Quantification of Economic, Ecological and Social Impacts of Climate Change in the EU

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Abstract

The article focuses on the current, urgent, and much discussed global issue of climate change, the impacts of which are expansive and involve a wide range of expertise. The base forms the evaluation of a sample of European Union member states using the quantification of threats and intensity of two key factors. The main objective of this article is to evaluate EU countries the INFORM assessment tool and to highlight the link between the effects of climate change (environmental, social, and economical) as quantified by respective threats posed by emission volume and poverty. In the present research, we relied on the new INFORM Risk Index assessment indicator because it represents a completely new but also globally applicable, reliable, and transparent tool to understand the risk of humanitarian crises and disasters. The significant results of the performed quantitative analysis suggest that security risk, poverty, and pollution levels operate as closely linked areas. It can be expected that recent changes (the COVID-19 pandemic, state of war) will mean that these influences will increase in severity.

Keywords: climate change; environment; national economy; poverty; emissions

JEL Classification: Q56; Q01; F01;

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1. Introduction

Today’s world faces numerous economic, social, socio-political, and environmental problems, all of which have a global dimension due to the blurring of borders and interconnections (Ključnikov *et al.,* 2022). Certain factors that determine economic or social aspects are also influenced by seemingly less influential factors. Yet global problems of both international and non-economic origins are proving to have an increasingly fundamental impact on the economic functioning of the world's countries. Although

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technological progress, the latest innovations and solutions, and the intensive use of natural resources provide benefits to meet the needs of businesses (Civelek *et al.*, 2020; Ključnikov *et al.*, 2021), especially in manufacturing, service industries (Stefko *et al.*, 2020a; Stefko *et al.*, 2020b), people, workers (Zamir and Kim, 2022), and wider society, they also have negative consequences. This is especially true in terms of the environment even though some businesses implement strategies regarding corporate social responsibility (Metzker and Zvarikova, 2021; Metzker *et al.*, 2021). In addition to other environmental problems, climate change is also having an increasing impact on the global economy. The concept of climate change is becoming increasingly familiar not only in professional circles but also with the lay public. Climate change is a long-term change in the average weather patterns that have come to define Earth's local, regional and global climates (Shaftel, 2022). The negative effects of climate change could be prevented, albeit only partially, by, for example, political decisions and more effective public policies aimed at gradually reducing greenhouse gas emissions. In recent days, the issue of refugees fleeing war has increasingly come to the fore. There are well-known reasons for migration connected with the difference in the quality of life and social justice (Mishchuk *et al.*, 2018), job opportunities (Bite *et al.*, 2020; Oliinyk *et al.*, 2022; Přívarová *et al.*, 2022; Cizrelioğullari and Babayiğit, 2022) and overall well-being (Khalid and Urbański, 2021; Mishchuk and Grishnova, 2015; Vučković and Škuflić, 2021). Yet little is said about 'environmental refugees', who can be viewed as a very contemporary type of refugees (Venkataraman, 2018; McLeman and Gemenne, 2018; Ilmarinen *et al.*, 2021). We term environmental refugees as those who move en-mass to another part of our planet—mainly because of the negative impacts of natural disasters and accompanied by a lack or complete unavailability of clean drinking water, basic food, health care, infrastructure, homes, and other factors essential for human life. This issue is especially pressing from a geographical point of view, especially in sub-Saharan Africa. In terms of migration, the largest numbers are arriving in Europe due to the negative impact of poverty or various military conflicts (Black, 2018; Vettorass-Amorim, 2021). Climate change is primarily evaluated from the perspective of experts in environmental science, ecology, biosphere, and physics. But is climate change solely an environmental problem? Does climate change only impact the environment and nature or human life? The driving force behind this article is the belief that climate change's negative effects also spill over into the economy, businesses, tourism, and other domestic economy sectors and that it is necessary to adopt a more proactive approach to studying climate change and its effects concerning the business sector.

Climate change not only affects everyday life and the environment but also impacts factors necessary for the production of goods and economic activity as a whole. The vulnerability to climate change has different extent which leads to more vulnerable countries seeking responses in the light of achieving sustainable development goals (Bolesta, 2020), including green economy programs, energy strategies, and other initiatives related to climate change (Krzymowski, 2020). The economy is not only affected by climate change, but it is also its perpetrator as growth in production and consumption gives rise to more greenhouse gas (henceforth GHG) emissions. The most important part of the economy that determines the rate of emissions is the energy system or the forms and uses of energy (Nikas *et al.*, 2019). Although the direct impact of climate change is local, its impact goes beyond and can also be seen in more remote regions and several national sectors, as they are not only economically but also financially interconnected according to the McKinsey Global Institute (Woetzel *et al.*, 2020a). It is clear that the world's poorest countries are most affected and therefore the most vulnerable. Climate change is a form of risk that contributes to shaping spatial inequality, which in practice means that while climate change can harm one region, it can conversely benefit another. From an economic point of view, it can be agreed that climate change can—for example—disrupt food production due to extreme drought, high temperatures, or heavy rains that cause floods and destroy crops and soil. As a result of these natural disasters that stem from climate change, physical assets entering the economic cycle may also be damaged or rendered inaccessible. Buildings and technologies are essential for the production of many goods and, if destroyed by floods, torrential rains, fires, or other risks, become economically unusable. But the negative effects of climate change are felt economically beyond the production of tangible goods. Also impacted is the production of services, as damaged infrastructure/assets can lead to decreased services/revenues and increased costs to compensate for such losses. In the last two years, oft-cited tourism has also been feeling the impacts of climate change. The northern regions of Europe are seeing rising temperatures which can support tourism, but economic activity may be reduced in southern European countries as a result of that climatic impact. This is a serious problem because the Mediterranean is characterized by a climate that supports the development and existence of both tourism and agriculture (Woetzel *et al.*, 2020b).

It has been widely observed that climate change also includes a general increase in temperature. In practice, this means that the number of days with an average temperature above 37°C is increasing. These changes in temperatures and climate negatively impact both tourism and the primary sector. According to the McKinsey Global Institute (Woetzel *et al.*, 2020b), Mediterranean countries will have to invest increasingly in adaptation programs. Forecasts suggest that countries such as Italy, Portugal, Spain, and parts of Greece will face drought for at least six months of a year. This will be accompanied by the gradual scarcity of water in these popular destinations. Mediterranean agriculture is focused on four standard crops: grapes, wheat, tomatoes, and olives, most of which are water intensive. So, in Italy, Portugal, and Spain there is a genuine risk of a major decline in agricultural production due to these climate changes and their negative effects. Coastal farmers are already actively taking measures to grow crop varieties that are less water-intensive and mature more slowly. In terms of tourism, the situation is different: the summer season is extended due to the Mediterranean's warming climate, so tourist destinations can offer residential and recreational services even during 'off-season' months.

As has been shown, climate change has a much wider impact on the functioning of economic actors across the whole range of the national economy (Ahmad *et al.* 2022). These are not only commercial interests but also other economic units that perform economic or similar economic activities (Can *et al.* 2022). The biggest threats and active connection of natural resources to the climate are apparent in the primary sector, as a country without a well-functioning primary sector will struggle to get by. The effects of climate change on tourism are differentiated due to a change in climatic temperatures, with disparities that can secondarily cause less-than-welcome effects.

Potential losses arising from climate and environmental risks depend primarily on the adoption of future climate and environmental policies, technological developments, and changes in consumer preferences and market attitudes (Neagu *et al.*, 2022). Yet regardless of these factors, a certain combination of physical and transitional risks is most likely to be reflected in the balance sheets of eurozone institutions and the economic value of their business exposures.

Current estimates of the adverse long-term macroeconomic effects of climate change point to significant and enduring asset losses. Such may be due to a slowdown in investment and lower productivity in many economic sectors, as well as lower potential gross domestic product (GDP) growth, an issue summarized by Dunz and Power (2021).

After outlining the significance of the presented topic and the reasons for a deeper analysis of climate change in relation to economic life, the next part of this article will deal with the theoretical background.

Although various studies investigate the impacts of economic, social and demographic variables on various disciplines and in various countries, this study differs by aiming to analyze EU countries by using the INFORM Risk Index evaluation tool. It also seeks to highlight the link between the effects of climate change (environmental, social, and economic) as quantified by the respective threats of emission intensity and poverty. This article also verifies the validity of the following two hypotheses.

H1: There is a significant correlation between the effects of climate change (environmental, social, and economic) as quantified by the respective threats and emission intensity.

H2: There is a significant correlation between the effects of climate change (environmental, social, and economic) as quantified by the respective threats and poverty.

2. Material and methods

In addition to the issue's theoretical background, this article also addresses the empirical side with a focus on the effects of climate change. Hence, this article's concept required the initial search, summary, classification, and identification of literary sources that are appropriate and relevant to this topic. Within the definition of material, the paper relies mainly on the latest published studies from academics, experts, and international institutions that have had an active and long-term interest in the subject matter. Start-point sources were secondary literary sources, which were mostly of foreign origin as climate change has global impacts. The topic also concerns European Union member states, including Slovakia. Hence, the opinions and views of European and Slovak experts are also presented. Furthermore, both the latest and most relevant sources, as registered in international scientific databases, were used to reflect the very latest scientific knowledge. Studies and documents from international institutions helped to gain a more comprehensive understanding of the issue as well as its complexity, interdisciplinarity, and connection to the world's economic functioning.

A methodological approach to an issue is one of the most challenging areas of scientific research. Before the actual methodological anchoring, it is necessary to consider the research sample that will be the subject of deeper research. The research sample for a more detailed assessment consists of all 27 European Union member states (European Commission, 2022). In addition to the research sample, methods and methodological procedures crucial for scientific work are also defined. The present research relies on the new INFORM evaluation indicator.

Lal *et al.* (2011) classify climate impacts into three sub-areas: ecological, social, and economic. The INFORM assessment tool is a completely new and global, reliable, transparent open-access tool with continuous updates to understand the risk of humanitarian crises and disasters. It is a proactive framework for crisis and disaster management that helps to objectify the allocation of resources at times of disaster. It focuses on the opportunity to coordinate respective activities related to forecasting and mitigation options as well as crisis preparation. The INFORM assessment tool includes a combination of indicators that can be stratified into three risk levels (Marzi *et al.*, 2021):

- Hazards and exposure (i.e., events that may occur/are occurring),
- Vulnerability (i.e., the sensitivity of communities to these threats),
- Lack of coping capacity (i.e., lack of resources to mitigate the impact of threats).

The mathematical quantification is represented by the following formula:

$$Risk = \sqrt[3]{Hazard\ \&\ Exposure \times Vulnerability \times Lack\ of\ coping\ capacity}$$

To interpret the INFORM indicator, it should be noted that individual components are normalized to an evaluation score from 1 to 10: the higher the indicator's values, the worse the conditions suggested. Values are also aggregated through an average, either arithmetic or geometric, based on the metric. Thow *et al.* (2020) highlight that the index has had periodic annual updates and innovations since 2015. A graphical representation of the INFORM Risk Index's structure is illustrated in the following ***Table 1***.

Table 1. Structure of the INFORM Risk Index

Risk	Dimensions	Categories	Components
INFORM	HAZARD & EXPOSURE	Natural	Earthquake, Tsunami, Flood, Tropical cyclone, Drought, Epidemic
		Human	Current conflict intensity, Projected conflict intensity
	VULNERABILITY	Socio-Economic	Development deprivation, Inequality, Aid dependency
		Vulnerable groups	Uprooted people, Other vulnerable groups
	LACK OF COPING CAPACITY	Institutional	Disaster Risk Reduction, Governance
		Infrastructure	Communication, Physical infrastructure, Access to health care

Source: according to INFORM (2022).

The most common basic measure of national wealth is the GDP, which measures the value of all goods and services produced by a country during a given period (usually a year). Purchasing Power Parities (PPP) are generally defined as spatial deflators and currency converters, which eliminate the effects of differences in price levels between countries. GDP per capita in purchasing power standards is a very important indicator among the wide range of available statistical indicators. It is an important analytical tool and is closely monitored by policymakers, who seek to compare the economic development of member countries, and even economic policy.

The first effects of climate change are already beginning to affect the world, including Europe. Extreme weather fluctuations such as drought, heavy rain, floods, and landslides are becoming more common. Climate change is also resulting in rising sea levels, overpopulation of regions due to migration, and loss of biodiversity. Greenhouse gases differ considerably in their quantitative climatic effects, as such gases have different properties and different lifetimes. Carbon dioxide is a major contributor to global warming (Nordhaus, 1991). The CO_2 emissions per unit of value added (GVA) indicator represents the number of emissions from fuel combustion produced by an economic activity per unit of economic production. In a calculation for a whole economy, it combines the effects of the average carbon intensity of energy mix (associated with the share of different fossil fuels in the total number); the structure of the economy (linked to the relative weight of energy-intensive industries); and average energy efficiency.

From the methods used, this paper considers it methodically necessary to clarify the main component analysis (PCA). In addition to the summary, the research also helps to visually present information that is part of the observation data set that describes many mutually correlated quantitative variables. The database's information can be quantified through overall variance. The PCA mainly aims to reduce the breadth of multidimensional data by creating two or three significant components. These can then be graphically visualized.

Biplot as a graph represents a generalization of the classical scatter plot using two variables. Such a graph also enables the visualization of data matrix information, including observations and variables, in a single graph. The principal component maintains a certain amount of variance, which the present study quantifies by the eigenvalue of the correlation matrix. The total variance of the "reduced" data is then equal to the sum of the eigenvalues. It can also be stated that the proportion of variance given by the main component is equal to the value of the eigenvalue divided by the sum of all eigenvalues. In terms of standardized data, the number of variables is equal to the sum of the eigenvalues of the correlation matrix (Kassambara, 2017).

The applicability of the INFORM Risk Index to similar objects supports its usage for the grouping of similar objects that result in cluster compactness. This article uses the abbreviations of the states of the European Union according to Eurostat (2022). The calculations were performed in the R computing environment.

3. Results and discussion

The focus of this article is to support the presentation of the study's findings based on processed data. In addition to the presentation of achieved results, this part of the scientific article is supplemented by an active discussion with other experts, i.e., the authors of highly-regarded outputs regarding this issue. Thus, the study's results are measured against the results and opinions of other experts across the academic spectrum.

The first part of the result's presentation interprets the results that were obtained from calculations within descriptive statistics. The results are shown in ***Table 2***.

Table 2. Descriptive statistics

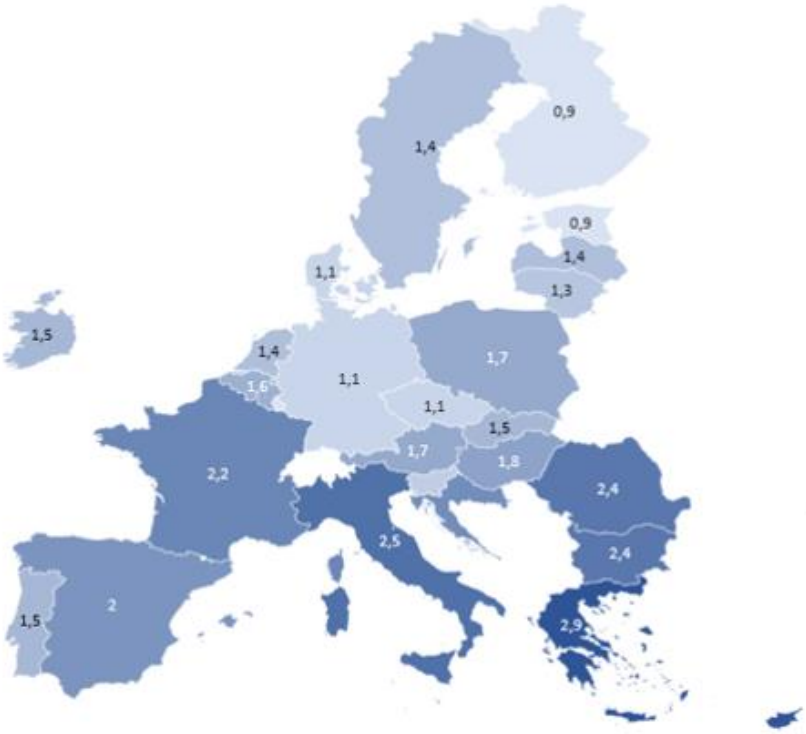
Indicator	Acronym	Mean	Standard deviation	Median	Minimum	Maximum	Skewness
Greenhouse gases */	GVA	0.34	0.19	0.30	0.10	0.92	1.17
GDP per capita PPP	GDPperCAPITAPPP	26547	17523	20410	6380	82250	1.42
INFORM Risk Index	INFORMRISK	1.68	0.58	1.50	0.90	2.90	0.56
Natural hazard	NATURAL	2.73	1.38	2.50	0.50	5.90	0.37
Human hazard	HUMAN	0.05	0.12	0.00	0.00	0.50	2.73
Socio-Economic	SOCIOECON	0.64	0.44	0.50	0.20	1.90	1.34
Vulnerable groups	VULNERABLE	2.82	1.62	2.70	0.80	6.40	0.44
Institutional	INSTITUTIONAL	3.03	0.88	3.00	1.70	4.70	0.18
Infrastructure	INFRASTRUCTURE	0.95	0.35	0.80	0.50	1.90	0.97

Note: */ Greenhouse gases (in CO_2 equivalent) in grams per Euro of gross added value
Source: own calculations

Digging deeper into the calculated values reveals that the skewness coefficient has positive values for all indicators. This practically infers that most of the values are more to the left of the average. The highest skew was recorded in the category HUMAN HAZARD (2.73). Up to 21 states have a recorded value of zero in this category. Within all INFORM Risk Index categories, the highest degree of variability was found in the category VULNERABLE GROUPS (1.62) and the lowest in HUMAN HAZARD (0.12). The highest maximum measured value (6.4) can also be found in the VULNERABLE GROUPS category. In the case of Balkan countries (i.e., South-Eastern Europe represented by Bulgaria, Romania, etc.) and the Mediterranean (i.e., Greece, Croatia, Italy, France, Spain, Cyprus, etc.), the highest INFORM Risk Index values were recorded (2+).

In order to achieve the best possible picture, the next part evaluates individual categories of the three INFORM Risk Index dimensions. The values of the INFORM Risk Index for 2020 can be seen in ***Figure 1***.

Figure 1. INFORM Risk Index values in 2020



Source: own graphic presentation of INFORM Risk Index values

3.1. Analytical view of the HAZARDS & EXPOSURE dimension

A typical hazard-dependent factor is physical vulnerability, which is assessed separately in the HAZARDS & EXPOSURE dimension (***Figure 2***). The HAZARDS & EXPOSURE dimension has two aspects natural hazards and human-caused hazards. In the natural hazard category (NATURAL), we can monitor six components that are aggregated by a geometric mean. These components include people annually exposed to the risk of earthquakes, tsunamis, floods, cyclones, epidemics, and drought (number affected, frequency of drought, exposed cropland).

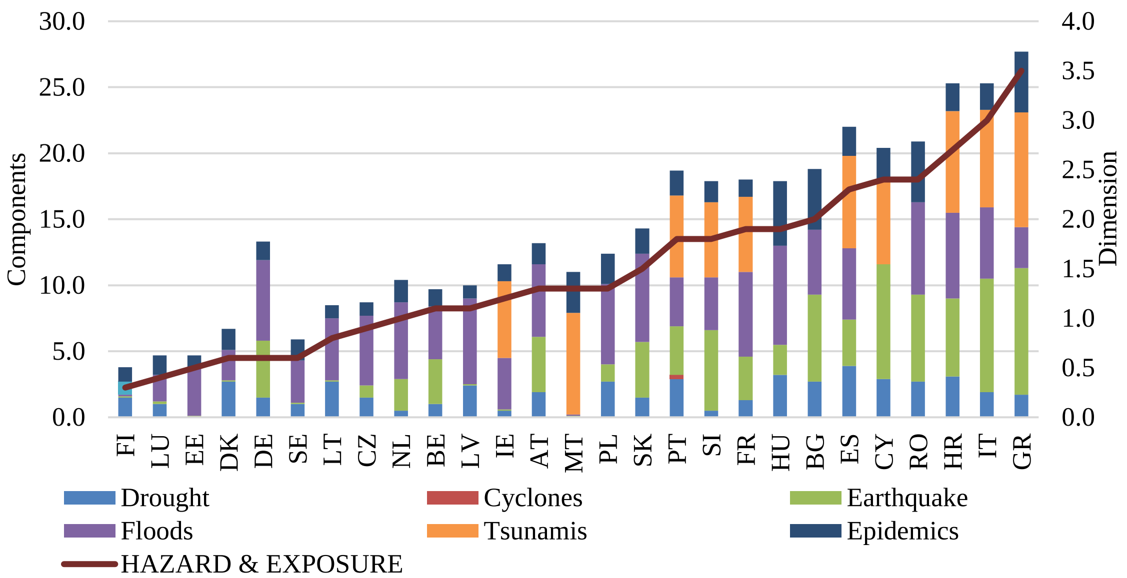
Biological risks i.e. epidemics, pandemics etc. (Marzi *et al.*, 2021) have a significant impact on mortality and morbidity, as well as on trade, tourism, and other socio-economic areas.

The component epidemic was included in the HAZARD & EXPOSURE dimension in 2020.

In terms of epidemic risk, HU (4.9), BG (4.6), GR (4.6), RO (4.6), and MT (3.1) have the highest values. The average value is 2.10. Tsunamis represent a significant threat in coastal countries; these include GR (8.7), MT (7.7), HR (7.7), IT (7.4), ES (7.0), CY (6.4), PT (6.2), IE (5.8), SI (5.7), and FR (5.7). The average threat, in this case, is 2.53. Water is an abundant element, hence flooding also plays a key role. The average threat assessment for flooding is 4.44. Floods are the biggest risk in countries such as FR (6.4), HR (6.5), LV (6.5), SK (6.7), RO (7.0), and HU (7.5). Another natural threat are earthquakes. In this case, the average threat value is 3.21. The most vulnerable countries to earthquakes are GR (9.6), CY (8.7), IT (8.6), RO (6.6), and BG (6.6). Countries are increasingly plagued by drought; its average threat value is the lowest with -1.82. In this case, the most at-risk countries are ES (3.9), HU (3.2), HR (3.1), PT (2.9), and CY (2.9).

Human-caused risks (HUMAN) are, for example, technological in nature; an example of the impact of industrial accidents on the environment or their sociological nature—e.g., high crime, civil unrest, terrorism—will be given. In terms of population and economy, all disasters also have humanitarian risks. These include supply disruptions, water shortages, destruction of civic authorities, refugees, and hindered access to healthcare or negatively impacted quality or scope of such healthcare (Marzi *et al.*, 2021). Human-caused risks have a non-zero value only in RO (0.6), BE (0.4), BG (0.1), FR (0.1), and PL (0.1).

Figure 2. Components of the Natural Hazard category



Source: own representation according to the INFORM Risk Index values in 2020

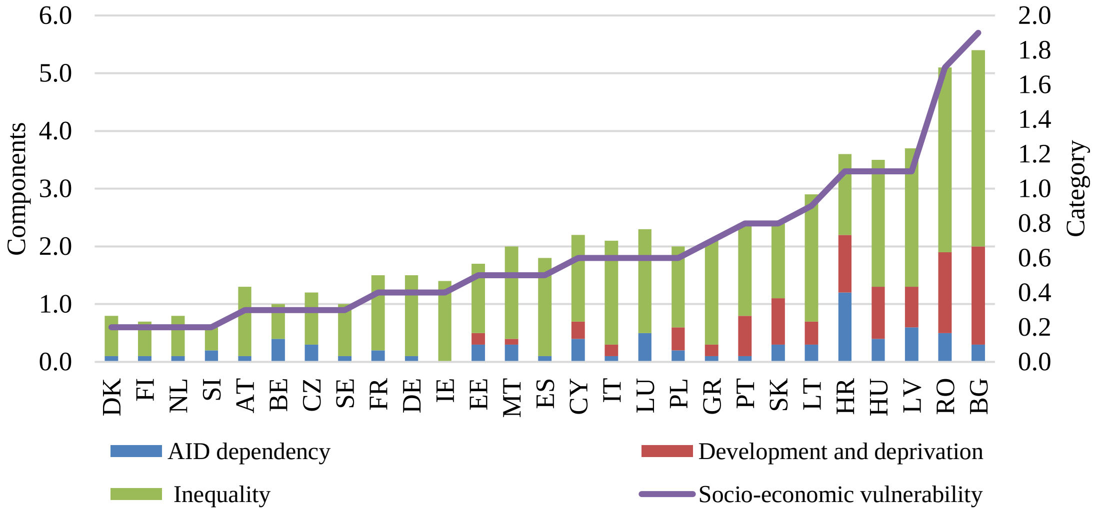
Natural phenomena such as floods, extreme drought, and fires result from frequent acute and extreme weather events. These are more intense results of climate change and cause decreased quality of life, disruption of business activities, and property damage. Countries in the southern part of the European Union have higher values in the HAZARDS & EXPOSURE dimension. In this case, the category of natural hazards clearly prevails.

3.2. Analytical view of the VULNERABILITY dimension

The VULNERABILITY dimension represents the economic, political, and social determinants of a community that can be destabilized in the case of a risk event. In this dimension, two categories can be distinguished: SOCIO-ECONOMIC VULNERABILITY (SOCIOECON) and VULNERABLE GROUPS (Marzi *et al.*, 2021). The SOCIO-ECONOMIC VULNERABILITY category refers to a country's demographics at a general level. Its component development and deprivation (weight 0.50) is a function of the Human Development Index and Multidimensional Poverty Index. The component inequality (weight 0.25) includes the Gini Index and Gender Inequality Distribution. The AID dependency component (weight 0.25) helps to identify those countries that are characterized by a reserve for sustainable development growth as a result of economic instability and humanitarian crisis. This dimension comprises two indicators: Public aid per capita and net official development assistance (ODA), which has been accepted by the World Bank as a percentage of the gross national income.

Figure 3 illustrates that the biggest differences can be identified in the category of SOCIO-ECONOMIC VULNERABILITY. These are included in the inequality component. Countries such as BG (3.4), RO (3.2), LV (2.4), HU (2.2), LT (2.2), GR (1.8), LU (1.8), and IT (1.8) show the highest values.

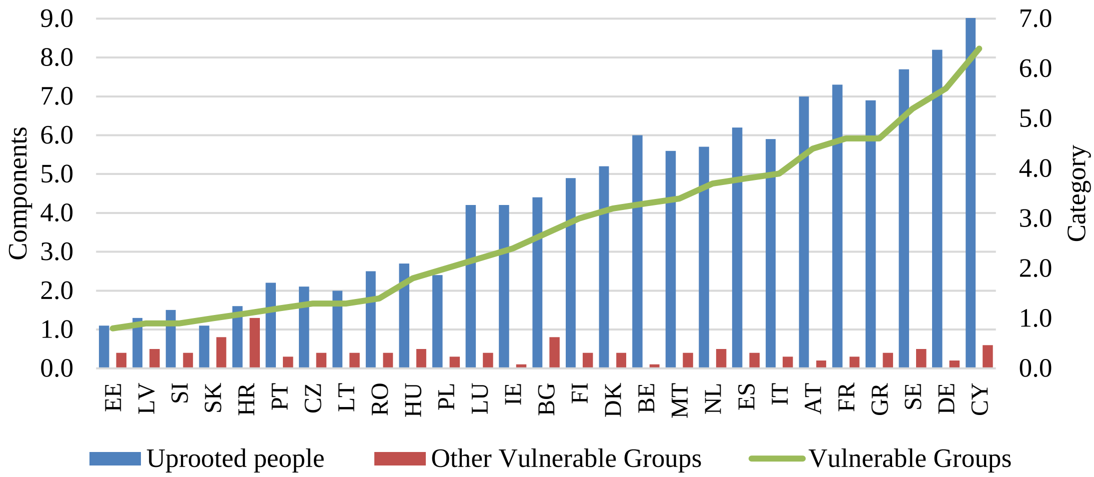
Figure 3. Components of the Socio-economic Vulnerability category



Source: own representation according to the INFORM Risk Index values in 2020

The VULNERABLE GROUPS category (***Figure 4***) represents those social groups that have limited access to social and health care systems. The VULNERABLE GROUPS category comprises two parts: "uprooted people" and vulnerable groups. The term "uprooted people" refers to refugees, returned refugees, and internally displaced persons. Uprooted people are effectively less respected, as they are not part of society or the social system. These sections of the population are only partially supported by the community and are often the trigger for humanitarian intervention. From an analytical point of view, Other Vulnerable Groups are calculated from the values of the prevalence of HIV-AIDS for 15+ years, as well as other diseases and their prevalence. These include tuberculosis, malaria mortality, child malnutrition, child mortality, relative populations affected by natural disasters over the last three years, malnutrition prevalence, average adequacy of energy supply, domestic food price index, and domestic food price volatility (Marzi *et al.*, 2021).

Figure 4. Selected components of the Vulnerable Groups category



Source: own representation according to the INFORM Risk Index values in 2020

In the case of the Uprooted people indicator, countries with the highest values are typical destinations for migrant flows (European Parliament, 2020). These are countries such as CY (9.1), DE (8.2), SE (7.7), FR (7.3), AT (7.0), GR (6.9), ES (6.2), BE (6.0), IT (5.9), NL (5.7), and MT (5.6). The indicator Other Vulnerable Groups shows its highest values in the case of countries such as HR (1.3), SK (0.8), BG (0.8), CY (0.6), LV (0.5), HU (0.5), NL (0.5), and SE (0.5).

3.3. Analytical view of the LACK OF COPING CAPACITY dimension

A country's ability to cope with disasters can be quantified using the LACK OF COPING CAPACITY dimension. Aspects can include organized activities and efforts of a country's government, the formal aspect as well as the existing infrastructure that can contribute to disaster risk reduction (DRR) being taken into account. The dimension includes the INSTITUTIONAL and INFRASTRUCTURE categories (Marzi *et al.*, 2021).

The INSTITUTIONAL category can be used to quantify government priorities as well as the institutional basis for implementing DRR activities. In terms of calculation, the calculation is based on the arithmetic average of the two components DRR and Governance.

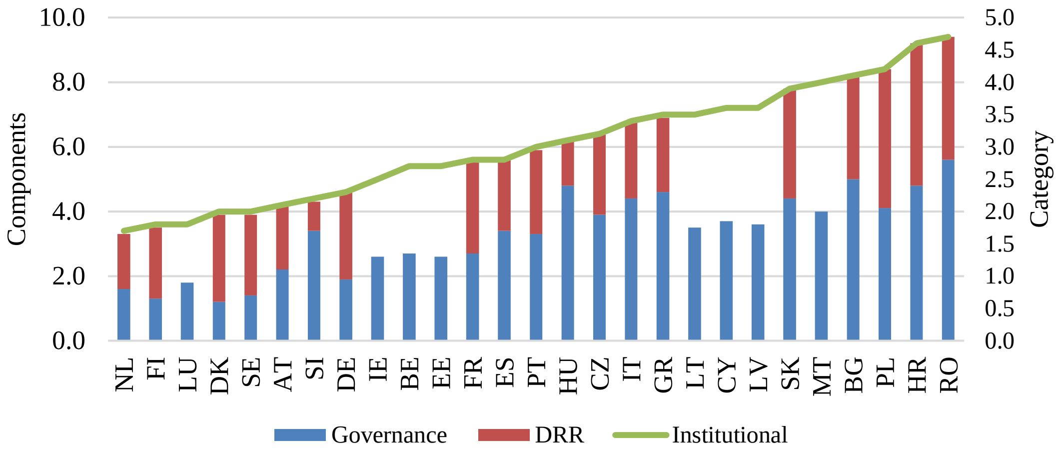
DRR includes the following thematic areas: Ensuring disaster risk reduction processes so that these activities are not only a local but also a national priority, with a strong institutional basis for implementation; Disaster risk identification, assessment, and mapping and improvement of early warning; Building a multi-level process of security and resilience through the use of knowledge, innovation, and education; Strengthening disaster preparedness, which can be an effective response at all levels.

The Governance component includes the perception of public service quality, state administration and its degree of independence from political pressures, as well as the quality of policy formulation and implementation. This component is calculated from two indicators: Government Effectiveness and Corruption Perception Index.

The INFRASTRUCTURE category has the components Communication Networks (with several indicators such as access to electricity, internet users, and mobile cellular subscriptions), Physical Infrastructure (including road density and access to improved sanitation facilities), and Accessible Health Systems (including density of Physicians Health Expenditure per capita and Measles Immunization coverage).

Figure 5 shows the values of the INSTITUTIONAL category components (Governance, DRR). In terms of the INSTITUTIONAL category, the highest values in this category were recorded in the following countries: RO (4.7), HR (4.6), PL (4.2), BG (4.1), MT (4.0), SK (3.9), CY (3.6), LV (3.6), GR (3,5), and LT (3.5). In the case of the DRR component, it is evident from the figure that the worst values are reported by countries such as HR (4.4), PL (4.3), RO (3.8), SK (3.4), BG (3.2), and FR (2.9). In the latter case, for the Governance component, the highest values (which represent the worst evaluation) are achieved by countries such as RO (5.6), BG (5.0), HU (4.8), HR (4.8), GR (4.6), IT (4.4), and SK (4.4).

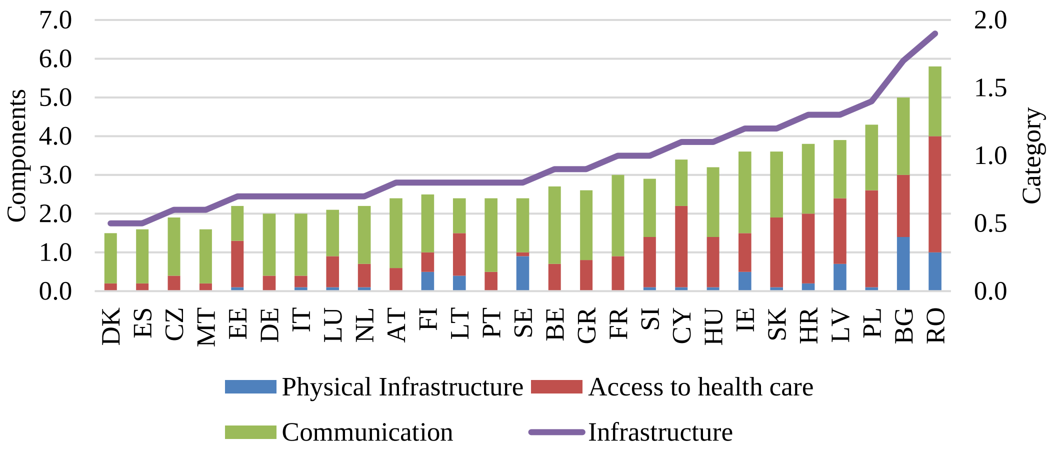
Figure 5. Institutional category components



Source: own representation according to the INFORM Risk Index values in 2020

The indicators in ***Figure 6***—physical infrastructure, access to health care, communication, and infrastructure—are essential for daily life and, therefore, key to the assessment. The first indicator, which assesses Infrastructure, is worst for countries such as RO (1.9), BG (1.70), PL (1.4), HR (1.3), LV (1.3), IE (1.2), and SK (1.2).

Figure 6. Contents of Infrastructure category



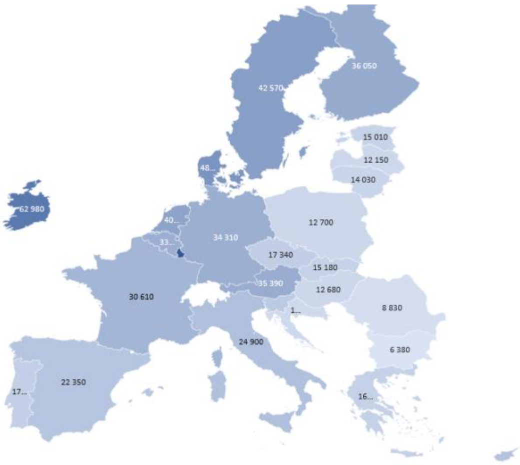
Source: own representation according to the INFORM Risk Index values in 2020

The situation differs for Physical Infrastructure, where the worst situations arise in the following countries: BG (1.4), RO (1.0), SE (0.9), LV (0.7), FI (0.5), and IE (0.5). The best ratings (equal to zero) are achieved by DK, ES, CZ, MT, DE, AT, PT, BE, GR, and FR. The values of the Access to Health Care indicator are most unfavorable in countries such as RO (3.0), PL (2.5), CY (2.1), SK (1.8), HR (1.8), LV (1.7), and BG (1.6). RO, PL. The indicator evaluated last was Communication; the worst values in this case are reported by FR (2.1), IE (2.1), BE (2.0), BG (2.), and PT (1.9).

3.4. GDP per capita in purchasing power parities, air pollution and INFORM Risk Index dimension categories

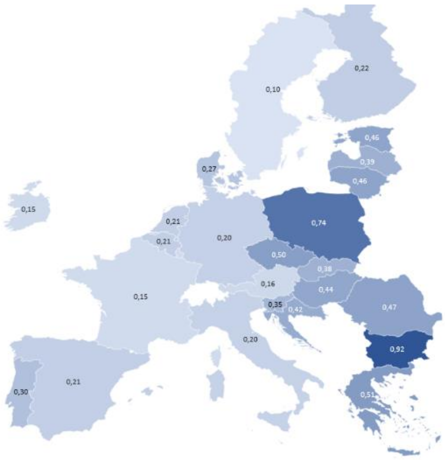
Figure 7 shows that the lower values of the GDP per capita PPP are countries in the eastern part of the EU (EL, BG, RO, HU, SR, PL, LV, LT, and EE) and PT. In the case of the GVA (***Figure 8***), the highest levels are achieved by former socialist bloc countries, followed by Greece and Portugal.

Figure 7. GDP per capita PPP (2020)



Source: own illustration

Figure 8. GVA (2020)



Source: own illustration

Understanding the complex economic relations within the European Union member states is key to European policy. Richer countries contribute more to the shared budget, and poorer countries are trying to converge toward a higher GDP. There are many programs and funds within the EU to support this convergence.

CO_2 emissions are a major driver of global climate change. Although rising CO_2 emissions have verifiable negative environmental impacts, they, historically, also have been a by-product of an improvement in living conditions. Prosperity is the primary driver behind CO_2 emissions, yet political and technological decisions clearly make a difference. But it is also true that reducing CO_2 emissions is important for protecting the living conditions of future generations. On a global scale, there is a strong direct relationship between per capita income and CO_2 emissions.

Table 3 presents, in synthetic form, the calculated Pearson correlation coefficients for individual factors of the three dimensions of the INFORM Risk Index separately for GVA and GDP per capita PPP.

Based on the performed calculations, it can be stated that the intensity of emissions per unit of value added is very positively dependent on SOCIOECON, INSTITUTIONAL, and INFRASTRUCTURE. Yet we find a negative dependence in the case of the relationship between GVA and VULNERABLE. Based on the calculated values, it can also be stated that GDP per CAPITA PPP is significantly negatively dependent on parameters such as NATURAL, SOCIOECON, INSTITUTIONAL, and INFRASTRUCTURE. Lower-income countries are, on average, more likely to be exposed to certain climatic risks than many higher-income countries, mainly due to their geographical location as well as the nature of their economies. This finding is in line with the existing knowledge of a significant negative monotone dependence between HAZARDS & EXPOSURE and annual CO_2 emissions per capita.

Table 3. Pearson correlation coefficients for dimension categories INFORM Risk Index and GVA, GDP per CAPITA PPP

Indicator	GVA	GDP per CAPITA PPP
NATURAL	0.23	-0.47*
HUMAN	0.14	-0.16
SOCIOECON	0.65***	-0.53**
VULNERABLE	-0.40*	0.31
INSTITUTIONAL	0.62***	-0.73***
INFRASTRUCTURE	0.59**	-0.41
INFORMRISK	0.26	-0.40 **
GVA	1.00	-0.66***
GDP per CAPITA PPP	-0.66***	1.00

Note: */significance at 0.10, **/significance at 0.05 ***/significance at 0.001
Source: own calculations

3.5 Evaluation of the similarity of EU countries at the level of INFORM Risk Index categories

To begin with, one of the most applied unsupervised machine learning algorithms—Principal Component Analysis (PCA)—was employed, which is used to reduce dimensionality. Following Kaiser's Rule, two main components will be used analytically, since there are two eigenvalues greater than 1. The two principal components explain 71.37 percent variability.

Table 4. Eigenvalue values and share of explained variability

Eigenvalue	Variance (percent)	Cumulative variance (percent)
3.07901	51.32	51.32
1.20301	20.05	71.37
0.87018	14.50	85.87
0.40509	6.75	92.62
0.24505	4.08	96.70
0.19767	3.29	100.00

Source: own calculations

Table 5 presents the calculated values of the Pearson correlation coefficient and the significance of correlation coefficients between the INFORM Risk Index categories and the first two main components.

Table 5. Pearson correlation coefficient values between INFORM Risk Index categories and the first two main components

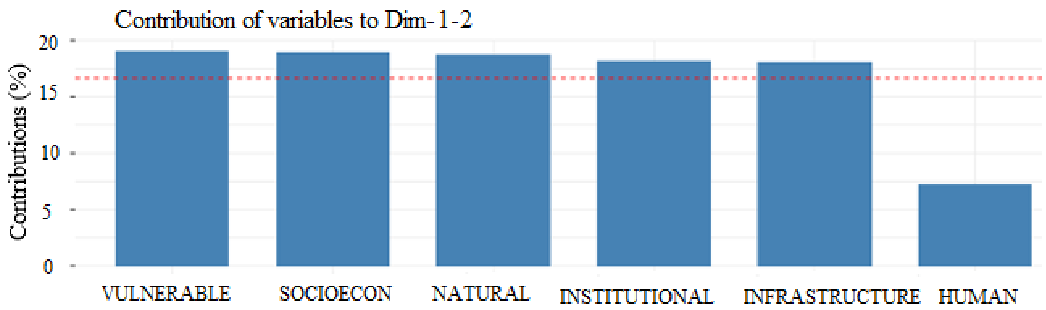
Category	First main component	
	Pearson correlation coefficient (p-value)	
SOCIOECON	0.8966	$2.4\ 10^{-10}$
INSTITUTIONAL	0.8766	$2.05\ 10^{-9}$
INFRASTRUCTURE	0.8741	$2.58\ 10^{-9}$
HUMAN	0.5523	$2.82\ 10^{-3}$
NATURAL	0.5481	$3.08\ 10^{-3}$

Category	Second main component	
	Pearson correlation coefficient (p-value)	
VULNERABLE	0.8240	$1.28\ 10^{-7}$
NATURAL	0.7072	$3.71\ 10^{-5}$

Source: own calculations

The quality of the representation of individual variables using the first two main components is shown in the following ***Figure 9***. All categories except the HUMAN category have above-average contributions to the first two components.

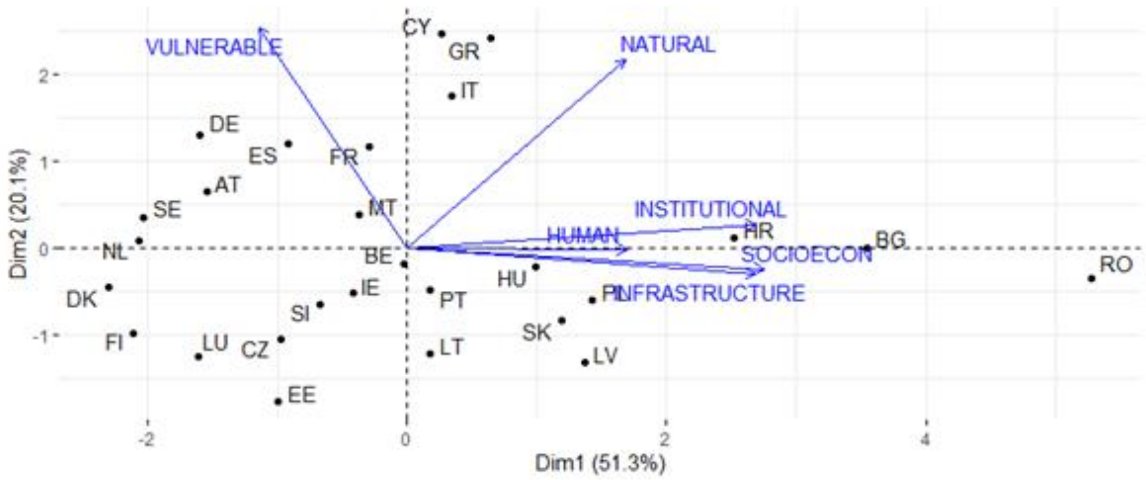
Figure 9. Contribution of variables to the first two components



Source: own calculations using R software

A biplot was used to graphically represent the performed calculations (***Figure 10***). Several facts can be ascertained from Figure 10: For example, the smallest angle can be observed for the variables INFRASTRUCTURE and SOCIOECON, which highlights these are the most closely linked. A small angle can also be seen in the case of the other two variables, HUMAN and INSTITUTIONAL, which in practice means again identifying the close connection between the examined variables. A geometrically approximate right angle can be observed between the variables NATURAL and VULNERABLE. This indicates that they are independent. An evaluation of VULNERABLE and other categories of variables finds that, geometrically, the angle is greater than 90 degrees and thus indicates an indirect dependence.

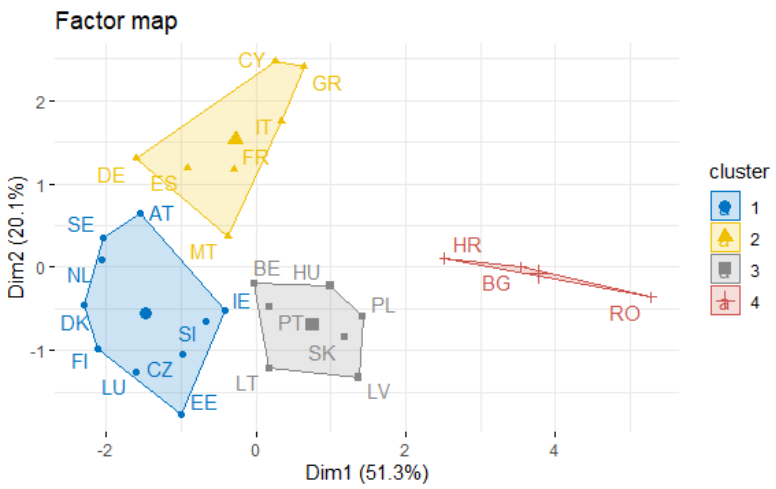
Figure 10. Biplot with evaluated categories and EU countries



Source: own calculations using R software

The origin represents the average value for each variable, i.e., it represents an object that has an average value in each variable; this average object has a 0 value in the centered data matrix. The closest to the average object is Belgium. States whose biplot points are in proximity are more similar in terms of the variables being evaluated than states whose points are distant. The intersections perpendicular to the point far from the beginning in the direction of the arrow indicate high values, while the intersections far on the extended line— in the opposite direction to the arrow—represent low values of the examined variable for the given object. For example, RO, BG, and HR have highly above-average values in all categories of the VULNERABILITY and LACK OF CAPACITY dimensions.

Figure 11. Factor map and clusters

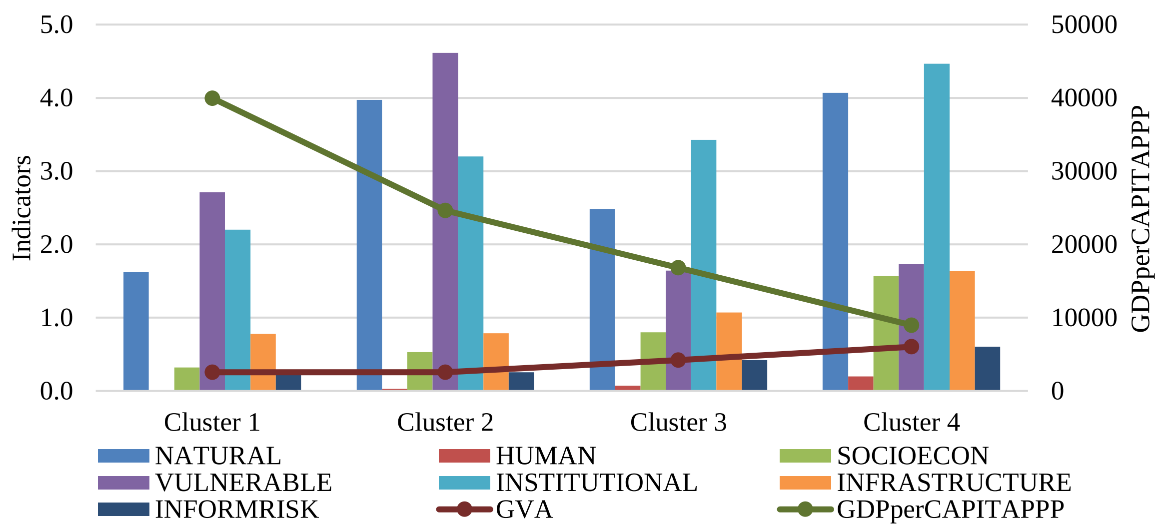


Source: own calculations using R software

Based on the results of the principal component analysis, the individual countries that have been evaluated were grouped into four clusters (***Figure 11***).

Figure 12 shows the average values of the individual categories of the INFORM Risk index, the value of the INFORM Risk Index, and the values of GVA and GDP per capita PPP for individual clusters.

Figure 12. The average values of the indicators for individual clusters



Source: own calculations

The following paragraphs will take a closer look at the created clusters. The first cluster is color-coded in pale blue and includes countries that have reached the highest GDP per capita PPP values, with the exception of three countries: CZ, SI, and EE. Their common characteristic is also that each has a value of zero for the HUMAN parameter.

In the case of the second cluster, the grouped states have an average VULNERABLE value of 4.6 (***Figure 12***). These are the countries with the highest numbers of asylum seekers:

DE (121.955), FR (93.470), ES (88.530), GR (40.560), IT (16.225), and CY (7.440). The highest INSTITUTIONAL value from all countries participating in the evaluation can be seen in the case of MT. For the NATURAL parameter, which represents the threat of natural hazards, we can find the second-highest average value. The common feature is that these are Mediterranean countries, except for Germany.

The third cluster comprises countries representing the former socialist bloc, i.e., HU, PL, LV, LT, SK and PT, and BE. These countries have the second-lowest average GDP per CAPITA PPP and the second-highest average GVA. This is in line with the GVA being high when using technologies that emit high emissions, and low when modern technology and services prevail rather than production. In the former socialist countries, there is a larger share of production than services, and older technologies are used more than in countries of the first and second clusters.

The fourth cluster represents the Balkan States and is specific. Countries in this cluster have a low GDP per capita (even the lowest), but also a high-intensity GVA. In practice, this means obsolete technologies and a low share of services, but also that fewer emissions are produced. All countries are affected by climate change. The poorest (fourth cluster) are more exposed and, therefore, more vulnerable. They have the highest average INFORM Risk Index value. Their climate is behind the high values in the NATURAL category. In their case, however, we see a high value of the NATURAL parameter. It is also evident that states grouped in the fourth cluster have the highest parameter averages, with the one exception being the VULNERABLE parameter. Poor states have less money to adapt quickly which shows through the highest value of the INSTITUTIONAL factor.

4. Conclusion

Despite environmentalists' protestations, climate change is not only an ecological or environmental problem. The consequences of climate change are in fact far greater, wider, and deeper than anyone might expect at first glance. Climate change is changing the whole life on Earth: It is changing processes, and procedures, and brings about many unfamiliar phenomena in respective regions and countries. It changes everyday life, business, and the environment. It fundamentally changes and shapes economic and business activities in other directions.

Extensive analyses help to uncover new facts and contexts that explain often concealed connections and correlations and provide insights into hitherto unknown problem areas. This scientific article seeks to best capture the impacts of climate change on the economy and society as a whole through the quantification of phenomena and the components thereof. In conclusion, the following statements can be made:

- Security risk, poverty, and environmental pollution are connected. There is a close link between these variables and the sensitivity to change of any of the indicators.
- In addition to environmental impact, higher environmental risk also has wider impacts, mainly economic and social. Climate change thus has a great impact on key macroeconomic indicators, such as employment, gross output, and structural changes in national economic sectors.
- The achieved results are significant, but changes are expected due to the final impact of COVID-19 and the ongoing war in Ukraine. Those two new developments will strongly impact the current state of affairs, which is why this research perceives them as limitations.

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