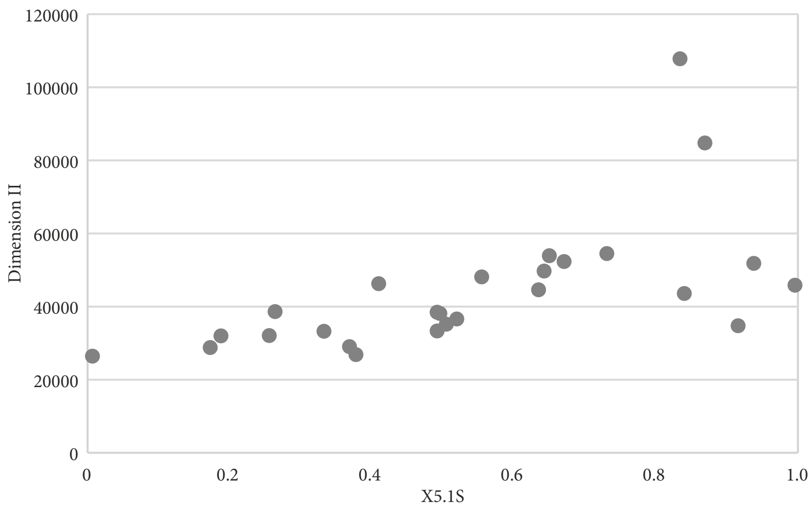

Figure 3. The correlation coefficients between synthetic measure estimated for the third dimension and real GDP per capita ($X_{5.1S}$) for Belgium and Sweden

Table 10. Pearson *r* correlation coefficients determined for dimensions of green growth and contextual indicators

Contextual indicators	Dimension I	Dimension II	Dimension III	Dimension IV
$X_{5.1S}$	–0.067	0.326	**0.615**	0.126
$X_{5.2S}$	**0.487**	–0.102	–0.056	–0.233
$X_{5.3S}$	0.061	0.165	**0.345**	0.035
$X_{5.4S}$	–0.219	–0.095	**0.585**	0.054
$X_{5.5S}$	0.209	0.017	**0.476**	–0.011
$X_{5.6S}$	–0.083	–0.055	–0.183	0.042
$X_{5.7D}$	0.147	–0.028	**–0.586**	0.098
$X_{5.8D}$	0.227	–0.174	**–0.825**	0.023
$X_{5.9D}$	0.171	–0.065	0.095	–0.005
$X_{5.10D}$	0.125	–0.139	**–0.592**	0.138
$X_{5.11D}$	0.048	0.047	**–0.568**	0.024
$X_{5.12S}$	0.069	0.114	**0.457**	0.175
$X_{5.13S}$	–0.063	0.272	**0.608**	0.113

5. Discussion

Green transition has become a new motto in contemporary discussions on sustainable development. It is gaining popularity in political debates on global environmental changes. However, it still arouses much controversy and ambiguity due to its complexity and multidimensionality. The growing importance of this type of transition is observed both in highly developed and developing countries.

Despite a growing number of publications on green transition (Crespi et al., 2016; Patterson et al., 2017; Fazey et al., 2018), research on how it is conceptualised and operationalised remains relatively scarce (Feola, 2015). Published papers differ both in the way the term is defined and in the scope of proposed changes that should be implemented in different regions of the world (Bennett et al., 2019). Hence, research in this regard is crucial both for the further development of scientific literature and for the empirical studies on the course of green transition, particularly in terms of the factors affecting it. This article contributes to filling this research gap by indicating the critical determinants of the green transition process and characterising its current status in European Union countries.

The literature review (Feola, 2015; Godlewska & Sidorczuk-Pietraszko, 2019) indicates that a transition is most often defined very broadly – as fundamental restructuring both in specific sectoral systems like energy, food, and municipal systems as well as in social, economic, and political systems. Difficulties in defining a general model of this process are not without impact on the application value of the research conducted. Methodological challenges also relate to the statistical method of measurement, with a particular focus on the regional or local context.

Numerous organisations, national and international alike, have already proposed various indicator sets that can be used in research on the course of the green transition. The best known and most commonly used indicator set is that developed by the OECD (2011), focusing on the study of the relationship between the economy and the environment and taking into account the social aspects directly related to both. The main dimensions covered by the indicators include the environmental and resource productivity, natural resources, environmental dimension of quality of life, economic opportunities and policy responses, as well as socio-economic context.

According to United Nations Environment Programme [UNEP] (2017), the optimal approach to measuring changes in the green transition is to use both an aggregate (comprehensive) indicator and an array of specific indicators. A summary index gives an opportunity for a synthetic view of the development of EU countries based on particular dimensions but comprised as a whole. The main purpose of the analysis provided based on the results obtained in the particular dimensions is complementary information and helps to better understand inter-regional differences (between countries, cities, etc.). It allows also us to compare the differences between them over time. This study also uses such an approach. Apart from the indicators normally used in green transition analyses, the research conducted takes into account an extensive set of the so-called contextual indicators, which may determine the course of the transition process. It must be noted here that the literature (Bennett et al., 2019) has long stressed that the state of the environment is determined by many factors, including social and economic ones. Therefore, progress in greening the economy should be made while taking into account the socio-economic circumstances of specific countries (Ocampo, 2011; Samans, 2013). Hence, it is necessary to analyse the relationship between individual dimensions linked to the green transition and macroeconomic condition indicators (e.g. GDP, employment rate), as well as social indicators (education, poverty, life expectancy). This approach, which was also used by the authors of this paper, broadens the scope of the analyses conducted and prompts the search for a universal green transition model.

This paper uses multidimensional comparative analysis methods to identify factors determining the course of the green transition process. Indicator sets characterising selected dimensions of the green transition process that were deemed important were used to classify EU countries. It was also assumed that the multidimensional comparative analysis should follow two lines of research. The first line of research was to cover the changes occurring in the course of the green transition process in individual EU countries, while the second was to cover the socio-economic aspects that may condition its course.

The use of statistical analyses in the study of green transition is quite common in scientific research; however, it typically applies to the construction of a synthetic variable for individual dimensions describing this process or all dimensions together. The authors of this study go beyond such a scheme of research and also search for relations occurring between the dimensions vital to the green transition process and the features characterising the socio-economic situation of the EU Member States. This makes it possible to indicate the extent to which the structures of "green" transitions differ depending on the environment in which they take place.

The interpretation of the results obtained is by no means a simple and unambiguous process. The literature (see: Szopik-Depczyńska et al., 2018) emphasises that the leaders in terms of sustainable development indicators, green economy or green growth are the Scandinavian countries (Denmark, Norway and Sweden), or in a broader sense, the Nordic countries (including Finland), which have managed to permanently separate economic growth from the negative environmental impact of human activity. Such opinions are only partly confirmed by the research results presented in the article. In particular, it is worth noting that the performance of three of the Nordic countries which are also members of the EU (apart from Norway) varies considerably. The leader in the case of the first three dimensions analysed, i.e. dimension I – natural asset base, dimension II – environmental and resource productivity and dimension III – environmental dimensions of quality of life, is Sweden, which ranked third, first and second, respectively. On the other hand, its performance is much lower in the fourth dimension, covering indicators from economic opportunities and policy responses group (14th place). Denmark performed much better in this dimension and ranked second. Finland, on the other hand, ranked highly in dimensions one and three (second and first place, respectively) and much lower in terms of dimensions two and four (11th and 15th place, respectively). This may indicate that Finland's natural resources are, for example, relatively less transformed compared to other countries, which also results in a higher level of environmental quality of life. Its poorer performance in the second and fourth dimensions, which are directly linked to human activity and include indicators relating to e.g. energy consumption in transport, manufacturing and agriculture, and indicators describing the level of maturity of green technologies, indicate that there are countries in the EU which are more oriented towards the development of green technologies.

In comparison, Malta's results are quite puzzling; this particularly applies to dimension IV in which Malta is the leader, followed by Denmark and Belgium. The high performance of these three countries is the result of the following:

- high values of such indicators as: $X_{4.1S}$ – development of environment-related technologies (% all technologies) and $X_{4.2S}$ – relative advantage in environment-related technology (ratio),
- and very low values of indicators considered to be destimulants, i.e $X_{4.6\ D}$ environmentally related taxes (% GDP) and $X_{4.7D}$ – environmentally related taxes (% total tax revenue).

Despite the use of diagnostic features in the form of intensity indicators in the survey, Malta's results should not be taken as a reference (benchmark) for other, much larger EU countries. Although Malta's performance in terms of indicators such as $X_{4.1S}$ and $X_{4.2S}$ is the highest among EU countries (26.67% and 2.95 respectively), its score for $X_{4.3S}$ – development of environment-related technologies (% inventions worldwide) is among the lowest at 0.02%. In this case, the top spot is held by Germany with a score of 10.76%. In the case of the next two indicators significantly affecting the ranking results in this dimension, it must be noted that individual EU countries perceive environmental taxes differently. In most of them, the "polluter pays" principle applies. The tax amount is therefore strongly linked to such things as the volume of pollutant emissions from environmentally burdensome production facilities. While large production facilities in Scandinavian countries also pay higher taxes, these are treated as a solidarity-based contribution to the state budget for environmental protection. As such, they are not always directly proportional to the amount of pollution emitted.

In terms of the fourth dimension analysed, a point of reference for Sweden and Finland – apart from Denmark – may also be the results of Germany, France and Great Britain, which are also leading innovators, including in green technologies. Yet the analysis shows that of these three, only Germany ranks among the top ten most developed countries in this dimension. The results obtained by France (ranked 22nd) and the UK (ranked 23rd) are significantly lower. The main reason is the heavy environmental taxes and the relatively average performance in terms of environmental technologies.

The literature (see: Blythe et al., 2017) emphasises that along with economic growth comes an increase in negative human-induced environmental pressure. Only upon reaching a certain level of such growth does the interest in environmental issues begin to increase. A similar type of relationship can be expected to occur in the case of indicators describing the social determinants of development (Duran et al., 2015). As stated by (Cobbinah et al., 2015), poverty-stricken and less educated populations may also be less active in the dimension of environmental protection activities. In no way does this automatically translate into inferior results in terms of indicators concerning things like the volume of harmful emissions or general pollution, as these are also the result of economic growth. It is difficult to estimate the degree of variation and number of relationships that may occur between contextual indicators and indicators that directly describe the level of development in terms of green growth. The literature examines such relationships in various contexts. Research on the way external conditions affect the attained level of green transition was conducted by such scholars as Horberry et al. (2006). On the other hand, Schot and Geels (2008) described the social impact of the energy transition. Among the recent frequent considerations in this dimension, it is also worth mentioning the proposals to involve various stakeholders in the green transition process, as in the paper of Borel-Saladin and Turok (2013).

Conclusions

Green transition is a long-term process. Many EU countries are still in a phase of development, meeting consumer needs and industrialisation, which requires the use of natural resources and energy. This transition is impossible without the commitment of individual countries, hence the importance of analysing indicators related to the green economy and its links to the current socio-economic situation of EU countries, as done in this study.

The empirical results obtained and findings on the green economy may help identify critical conclusions concerning the rules and ways of the measurement of the green transformation, the comparison of the level and direction of this transformation and the identification of the condition of this process. The information thus obtained can provide valuable guidance for taking concrete practical steps useful during the transform national economies into modern and competitive systems with minimal as possible environmental impact.

It is also worth noting that the research conducted has its limitations. The first limitation concerns the indicators selected for the study, which must be based on information published in recognised databases. This is for reasons of data availability, a critical factor in international comparisons. To that end, this paper uses indicators developed by the OECD and Eurostat. The second major limitation – one strongly related to data availability – is the static approach used in the paper, which does not make it possible to track changes in the course of the green transition process. A potential solution to this problem could be to study the differences between the status of the green transition process, e.g. in two available time units. The authors are considering using such an approach as part of the next stage of their research. In the context of future research in this dimension, it is also vital to look for new factors that may influence the course of the green transition process and to combine quantitative desk research with qualitative research conducted among the main stakeholders of this process – the residents, entrepreneurs and public institutions. Such an approach is also increasingly often identified as an important complement to research in this dimension.

Author contributions

Conceptualization: K.Ch., I.B. methodology: K.Ch., I.B.; software: K.Ch., I.B., M.P.; validation: K.Ch. I.B., M.P.; formal analysis: K.Ch., I.B., M.P.; investigation: K.Ch., I.B., M.P.; resources: K.Ch., I.B., M.P.; data curation: K.Ch., I.B., M.P.; writing original draft preparation: K.Ch., I.B., M.P.; writing review and editing: K.Ch., I.B.,M.P.; visualization: K.Ch., I.B., M.P.; supervision: K.Ch., I.B.; project administration: K.Ch., I.B., M.P.; funding acquisition: K.Ch., I.B., M.P.

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