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Evaluation Model of Environmental Sustainable Competitive Tourism Based on Entropy

Model oceny środowiskowej zrównoważonej konkurencyjnej turystyki opartej na entropii

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Abstract
Despite the valuable economic benefits of tourism, it must be highlighted that the tourism industry is an important source of stress for the environment with the main influence on tourist destinations. The aim of this study is to investigate the elements of environmental sustainability in tourism as key factors in the competitiveness of tourism using entropy methods. According to the authors' knowledge, it is the first time that the entropy model applied to Environmental sustainability indicators, regarding entropy as a measure of non-uniformity among sustainability indicators of EU countries. The data of the EU were used and Environmental sustainability pillar of the Travel & Tourism Competitiveness Index. The results show that the total entropy of the competitiveness of tourism within the environmental sustainability sub-index of the EU countries speaks in favor of the uniformity of the indicators. The study also reveals significant differences among the EU27 in the domain of the Global Climate Risk index, Baseline water stress and Forest cover loss. Furthermore, convergence has been achieved so far in the indicators Red List Index and Environmental treaty ratification. Finally, the methodological approach of this study has the potential to be extrapolated worldwide, especially in the future era of global environmental problems.

Key words: environmental sustainability, competitiveness, tourism, entropy methods

Streszczenie
Pomimo cennych korzyści ekonomicznych płynących z turystyki, należy podkreślić, że przemysł turystyczny jest ważnym źródłem stresu dla środowiska, wpływającego na wybierane destynacje turystyczne. Celem niniejszej pracy jest zbadanie elementów zrównoważenia środowiskowego w turystyce jako kluczowych czynników konkurencyjności turystyki przy użyciu metod entropii. Według wiedzy autorów po raz pierwszy zastosowano model entropii do wskaźników zrównoważenia środowiskowego, traktując entropię jako miarę niejednorodności wskaźników zrównoważenia krajów UE. Wykorzystano dane z UE i filar zrównoważonego rozwoju środowiskowego Indeksu konkurencyjności w zakresie podróży i turystyki. Wyniki pokazują, że za jednolitością wskaźników przemawia łączna entropia konkurencyjności turystyki w ramach subindeksu zrównoważenia środowiskowego krajów UE. Badanie ujawnia również znaczne różnice między krajami UE-27 w dziedzinie globalnego wskaźnika ryzyka klimatycznego, podstawowego stresu wodnego i utraty pokrywy leśnej. Ponadto osiągnięto dotychczas zbieżność wskaźników Czerwonej Listy i ratyfikacji traktatu środowiskowego. Wreszcie, metodologiczne podłoże tego badania ma potencjał do ekstrapolacji na cały świat, zwłaszcza w erze globalnych problemów środowiskowych.

Słowa kluczowe: zrównoważoność środowiskowa, konkurencyjność, turystyka, metody entropijne

1. Introduction

Tourism is developing at an incredible momentum. Despite, the pandemic caused by the COVID-19 virus hit hardly the tourism sector, generating a decrease of approx. 75-80% in 2020 comparing to 2019, of outbound tourism and a considerable decrease of revenues from touristic activities (Dias, 2017), but it is expected according to the World Tourism Organization (WTO) that 1.8 billion people will engage in tourism by 2030 (World Tourism Organization, 2015). On the other hand, the tourism industry is an important source of environmental stress for the destination. Bearing in mind all the above, tourism destinations should mainly focus on sustainable development through sustainable ways in order to achieve long-lasting success (Buhalis, 2000) and find solutions that allow smarter use of resources and improve the quality of life for residents and tourists (Shafiee, 2019).

Increased awareness of people about environmental, cultural, and economic effects of tourism on destinations has caused the emergence of a sustainable approach to tourism management both in theory and practice. Some authors (Huybers & Bennett, 2003; Hu & Wall, 2005; Pulido-Fernández et al., 2015; Dimitrijević et al., 2022) have specifically referred to environmental sustainability as a key variable for the competitiveness of touristic destinations over the long term, or for improvement in the quality of life of the local population (Farsari et al., 2007). The report UNEP-UNWTO (2012: 41) suggested that investing in sustainable tourism *offers a wide range of opportunities that can generate significant returns*. This report shows so many examples of initiatives for the sustainable management of energy, biodiversity, water, or waste, which have contributed to a reduction in costs for the tourism industry. Therefore, it is important that stakeholders of tourism industry have a greater awareness of the importance that sustainability in the destination's competitiveness. In order to achieve sustainability, a continuous process of monitoring impacts and implementing preventive and corrective measures is required; it is also key to involve tourists firsthand in this process, so that they become aware and can implement good practices (Lerario & Di Turi 2018).

It is true that an investment in sustainable tourism could generate costs over the short term, but there is also evidence that the widening of these types of measures has contributed to the improvement of primary economic levels for tourism in some of the destinations where they have been implemented and so these measures have, therefore, created an improvement in those destinations' global competitiveness (Pulido-Fernández et al., 2019). Therefore, an improvement in environmental sustainability in destinations will become the key variable of touristic growth in the future.

2. Literature review

2.1. Environmental Sustainability and Tourism competitiveness

The competitive advantage in the tourism sector and the concept of destination competitiveness were subjects of numerous studies (e.g., Porter, 1990; Hong, 2009; Kayar & Kozak, 2010). Available studies indicated factors that are involved in the micro and the macro environments of tourism competitiveness and measurement indices data of competitiveness (Sanli & Baloglu, 2006). According to Manrai et al., (2018) the competitiveness of the destination should be provided a direction based on the multidimensional system, the level of economic, social and environmental conditions offered to residents and their standard of living. According to Kayar & Kozak (2010), some of the first studies related to competitive advantages and destination competitiveness in the tourism sector analyzed quantitative factors such as tourist numbers and tourism revenues while qualitative factors are considered in relation to tourist opinion (likes and dislikes) regarding their destinations. In addition, Kozak and Rimmington (1999) included additional qualitative parameters (e.g. local transport, natural environment and food, friendliness of the local people, etc.) to analyze the competitive advantages and destination competitiveness of the Mediterranean destinations. To improve the competitiveness of destinations, recent research shows the increasing importance of including indicators of sustainability (ecologically, socially, culturally, and politically). Recently, Dias (2017) analyzed the environmental sustainability index which has been included in the Travel & Tourism Competitiveness Index and published by the World Economic Forum.

Tourism as a strategically important sector provides around 12 % of the labor force and it offers further significant growth potential for the European Union, but it must be highlighted that it is a source of *environmental stress* (Dias, 2017). Today, especially in the post-COVID-19 era, the tourism industry underwent a lot of challenges and should intend more competitiveness and resilience surrounding the enhancement of social and sustainability achievements dealing with global issues (e.g. climate change and global ecological problems, and demography). In this sense, the EU tourism policy (Environmental sustainability pillar of the Travel & Tourism Competitiveness Index) is focused on promoting competitiveness and sustainability encouraging environment, transport, agriculture, culture and IT research. Opportunities for sustainable tourism development and preservation of its competitiveness are largely influenced by the quality of the environment, to preserve attractive natural and cultural heritage and other values, goods and resources (Angelkova, 2012). The level of ecological-socio-economical system development of tourist destinations indicates their competitiveness abilities. This trend is a basis for the destination's survival in the global market and ensures that the environmental dimension through the environmental sustainability standards is applied by countries and becomes a criterion for sustainable competitiveness achieving (El-Aidie et al., 2021). From the methodology point of view, previous research based on sustainability indicators was based on benchmarking analyzes and the use of Promethee model, Cluster analysis and multidimensional scaling techniques, which included competitiveness indices such as air transport infrastructure, natural and cultural resources, ground transport infrastructure, and health and hygiene (Nazmfar et al., 2019) and tourist arrivals and departure (Kayar & Kozak, 2010), or recent empirically assess the psychometric properties of the Environmental Sustainability Index reported in Crotti and Misrahi, (2015), or exploratory and confirmatory factor analyzes for 10 indicators used in the Environmental Sustainability pillar (Dias, 2017). According to the author's knowledge, this study applied the Entropy Model to Environmental sustainability indicators that have not been analyzed so far.

2.2. New innovation – Travel & Tourism Development Index

Despite the multitude benefits of tourism for many world economies, it must be highlighted that tourism is the most complicated business in many countries (Nazmfar et al., 2019). The new socio-economy crises (e.g., COVID-19 pandemic, and the war in the Ukraine) showed and confirmed that the global Travel and Tourism sector is very vulnerable and strongly depends on local, national and global occasions. This is deeply confirmed by the dramatic balance of the newest crisis, a loss of $4.5 trillion in T&T GDP and 62 million jobs in 2020. To point out, tourism is a notable sector and a valuable source of income for developed as well as developing countries. The growing diversification of tourism demands the differentiation of the advantages and disadvantages of particular destinations as crucial parameters for the improvement of tourism offers of traditional destinations and increased prospective tourist selection of new destinations (Rodríguez-Díaz et al., 2020).

In order to promote and compare the tourist destination (new and traditional) based on competitiveness, the most applied measure until now was the Travel and tourism competitiveness index (TTCI) (Kunst and Ivandić, 2021). Although according to Croes & Kubickova (2013), TTCI is highlighted as the most desirable tool for ranking countries in terms of tourism performance. Taking into account, the new occasion in tourism demands TTCI is upgraded to Travel & Tourism Development Index (TTDI) due to the importance of better understanding the new occasion in global tourism. Thus, TTDI, a direct evolution of TTCI, can be defined as *the set of factors and policies that enable the sustainable and resilient development of the Travel and Tourism (T&T) sector, which in turn contributes to the development of a country* (World Economic Forum, 2022). Comparing these two indexes, the main difference is that TTDI does not measure the level of T&T development that an economy possesses, but the potential drivers of T&T development. In essence, deeper difference analyses among them show that TTDI measures five general factors of competitiveness (environment empowerment, T&T policy and enabling conditions, infrastructures, T&T demand drivers and T&T Sustainability), thus, one more (e.g., T&T Sustainability) than the travel and tourism competitiveness index. Additionally, natural and cultural resources (a component of TTCI) are changed to travel and tourism demand drives which are split into one more subcategory non-leisure resource. Although the division of this subcategory is different, the main purpose of this component in both cases is to define the main reason for travel (Stoica, 2022).

Currently, the TTDI covers 117 countries including all member countries of the European Union. In the present study, the countries of the EU are studied in order to be compared and analyzed the new indicators of Environmental sustainability, as a part of the TTDI. Generally, it can be the direction to equalization of travel and tourism practices and policies among them.

3. Study area and data set

The study area includes 27 states from Europe, both member, and non-member states. The selection of countries is conducted considering important touristic regions and parameters (European Travel Commission, 2022; Tourism statistics- Eurostat 2021), as well as respecting the diversity of countries according to geographical distribution criteria, economic status and development. All selected countries are distributed to Central Europe, Eastern Europe, Northern Europe, Southern Europe, and Western Europe.

Herein, data from the official statistics of the Weforum Travel & Tourism Development Index for 2021 were used for the evaluation of the model of environmental sustainable competitive tourism. By updating the pillars of tourism competitiveness, emphasis was placed on Rebuilding for a Sustainable and Resilient Future. In that case, the new indicators about Environmental sustainability, developed as a separate pillar, were interesting for research within the 28 EU member states. Three groups of indicators were analyzed:

1. **Climate Change Exposure and Management** – CCM (a. Greenhouse gas emissions; b. Renewable energy; c. Global Climate Risk index; d. Investment in green energy and infrastructure),

2. **Pollution & Environmental Conditions** – PE (a. Particulate matter concentration; b. Baseline water stress; c. Red List Index; d. Forest cover loss; e. Wastewater treatment; f. Clean ocean water),
3. **Preservation of Nature** – PN (a. Environmental treaty ratification; b. Adequate protection for nature; c. Oversight of production impact on environment and nature; d. Average proportion of key biodiversity areas covered by protected area).

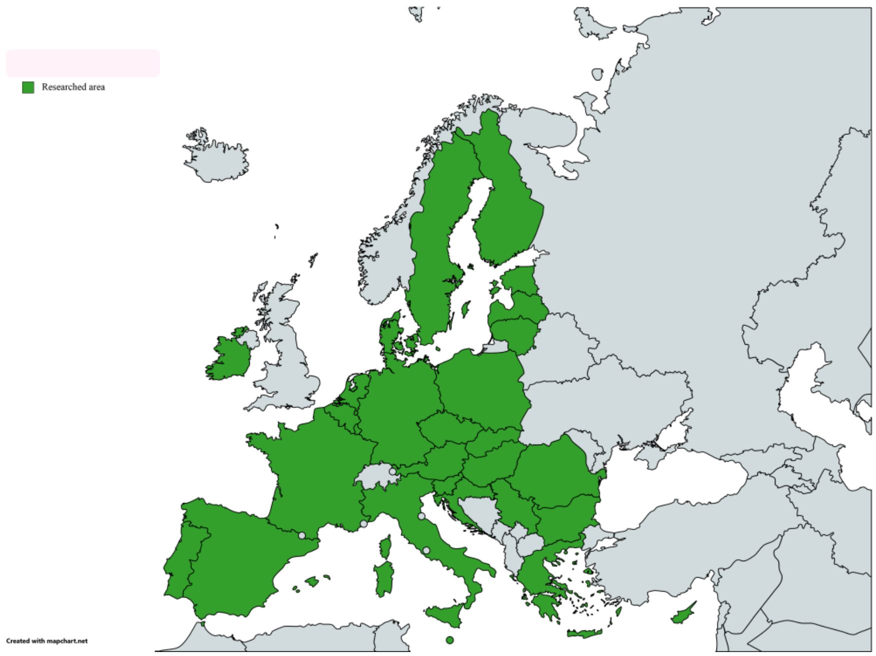


Figure 1. The map of study area (Source: Authors illustration, created by using www.mapchart.net)

The only indicator that was omitted from the analysis is Clean ocean water because data was not available for the countries Austria, Czech Republic, Hungary, Luxembourg, Slovakia and Slovenia. The value indicator within the index was taken as a measure. It was not possible to analyze and compare previous years due to the inclusion of this pillar in the competitiveness index from 2021.

4. Research methods and data analysis

Based on the regional analysis of the authors Czyz & Hauke (2015), the entropy method will be applied in the evaluation of the ecological sustainable competitive tourism model. In their research, Czyz & Hauke analyzed various entropy statistics based on Shannon's measure of entropy (Shannon, 1948), which is popular in systems theory. It starts from the assumption that any event with a low probability provides a lot of information, while an event with a high probability is less surprising and provides less information. In this way, an inverse relationship between the amount of information and probability is defined. Analogously, the methodology used by Czyz & Hauke to measure the entropy (unevenness) of regions in Poland was applied to the European Union level. In the case of measuring environmental sustainable competitive tourism, the European Union is seen as an integration of 27 regions.

The information obtained from certain events is determined by a monotone decreasing function with probability p which is displayed in the form of log $\log 1/p=-\log p$, which is also treated as a measure of the uncertainty of the occurrence of the event. For a sequence of events x_i with probabilities p_i, $i=1, 2....n$ follows (Czyz & Hauke, 2015):

$$0 \leq p(x_i) \leq 1, \sum_{i=1}^{n} p(x_i) = 1,$$

The entropy evaluation $H(x)$, defined by Shannon (1948), is a mathematical formula, which can be represented as:

$$H(x) = -\sum_{i=1}^{n} p(x_i) \log\, p(x_i)$$

or

$$H(x) = \sum_{i=1}^{n} p(x_i) \log_2 \frac{1}{p(x_i)}$$

The entropy statistic H(x) applied in this paper refers to the measure of uniform distribution that provides the basis for creating the measure of inequality I(x), i.e., the difference in the case of tourism competitiveness, the difference in the value of the given competitiveness parameter. This measure of inequality is useful in studying spatial differences between countries or regions. It can be represented by the equation:

$$I(x) = H(x)_{max} - H(x) = \log_2 n - \sum_{i=1}^{n} p(x_i) \log_2 \frac{1}{p(x_i)}$$
$$= \sum_{i=1}^{n} p(x_i) \log_2 [n\, p(x_i)\,]$$

for $0 \leq I(x) \leq \log_2 n$

where I(x) = 0 indicates the absence of inequality (or uniform distribution), while I(x) = $\log_2$ n indicates the maximum non-uniformity of the selected parameters x.

Table 1. Label and descriptive of variables, source: Authors' calculation

		Abbreviations	Minimum	Maximum	Mean	Std. Deviation
Climate Change Exposure and Management	Greenhouse gas emissions	CCM1	2.80	16.40	7.8889	3.44956
	Renewable energy	CCM2	4.40	52.50	21.6481	12.41613
	Global Climate Risk index	CCM3	41.30	125.70	81.6222	25.87604
	Investment in green energy and infrastructure	CCM4	3.50	5.70	4.6852	0.60682
Pollution & Environmental Conditions	Particulate matter concentration	PE1	5.60	22.60	12.9407	4.42921
	Baseline water stress	PE2	0.20	5.00	1.9556	1.36307
	Red List Index	PE3	0.80	1.00	.9370	0.06877
	Forest cover loss	PE4	0.00	4.00	.8111	0.77427
	Wastewater treatment	PE5	14.90	100.00	67.1259	25.02288
Preservation of Nature	Environmental treaty ratification	PN1	24.00	29.00	26.7778	1.64862
	Adequate protection for nature	PN2	2.70	5.80	4.4815	0.75143
	Oversight of production impact on environment and nature	PN3	3.20	6.00	4.5519	0.66874
	Average proportion of key biodiversity areas covered by protected area, %	PN4	46.00	94.70	71.2852	11.60185

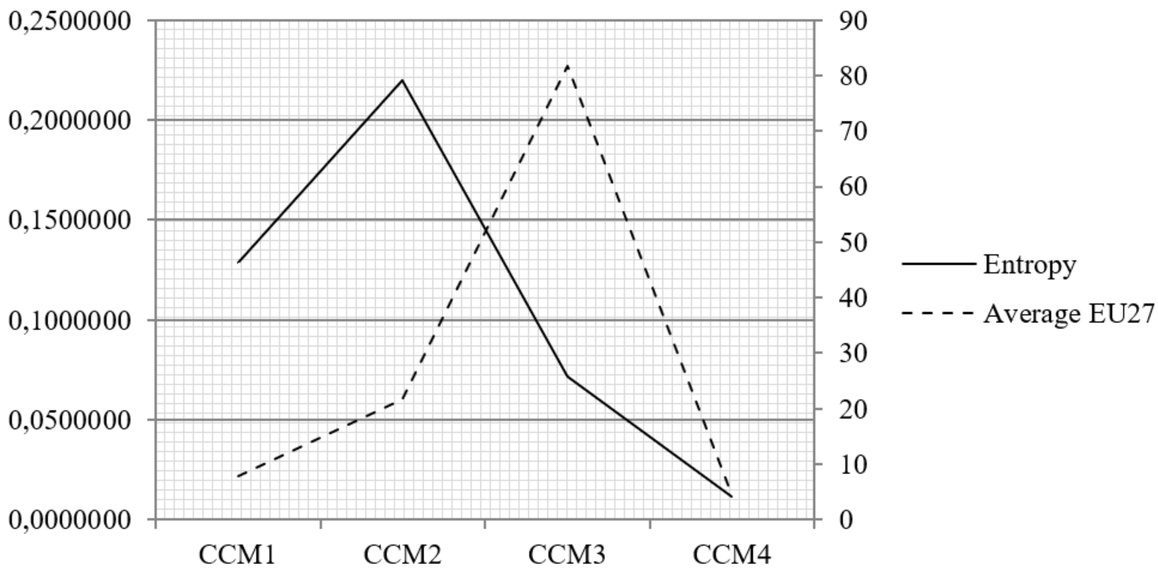
5. Results and discussion

5.1. Climate Change Exposure and Management

By evaluating the height of entropy, as a measure of inequality, we will find the results of convergence or divergence in Environmental sustainability among EU countries. Bearing in mind that the mentioned indicator is measured through three sub-pillars, the height of entropy was first calculated for Climate Change Exposure and Management in 2021.

Based on the data on the movement of entropy in 2021, we come to the result that the differences in Climate Change Exposure and Management are present mostly in the Renewable energy indicator and that in that indicator we can talk about a divergent state (because it weighs 1). This is because many countries record still low values of Renewable energy (CCM2), among which Romania, the Netherlands and Malta stand out. On the other hand, there are large oscillations in this indicator also because Sweden, Finland and Latvia have significantly higher values of this indicator. The differences are large considering Sweden which is rich in renewable energy sources (Nilsson et al., 2004) versus Romania which has very low competitiveness when it comes to renewable energy sources (Zamfir et al., 2016). Sweden uses wind energy, water energy and biomass energy as its good examples of renewable energy sources, while solar energy is less present (Qi et al, 2021). In contrast, Romania has had a low share of renewable energy in gross final consumption for years, well below its national target (Radulescu et al., 2018). Apart from renewable energy, the situation is similar with the Greenhouse gas emissions (CCM1) competitiveness indicator, but the differences between EU countries are reduced. The consequence of minor oscillations in this competitiveness indicator takes into account the EU report according to which Greenhouse gas emissions in the EU fell by 32% between 1990 and 2020 (Eurostat, 2022; European Commission, 2022). In addition to the above, the Global Climate Risk index (CCM3) also shows a height closer to 1, which indicates divergence in this indicator. On the one hand, Cyprus and Finland record this index above 120, while Italy has the lowest index with just above 40. It is assumed that the result of this high index in Italy stems from the increased hazards related to climate change, as well as the exposure and vulnerability of human and natural systems (Mysiak et al., 2018). The last indicator, Investment in green energy and infrastructure, shows the most uniformity, which results in true convergence in this indicator. This is in line with the support and obligations of the EU that by 2030, annual clean energy investments in emerging markets and developing economies must be multiplied by more than seven (WEFORUM, 2022) and EU funding possibilities in the energy sector (European Commission, 2022a).

Figure 2. Entropy Results for Climate Change Exposure and Management, source: Authors calculation



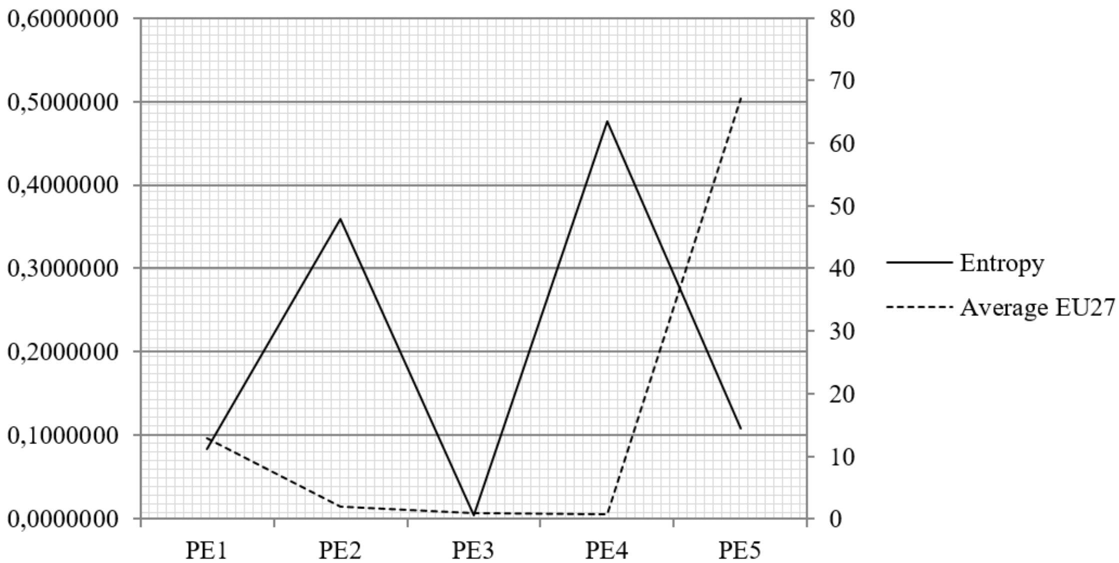
Apart from entropy, it is very important to include the movement of the average value of the Climate Change Exposure and Management sub-index in 2021. Based on the results presented, it can be concluded that during this period indicator had similar tendencies as entropy, except for the CCM1 indicator which shows the biggest differences between EU countries. However, the average values are the result of the emphasis of all countries on the sustainable concurrence of the economy, as well as the improvement of indicators.

5.2. Pollution & Environmental Conditions

In addition to the movement of the value of the Climate Change Exposure and Management competitiveness index, Pollution & Environmental Conditions in EU countries is also extremely important for the analysis of Environmental sustainability. Based on the data, the obtained results indicate large oscillations in the five indicators shown (Figure 3). The biggest differences are in the PE2 (Baseline water stress) and PE4 (Forest cover loss) indicators. The highest value of the Baseline water stress sub-index was recorded by Belgium, while the lowest level was recorded by Croatia. A higher value of this indicator also indicates higher competition. It is not surprising that, as a coastal country, Croatia records the lowest value of this indicator due to high temperatures and heat stress, as well as weak vegetation, which creates low water stress in Croatia (Eriksen et al, 2021). In addition to the above, high temperatures also complicate the requirements for crop development. On the contrary, due to its climate and temperature, especially near the coasts, Belgium has reduced summer temperatures, which also affects less stress in PE2 (Vanuytrecht et al., 2016). There are also high differences in the PE4 indicator, with the Czech Republic recording the maximum values, and Malta the minimum values. Malta is one of six geographic territories in the world (Aruba, the Faroe Islands, Greenland, Guernsey, Malta and Norfolk Island) that have reported zero forestation (Keenan et al, 2015).

In addition to the above, indicators such as Particulate matter concentration (PE1), Red list index (PE3) and Wastewater treatment (PE5) are also important. Countries with the highest values of Particulate matter concentration is Poland and Bulgaria, while Finland has the lowest value. For example, the authors point out that the Łódź region in Poland is the area with the most air pollution (Bem et al., 2003). More recent analyzes claim that these are Wroclaw and Poznan, which record the dominant process of fuel combustion as a source of particles (Sovka et al., 2019). On the other hand, as Bulgaria is part of the Danube region, the Danube region has the epithet of European *hot spots* of air pollution (Perrone et al., 2018). In fact, the countries of the Balkan Peninsula that record high CO_2 emissions include: Croatia, Serbia, Montenegro, Romania and Bulgaria. Contrary to the above, Finland has introduced vehicle innovations in its country. Thus, for example, in Finland, diesel fuel with ultra-low sulfur content is used in road traffic or so-called third-generation cars that use compatible natural gas (Tainio et al., 2005).

Figure 3. Entropy Results for Pollution & Environmental Conditions, source: Authors calculation



As for the Red List Index, the values here are quite uniform among all EU countries, so we can talk about absolute convergence in this indicator, which means that the monitoring of biodiversity sustainability is similar in all analyzed countries. The Wastewater treatment indicator has a slightly higher, but entropy value closer to 0 than 1. However, interestingly, the highest value is Malta (100), and the lowest is Cyprus (14.9). Malta is cited as one of the most active countries in the field of wastewater treatment, although some other countries have already adopted regulations on the reuse of wastewater such as Greece, Italy, Portugal and Spain (Lavrnić et al., 2017). Finally, it should be pointed out that the average values were different in relation to the entropy values and that these oscillations were significant.

5.3. Preservation of Nature

A long time ago, Preservation of Nature was highlighted as a very important component of the future development of tourism (Coppock, 1982). In this regard, this indicator is a component of the competitiveness of tourism. Environmental treaty ratification (PN1), Adequate protection for nature (PN2), Oversight of production impact on environment and nature (PN3) and Average proportion of key biodiversity areas covered by protected area (PN4) are considered within this sub-index. When it comes to the difference in this sub-index, EU countries achieve the greatest convergence in Environmental treaty ratification, bearing in mind the various Multilateral Environmental Agreements. The most discrepancies are observed in the PN2 indicator. Denmark has the highest value, and Malta and Romania have the lowest. Based on the UN Convention on Biodiversity, all EU member states are obliged to develop an agricultural indicator of high natural value (HNV). Denmark is one of the first countries to recognize the high value of fertile areas (Brunbjerg et al., 2014). The Danish government also presented its vision for the protection of nature and the countryside until 2050 (Danish Government, 2014). Malta's result is confirmed by the fact that it is the EU member state with the largest number of urbanized areas (Concepción, 2021), while Romania stands out as a country with a high risk of disasters that affect the natural environment, such as gas explosions or fires (Appleby Arnold et al., 2021). In order to carry out a comparative analysis of the measured inequalities in the observed indicators, Figure 4 shows the movement of entropy for all 13 observed indicators.

Figure 4. Entropy Results for Preservation of Nature, source: Authors calculation

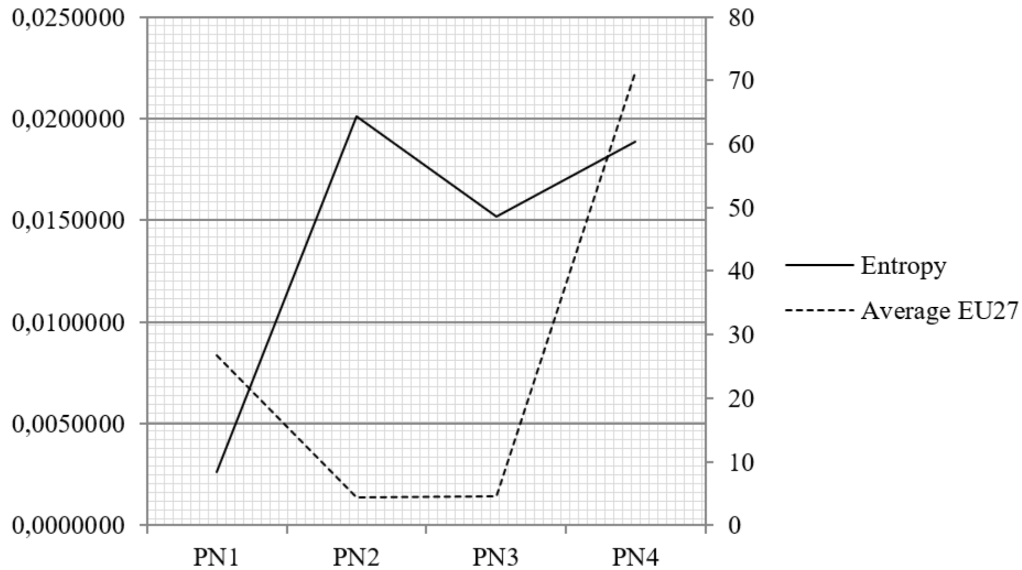


Figure 5. Composite representation of the entropy movement of the Environmental sustainability subindex, source: Authors calculation

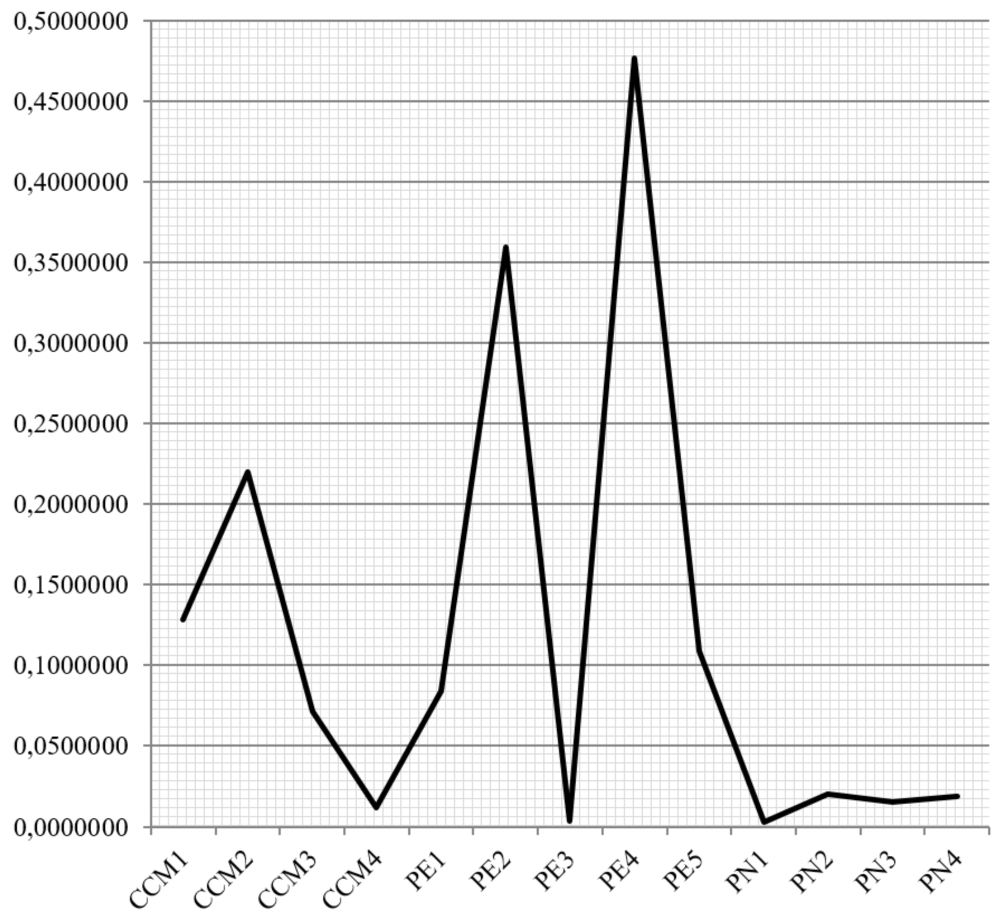


Figure 5 shows that the highest entropy is recorded precisely in the indicator showing Forest cover loss (PE4). This is because some countries, such as Malta, have zero forest cover, while other countries are in a much more competitive position. Entropy is also high in the indicator PE2 - Baseline water stress. Furthermore, the entropy is very low, and we can talk about convergence in the indicators PN1, PN3 and PN4, as well as CCM4. Finally, it can be pointed out that the biggest differences are in the Pollution & Environmental Conditions sub-index. However, no difference exceeds 0.5, which indicates that there are adjustments within this sub-index of tourism competitiveness.

6. Conclusion

The entropy method is applied by many authors in different scientific fields, in the natural as well as social sciences. This study also applied the entropy method, but in a multidisciplinary manner combining the knowledge from natural sciences (ecology, eco-management, etc.) and social sciences (tourism competitiveness). Comparing the sustainable development indicators, the potential existence of convergence or divergence in the given indicators of the EU countries was analyzed. The empirical assessment of entropy in this study contributed to the policy patterns of tourism competitiveness and sustainable development, as an inseparable integration unit. In addition, it has been proven that entropy can be an effective tool for determining and evaluating the differences among countries. The results of the entropy method estimate the heterogeneity of sustainable development among the EU28 countries, that request further harmonization in order to achieve sustainable development.

Empirical as well as theoretical basis pointed once again to the confirmation that the EU population is exposed to high PM particles that exceed the air quality prescribed by the World Health Organization. In addition, the biggest consequence of an unsustainable natural environment and polluted air are the costs of premature deaths, which is estimated at up to 100 billion euros (WHO, 2015). Taking in account all facts, it is urgent to define recommendations for the improvement of air quality and also all observed indicators, in oder to Europe can be estabished by sustainable development in the long term. First of all, it is necessary to remove disparities and improve convergence in the environment of sustainable development.

The research limitations refer to countries within Europe and an insufficient number of similar studies that analysed this set of parameters in the last period. Additional research should be spread on a large-scale and global level including analysis from other continents. The methodological approach of this study has the potential to be extrapolated worldwide, especially in the future era of global environmental problems.

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