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Sustainability Reporting Trends: A Systematic Literature Network Analysis

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Abstract

Compiling and submitting sustainable development reports is a key area for reforming corporate reporting in light of the implementation of the Sustainable Development Goals. In recent years, the share of companies that report sustainable development and corporate social responsibility has grown significantly. Thus, the study of the definition of the conceptual apparatus is important. The article aims to study the quantitative and qualitative structure of the documentary flow of scientific periodicals, the main areas of research, and development trends and. It also presents the results of a systematic review of publications on "sustainability reporting".
The study used bibliometric analysis of scientific periodicals from the Scopus scientometric database between 2011–2021. The scientific papers selected by the keyword "sustainability reporting" were exported for processing in the VOSviewer and R (bibliometrix package) computer programs. Based on the results of quantitative analysis, 625 publications were accepted, most of which were scientific articles. The main areas of research on sustainability reporting in accounting are sustainable development, sustainability, decision-making, sustainability reporting, and accountability.

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The study also made it possible to identify the authors and research schools that have made the most significant contribution to this topic, and to establish geographical clusters in the con text of countries around the world that work closely with each other and the highest-rated journals.
The originality of this study is that it helps to create a conceptual framework. It should guide the definition of future research, and it is designed to provide qualitative new insight int the role of sustainable development reporting. The article provides an opportunity to fill the gaps in quality research on sustainable development reporting. The main conclusions of this article will help researchers to expand their knowledge in this area through retrospective analysis of the research results.

Keywords: sustainability reporting, accounting, CSR, bibliometric analysis, network analysis

JEL: M41, Q01, Q56

Introduction

The concept of sustainable development aims to harmonize the economic, social, and environmental components of social development, making it possible to solve problems of environmental protection, increase social development, and overcome the effects of economic crises (Hyk 2021). The principles of sustainable development are embodied in sustainability reporting, which contains a set of data that reflect the environment, methods of cooperation with impact groups, and the results of the enterprise in the economic, social, and environmental spheres of society.

Given the current trends in economic systems and their impact on economic and environmental security and social consensus in society, sustainability reporting is a priority information tool to manage business activities and meet the needs of external users (Vysochan, Hyk, and Vysochan 2021a). Such reporting is public and is considered as a tool for informing the company's shareholders, employees, partners and customers about how and at what pace it is implementing the goals of economic sustainability, social welfare and environmental stability laid down in its strategic development plans.

Sustainability reporting is a means of communication between business, government and civil society, and it provides an opportunity for constructive dialogue between them to balance the interests of all stakeholders. This creates the preconditions for solving the problems of resource and energy conservation, improving the environmental safety of production and products, increasing productivity and territorial development, and taking a leading position in a competitive environment in domestic and foreign markets (Hyk, Vysochan, and Vysochan 2021).

In world and domestic practice, sustainability reporting can be presented in the following ways: Social reporting, Corporate Social Responsibility Reporting, Corporate

Responsibility Reports, Progress Reports, and Sustainable Development Reporting and others.

An important problem that needs to be solved is to determine the prospects for the development of corporate reporting in response to changes in the global economic system. Due to this, the rules, features and research areas for this type of reporting are becoming increasingly important in accounting science and practice. Therefore, there is a need to study the current state and trends in sustainable development reporting. The results will make it possible to argue the main approaches to understanding the essence of sustainable development reporting to determine the biggest priority areas of research and sources of its scientific and methodological support.

Literature review

The formation and development of the concept of sustainability reporting were raised in the works of many authors, including Herzig and Schaltegger (2006), O'Dwyer, Owen, and Unerman (2011), Boiral (2013), Hahn and Kühnen (2013), Brown and Dillard (2014), De Villiers, Rinaldi, and and Unerman (2014), Adams (2015), Stacchezzini, Melloni, and Lai (2016), Sukhonos and Makarenko (2017), Unerman, Bebbington, and O'Dwyer (2018), Makarenko et al. (2020), Petryk et al. (2020), Mysaka, Derun, and Skliaruk (2021), Siryk et al. (2021), Vysochan et al. (2021a) and other.

There have been relatively few systematic reviews of the scientific literature on sustainable development reporting. Kulevicz et al. (2020) searched 53 articles indexed in the ScienceDirect database between 2012 and 2017. Di Vaio et al. (2021) studied 60 publications in English with a release date from 1990 to 2019. Navarrete-Oyarce et al. (2021) conducted a bibliometric analysis of integrated reporting as a source of information in 268 articles published in the Web of Science database from 2011 to 2019. Baditoiu, Partenie, and Alexandru (2021) analyzed 262 sources from the Core Collection Web of Science (WoS) database from 1999 to 2021. Minutiello and Tettamanzi (2022) analyzed publications from 2010 to 2020. Pasko et al. (2021) analyzed scientific articles in Scopus and the Web Science Core Collection using CiteSpace software.

Separate literature reviews on the relationship between performance measurement and sustainable development reporting have been cited by Klovienė and Speziale (2014) and Speziale and Klovienė (2014), while Dienes, Sassen, and Fischer (2016) systematized the research area of sustainable development reporting. Traxler, Schrack, and Greiling (2020) investigated the interaction of the concepts of management control systems (MCS) and sustainability reporting (SR) in 53 publications from 2000 to 2018.

Without diminishing the valuable work of these scientists, those scientific articles have different orientations. To address this research gap, our paper explores the conceptual value of sustainability reporting based on bibliometric analysis and visualization of results using the VOSviewer and R (bibliometrix package) computer programs. The following questions were then formulated:

RQ 1: How many publications on sustainability reporting are in the Scopus scientometric database?

RQ 2: What keywords are most often used in conjunction with the term sustainability reporting?

RQ 3: Which articles and authors have the highest citation index on sustainability reporting?

RQ 4: What is the cooperation between countries and scientific journals on sustainability reporting?

Methodology

This article uses a mixture of general and specific methods to analyze the literature on sustainable development reporting. The study is based on a bibliometric analysis. A bibliographic analysis of documents is based on the study of formal, substantive and functional features. It makes it possible to identify the role and place of the document (or a homogeneous set) in the overall flow and its value properties, and it gives a meaningful interpretation of statistical and other indicators that are obtained.

A sample of publications for analysis was conducted in the scientometric database Scopus, using the search bar (Table 1).

Table 1. Stages of information selection in Scopus

Search steps	Query in Scopus	Description
1	TITLE-ABS-KEY	(“sustainability AND reporting”)
2	TITLE-ABS-KEY	(“accounting”)
3	OR LIMIT-TO PUBYEAR	(“> 2011 to <= 2021”)

Source: proposed by the authors.

Auxiliary search terms (e.g., environmental reporting, integrated reporting) were deliberately omitted because the purpose of the study was to accurately explore the specific concept of “sustainability reporting” in accounting.

The search was conducted in February 2022, and no restrictions on the language or type of publications were set. Before the quantitative and qualitative analysis, the data set was cleaned and corrected, i.e., duplicate documents were removed, and keywords were cleared.

The resulting data were imported to the VOSviewer and R computer programs (bibliometrix package). VOSviewer is designed to visualize bibliometric links and allows you to build a terminology map based on common terms in the titles and annotations of publications. R (bibliometrix package) is a tool for quantitative research in scientometrics and bibliometrics and includes all major bibliometric analysis methods (Aria and Cuccurullo 2017). In R program, the overall conceptual structure was investigated using Multiple Correspondence Analysis (MCA) and K-means clustering methods, which were successfully used in our previous studies (Vysochan, Vysochan, and Hyk 2021b; Vysochan et al. 2021b).

Results

General characteristics of information

Based on the results of the content analysis for 2011–2021, 625 publications were identified in terms of the following types of documents: abstract report – 1, article – 473, book – 14, book chapter – 49, conference paper – 40, conference review – 7, letter – 1, note – 2, and review – 38. As a result of the structural analysis, it was found that among all publications, most are articles, accounting for about 75% of the total. Generalized data on the number of publications are shown in Figure 1.

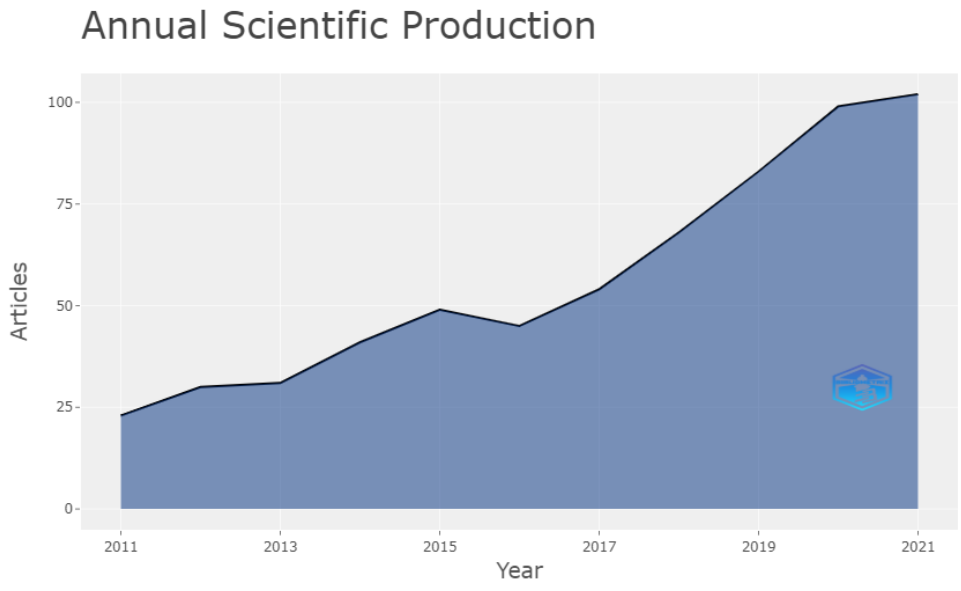


Figure 1. Total number of publications by year

Source: formed by the authors using R software.

Figure 1 shows that during the analyzed period, the number of publications on sustainability reporting grew steadily – from 23 in 2011 until 2021, inclusive, when it reached its highest value of 102, exceeding the initial number more than fourfold. In recent years, the growth in the total number and dynamics of publications indicates positive trends and increased scientific interest in this topic.

Characteristics and essential parameters are presented in the general information about the results of the study in Table 2.

Table 2. General information

Description	Results
Timespan	2011: 2021
Sources	300
Documents	625
Author's keywords	1535
Average citations per documents	20.03
Authors	1367
Author appearances	1639
Authors of single-authored documents	111
Authors of multi-authored documents	1256
Single-authored documents	137
Documents per Author	0.457
Authors per document	2.19
Co-Authors per documents	2.62
Collaboration index	2.57

Source: formed by the authors using R software.

From the description of the data in Table 2, on the topic of sustainability reporting for the period 2011–2021, 1367 authors were mentioned 1639 times. In total, the authors published 625 publications in 300 different types of documents. The average citations per document indicator were quite high, at 20.03. The vast majority of publications (91.88%) are co-authored by several authors; only 8.12% were written alone. The relative numbers of authors per publication (2.19) and the number of co-authors per publication (2.62) are low. An important indicator that characterizes international cooperation is the value of the Collaboration Index, which was 2.57, indicating a low level of cooperation.

Analysis of repeated words in documents

A keyword analysis is the starting point for any search query. It is conducted to determine which words and phrases are most often mentioned by scientists in articles. Bibliometric analysis by keywords makes it possible to establish the fundamental and priority areas of research development. Based on the results of the analysis, information was obtained on the frequency of use of keywords by authors in publications on sustainability reporting, which are summarized in Figure 2.

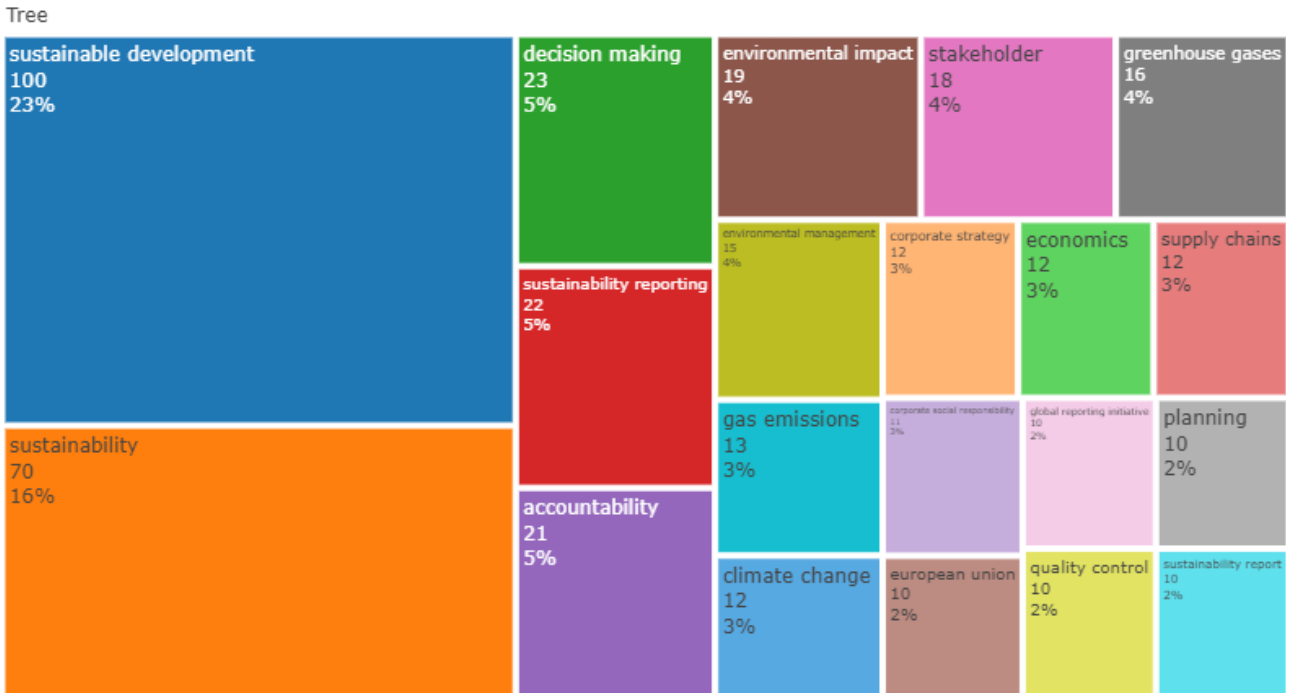


Figure 2. Use of keywords in publications (top 20)

Source: formed by the authors using R software.

According to the data, the most commonly used terms are sustainable development (23%), sustainability (16%), decision-making (5%), sustainability reporting (5%) and accountability (5%). However, among common terms were phrases associated with corporate responsibility, i.e., environmental management (4%), corporate strategy (3%), and corporate social responsibility (3%). This is not surprising. The use of such terms in sustainability reporting as an effective method of improving company management is directly related to the purpose of sustainability reporting, which is to reflect a responsible and balanced strategic social policy. As a result, social programs can be systematized, and areas for further implementation can be identified. Figure 3 gives a visual representation of integration chains by key terms.

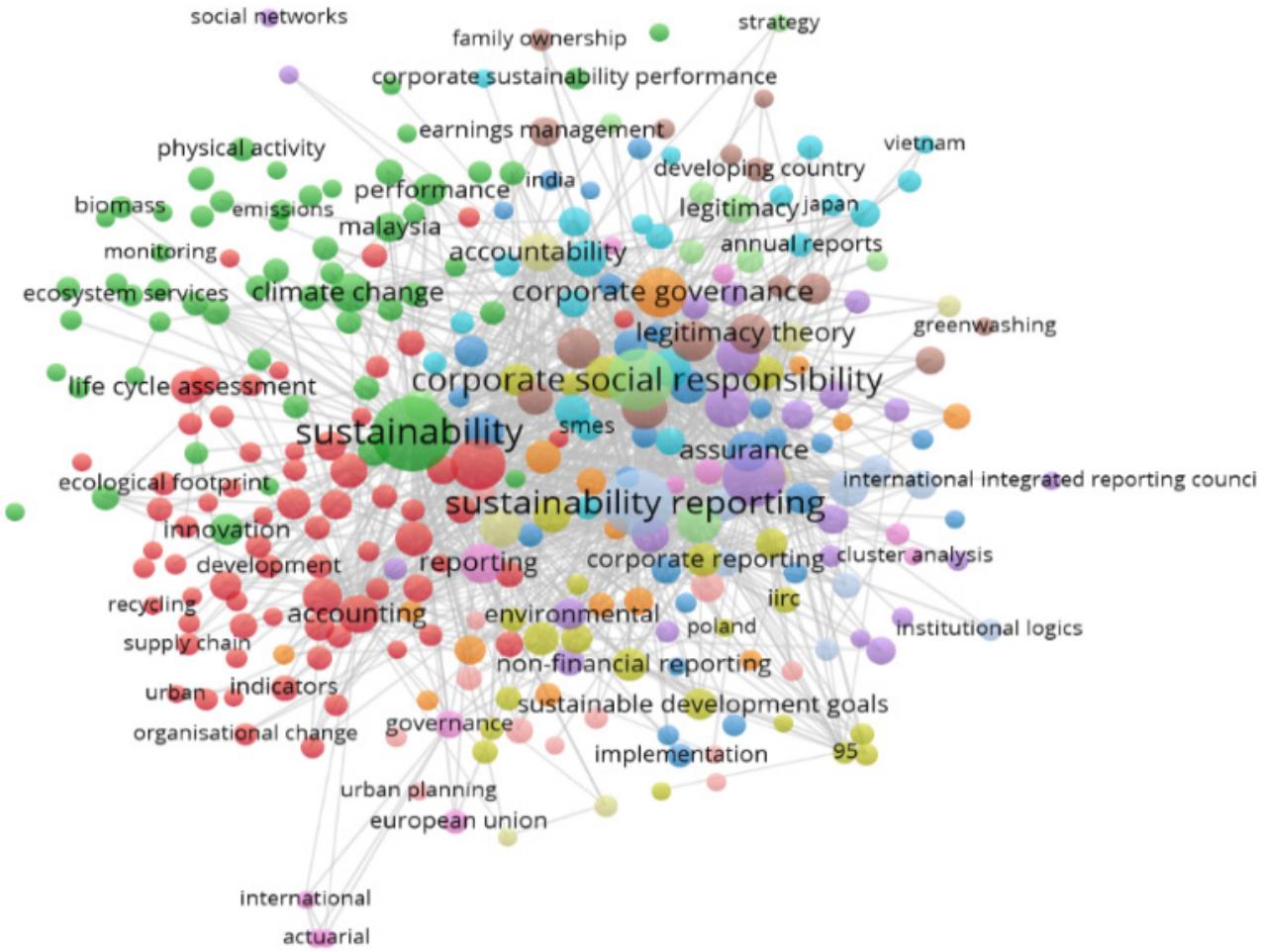


Figure 3. Visualization of a network of terms that are most common in sustainability reporting studies

Source: author's elaboration using VOSviewer.

To conduct the content analysis, we identified the frequency of use of keywords, making it possible to identify priority trend themes by year. The frequency of use of keywords by year is shown in Figure 4.

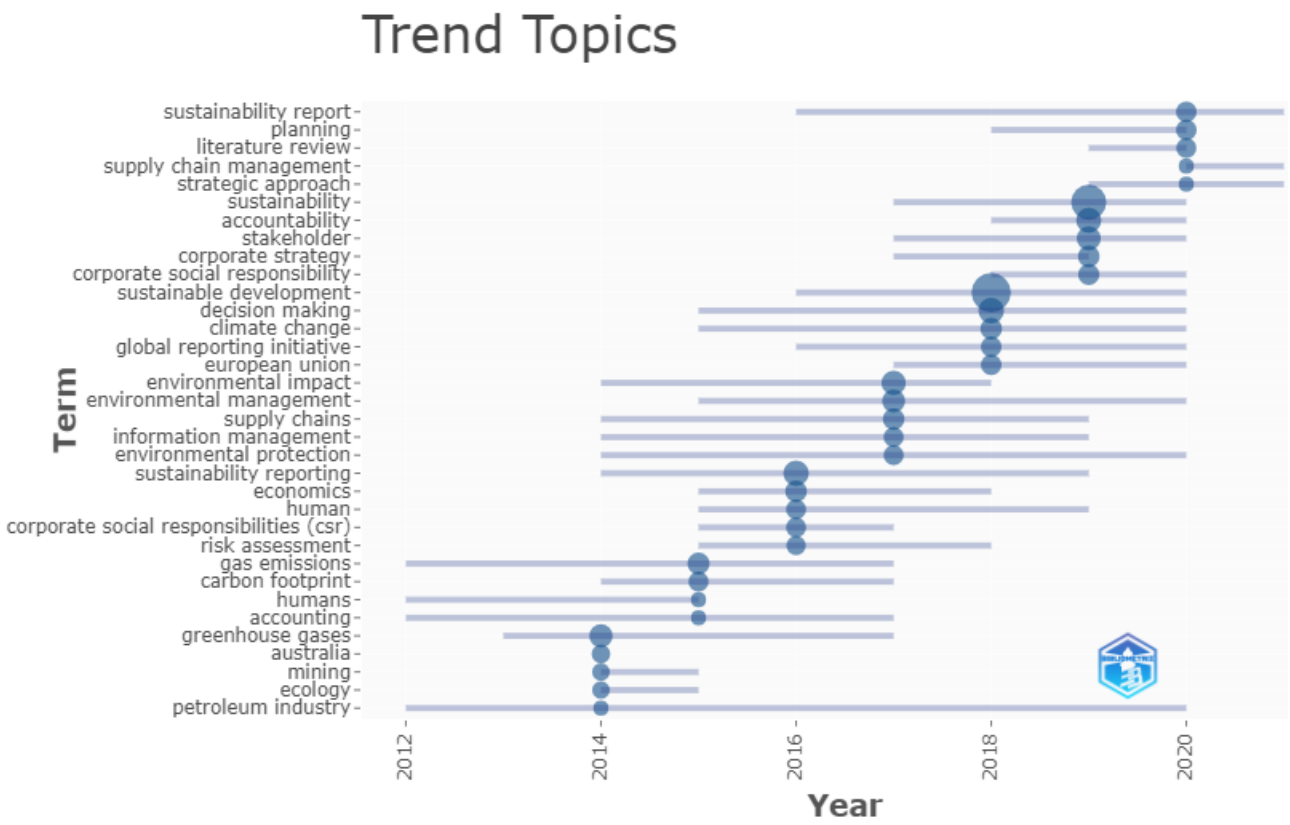


Figure 4. Trend Topics on sustainability reporting

Source: formed by the authors using R software.

To determine the trends in time measurement on this topic, we selected key terms by filter – Word Minimum Frequency = 5, Number of Words per Year = 5. As a result of using these filters, it was found that research topics such as sustainable development and sustainability were of maximum scientific interest among researchers, and they became especially relevant in 2018–2019. It was also determined that in recent years, economist-accountants are actively researching issues related to the terms sustainability report, supply chain management, and strategic approach. The works focus on a new direction in the development of supply chain management – Sustainable Supply Chain Management. It includes improving product quality, customer service, and corporate social responsibility, taking into account modern environmental challenges and regulating social processes.

Figure 5 shows a map of the conceptual basis built on the authors' keywords.

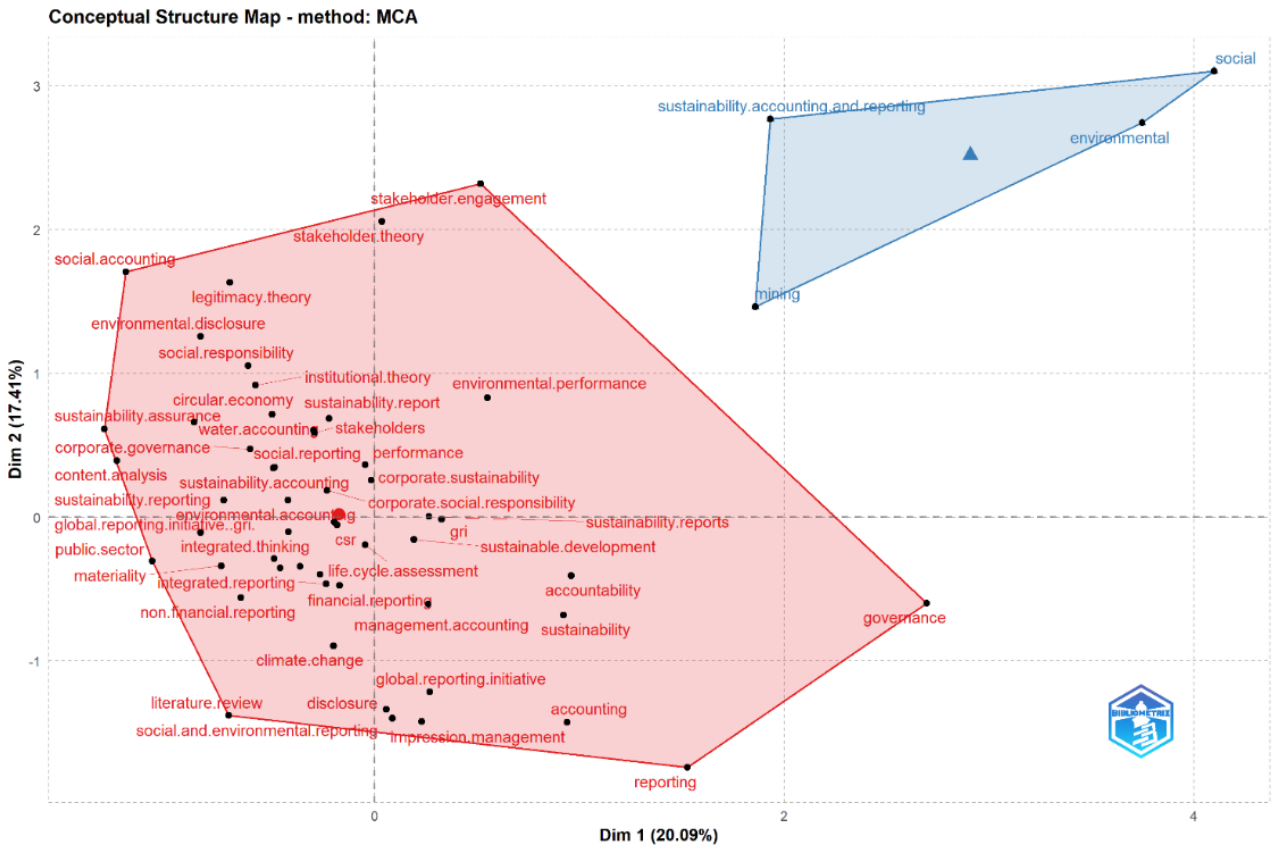


Figure 5. Map formed by keywords of authors

Source: authors' elaboration using R software.

This map was built using the MCA (Multiple Correspondence Analysis) method, in which two clusters can be distinguished. The most notable cluster size is the red cluster, which is characterized by a wide range of interrelated terms. The blue cluster is much smaller and is represented by only four keywords: sustainability accounting and reporting, social, environmental, and mining.

The results of the analysis by author and scientific work

An important qualitative feature of a scientific article is the number of citations. The most cited works of authors on this topic are given in Table 3.

Table 3. Works of authors on the indicator Local and Global Citations (top–15)

Document	Article title	Local Citation (LC)	Global Citation (GC)	GC/LC ratio (%)
O'Dwyer, Owen, and Unerman (2011)	Seeking legitimacy for new assurance forms: The case of assurance on sustainability reporting	40	304	13.16
De Villiers, Rinaldi, and Unerman (2014)	Integrated Reporting: Insights, gaps and an agenda for future research	38	331	11.48
Flower (2015)	The International Integrated Reporting Council: A story of failure	36	268	13.43
Brown and Dillard (2014)	Integrated reporting: On the need for broadening out and opening up	35	187	18.72
Hahn and Kühnen (2013)	Determinants of sustainability reporting: A review of results, trends, theory, and opportunities in an expanding field of research	34	558	6.09
Adams (2015)	The International Integrated Reporting Council: A call to action	30	236	12.71
Boiral (2013)	Sustainability reports as simulacra? A counter-account of A and A+ GRI reports	30	287	10.45
Stubbs and Higgins (2014)	Integrated Reporting and internal mechanisms of change	25	202	12.38
Owen (2013)	Integrated Reporting: A review of developments and their implications for the accounting curriculum	16	44	36.36
Stacchezzini, Melloni, and Lai (2016)	Sustainability management and reporting: the role of integrated reporting for communicating corporate sustainability management	14	116	12.07
Gond et al. (2012)	Configuring management control systems: Theorizing the integration of strategy and sustainability	13	233	5.58
Cho, Michelon, and Patten (2012)	Impression management in sustainability reports: An empirical investigation of the use of graphs	13	97	13.40
Clarkson, Overell, and Chapple (2011)	Environmental Reporting and its Relation to corporate environmental performance	13	279	4.66
Perego, Kennedy, and Whiteman (2016)	A lot of icing but little cake? Taking integrated reporting forward	12	88	13.64
Unerman, Bebbington, and O'Dwyer (2018)	Corporate reporting and accounting for externalities	11	54	20.37

Source: formed by the authors using R software.

Table 3 shows that according to the Local Citation (LC) criterion, the two best positions are occupied by works from:

the team of authors Brendan O'Dwyer from Alliance Manchester Business School (Manchester, United Kingdom), David L. Owen from the University of Nottingham (Nottingham, United Kingdom), and Jeffrey Unerman from Royal Holloway, University of London (Egham, United Kingdom);

the team of authors Charl De Villiers from The University of Auckland Business School (Auckland, New Zealand) and Leonardo Rinaldi and Jeffrey Unerman, both from Royal Holloway, University of London (Egham, United Kingdom).

They also occupy leading positions in the Global Citation (GC) index. They are preceded only by the team of authors Rüdiger Hahn from Heinrich-Heine-Universität Düsseldorf (Dusseldorf, Germany) and Michael Kühnen from Universität Hohenheim (Stuttgart, Germany).

According to GC/LC (%), Gareth Owen of the Association of Chartered Certified Accountants (United Kingdom) is the most important (36.36).

The analysis of the cited works shows that the authors mainly linked the development of the concept of sustainability reporting with improvements in the preparation and submission of integrated reporting, and its role in ensuring corporate governance.

An important indicator that is widely used around the world to evaluate the work of researchers and research teams is the citation index. The values of the impact factor (IF) of the authors on the subject are given in Table 4.

Table 4. Impact factors of Top 15 Authors

Author	h-index	g-index	m-index	Total citation	Number of publications	Publication year
S. Schaltegger	7	10	0.700	330	10	2013
O. Boiral	6	6	0.600	507	6	2013
C. De Villiers	5	5	0.556	521	5	2014
J. Hazelton	5	5	0.500	113	5	2013
S. Lodhia	5	6	0.500	234	6	2013
W. Maroun	5	9	0.625	204	9	2015
D.M. Patten	5	5	0.455	253	5	2012
J. Unerman	5	5	0.417	744	5	2011
J. Atkins	4	4	0.500	86	4	2015
A. Kaur	4	5	0.571	73	5	2016

Author	h-index	g-index	m-index	Total citation	Number of publications	Publication year
C. Larrinaga	4	5	0.667	58	5	2017
C.A. Adams	3	3	0.375	249	3	2015
A.H. Almagtome	3	3	0.750	50	3	2019
Ch. Cho	3	3	0.273	176	3	2012
L. Corazza	3	4	0.500	46	4	2017

Source: formed by the authors using R software.

The authors above published their works between 2011 and 2019, and received a large number of citations. As Table 4 shows, in first place is Prof. Stefan Schaltegger, with an h-index of 7, a g-index of 10, and 10 publications. He is followed by Olivier Boiral from the University of Laval (Quebec, Canada) with slightly lower values: h-index = 6, g-index = 6, and number of publications = 6. Charl De Villiers from The University of Auckland (Auckland, New Zealand) comes in third: h-index = 5, g-index = 5, and number of publications = 5. Based on the Total Citation indicator, Jeffrey Unerman has the highest value (744).

Figure 6 provides a visual representation of the relationships between authors on this topic.

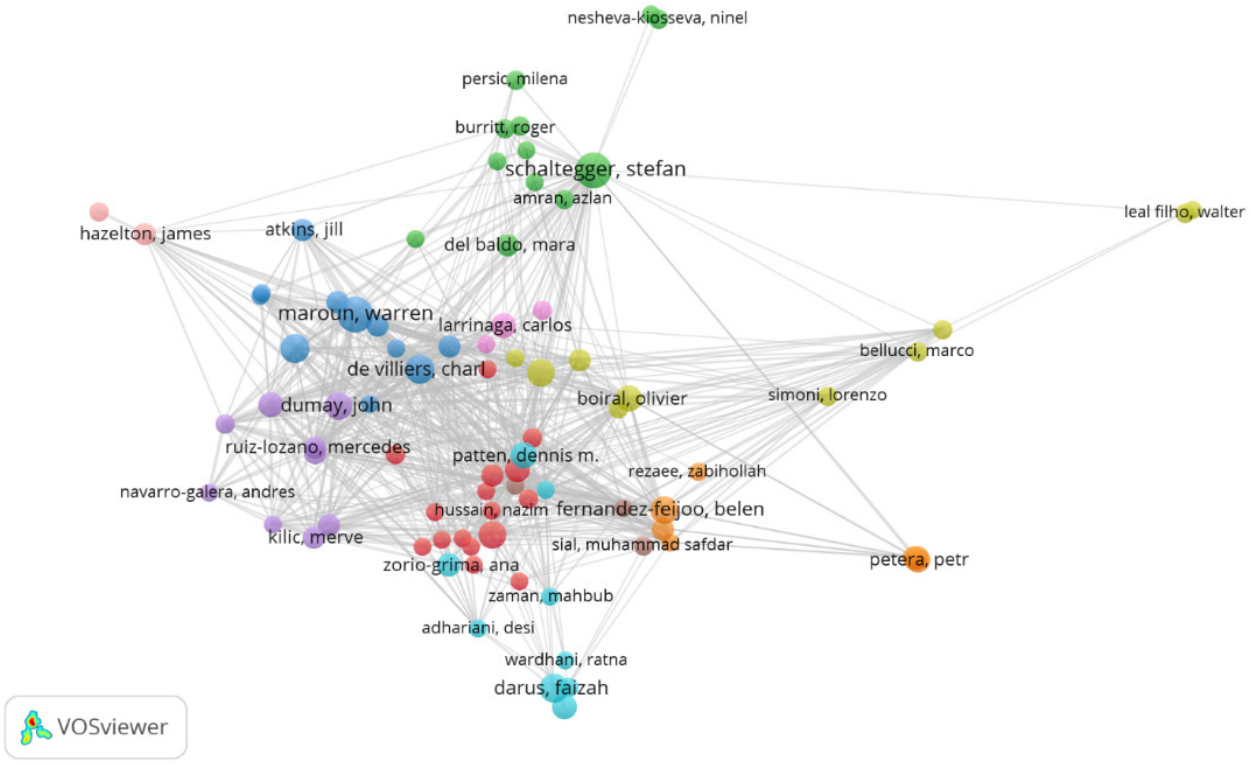


Figure 6. Map of relationships between authors on sustainability reporting

Source: authors' elaboration using VOSviewer.

From Figure 6, it is clear that researchers, united in clusters of different colors, form scientific schools and work closely with each other.

Results of the analysis of cooperation between countries

The next stage is related to the identification of trends and directions in the publishing activity of researchers from different countries. This type of bibliometric analysis gives an idea of which country has made the greatest contribution to the study of this issue. Table 5 provides information on publishing activity by country.

Table 5. Number of citations per publication for countries

Country	Total citation	Average article citation	Articles	Single Country Publications	Multiple Country Publications	MCP ratio
United Kingdom	2108	56.97	37	21	16	0.432
Australia	1629	33.94	48	43	5	0.104
Germany	1118	50.82	22	15	7	0.318
Italy	984	21.39	46	40	6	0.130
Canada	748	37.40	20	12	8	0.400
USA	658	20.56	32	24	8	0.250
Spain	604	20.13	30	22	8	0.267
Netherlands	539	67.38	12	5	7	0.583
New Zealand	351	29.25	12	5	7	0.583
France	172	21.50	8	4	4	0.500
Greece	159	26.50	6	3	3	0.500
Austria	158	26.33	6	5	1	0.167
Malaysia	153	17.00	9	5	4	0.444
South Africa	136	12.36	11	7	4	0.364
Brazil	114	14.25	8	6	2	0.250

Source: formed by the authors using R software.

The data in Table 5 show that the leaders in the total number of citations are the United Kingdom (n = 2108), Australia (n = 1629) and Germany (n = 1118). However, the number of publications was slightly different: 1) Australia (n = 48), 2) Italy (n = 46), and the United Kingdom (n = 37). The collaboration of authors from one or more countries is determined by the indicators Single Country Publications (SCP) and Multiple Country Publications (MCP), which are presented in Figure 7.

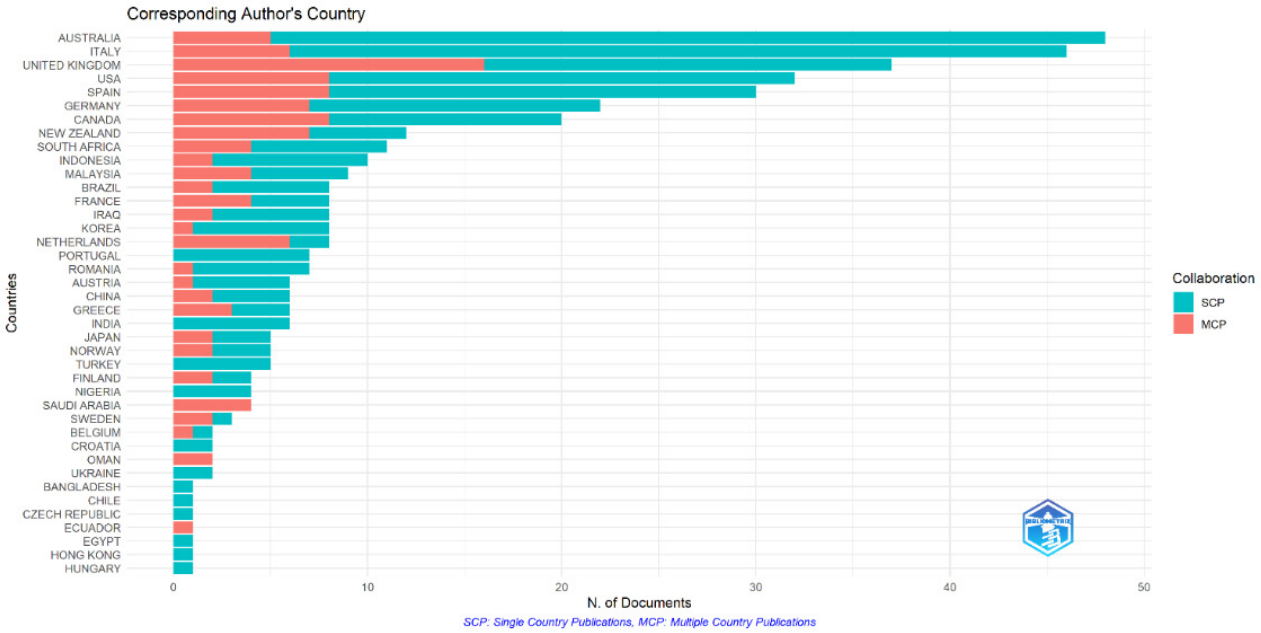


Figure 7. Ratios of Single Country Publications (SCP) and Multiple Country Publications (MCP) by country

Source: authors' elaboration using R software.

An important relative indicator is the MCP Ratio, which is determined by dividing the number of publications written in collaboration with foreign authors by the total number. The values for this indicator were the highest in the Netherlands (0.583), New Zealand (0.583), France (0.500) and Greece (0.500).

For a clearer visual understanding, a network of cooperation in the geographical dimension is presented in Figure 8.

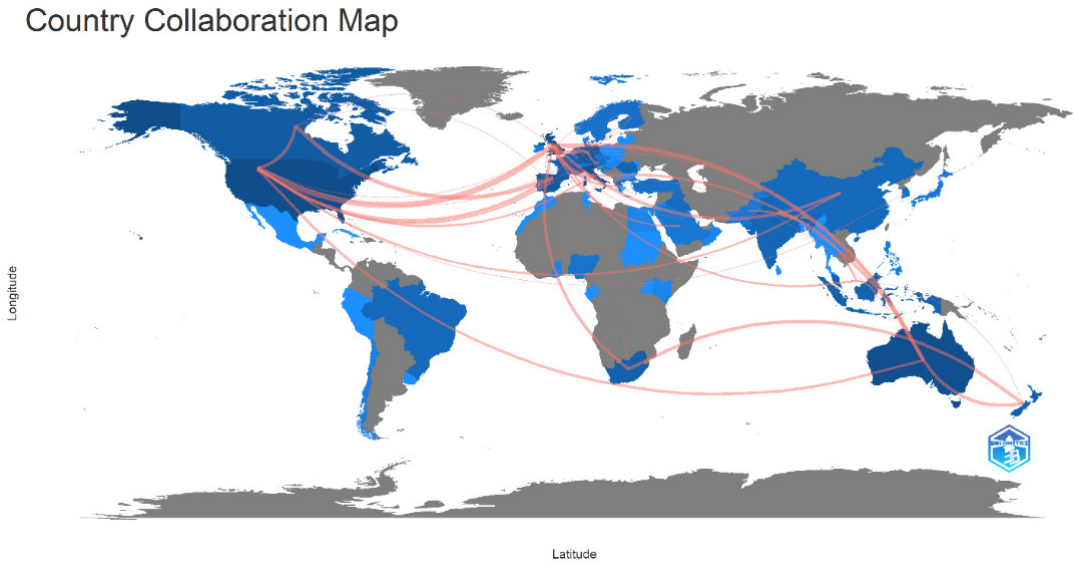


Figure 8. Map of cooperation between countries on sustainability reporting

Source: authors' elaboration using R software.

To build this map, the selection criterion was set: Min edges = 2. Different variants of cooperation between scientists from countries and their frequency of publishing activity are shown by nodes. Figure 8 shows that cooperation between countries is most clearly represented by English-speaking countries, i.e., the USA, the United Kingdom, Australia, New Zealand, and Canada, as well as some countries from the European Union, i.e., Italy, Spain, and Germany, as well as South Africa and China.

Based on this, a visual network of cooperation between countries on this topic was formed (Figure 9).

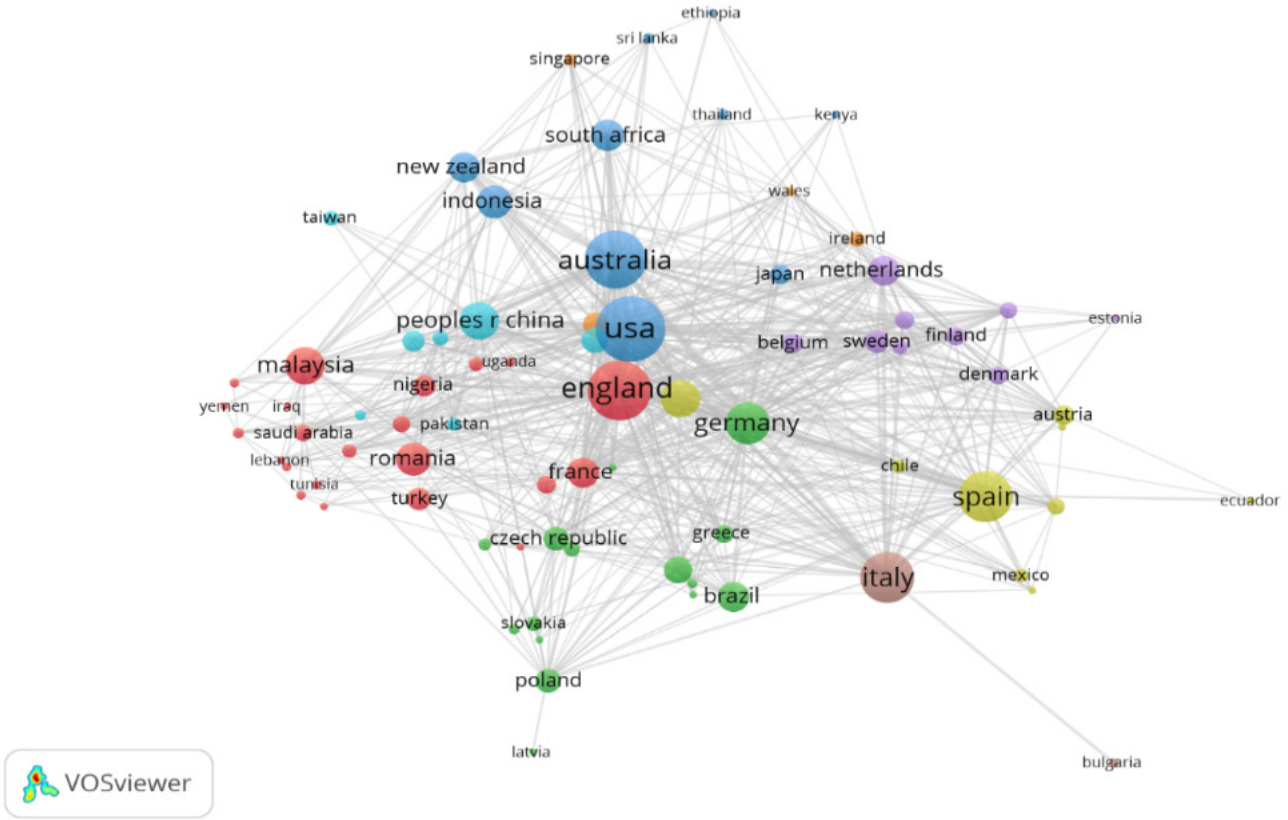


Figure 9. Map of relations between countries on the topic of sustainability reporting

Source: authors' elaboration using VOSviewer.

The size and area of the network node characterize the countries whose scientists have made the greatest contribution to the study of this issue. From Figure 9, it is clear that the red cluster is dominated by the United Kingdom (England), the blue cluster by the USA and Australia, the green cluster by Germany, the pistachio cluster by Spain, and the brown cluster by Italy.

The results of the analysis of journals

Typically, each journal's performance is determined using the Journal Impact Factor (JIF), developed by Eugene Garfield in the early 1960s as a magazine selection tool. It is also used as an indicator to determine a journal's relative influence. However, many evaluation agents use it to evaluate a researcher's performance, suggesting that articles published in journals with a high JIF will have a greater impact. In our study, the results of the journal analysis and the various coefficients of influence are given in Table 6.

Table 6. Source local impact Top 15

Sources	h-index	g-index	m-index	Total citation	Number of publications	Publication year
Accounting, Auditing and Accountability Journal	18	34	1.8	1519	36	2013
Journal of Cleaner Production	18	28	1.8	1642	30	2013
Sustainability (Switzerland)	11	18	1.1	393	43	2013
Sustainability Accounting, Management and Policy Journal	9	14	0.75	239	25	2011
Critical Perspectives on Accounting	7	7	0.64	817	7	2012
Journal of Business Ethics	7	9	1	354	10	2016
Meditari Accountancy Research	6	9	1	260	16	2017
Business Strategy and the Environment	5	5	0.42	266	5	2011
Corporate Social Responsibility and Environmental Management	5	6	0.625	142	6	2015
Journal of Accounting and Organizational Change	5	6	0.45	95	6	2012
Pacific Accounting Review	5	6	0.56	111	6	2014
Revista de Contabilidad-Spanish Accounting Review	5	5	0.42	125	5	2011
Social Responsibility Journal	5	8	0.5	69	10	2013
Journal of Legal, Ethical and Regulatory Issues	4	5	0.44	39	5	2014
Social and Environmental Accountability Journal	4	9	0.36	84	10	2012

Source: authors' elaboration using R software.

Table 6 shows that the leading indicators are the Accounting, Auditing and Accountability Journal (Emerald), the Journal of Cleaner Production (Elsevier), and Sustainability (Switzerland) (Multidisciplinary Digital Publishing Institute (MDPI). These are high-ranking and world-famous journals. However, based on the quantitative indicator Total Citation, the situation is somewhat different: 1) the Journal of Cleaner Production (1642), 2) the Accounting, Auditing and Accountability Journal (1519), and 3) Critical Perspectives on Accounting (817). Figure 10 shows the number of articles on the topic in these journals.

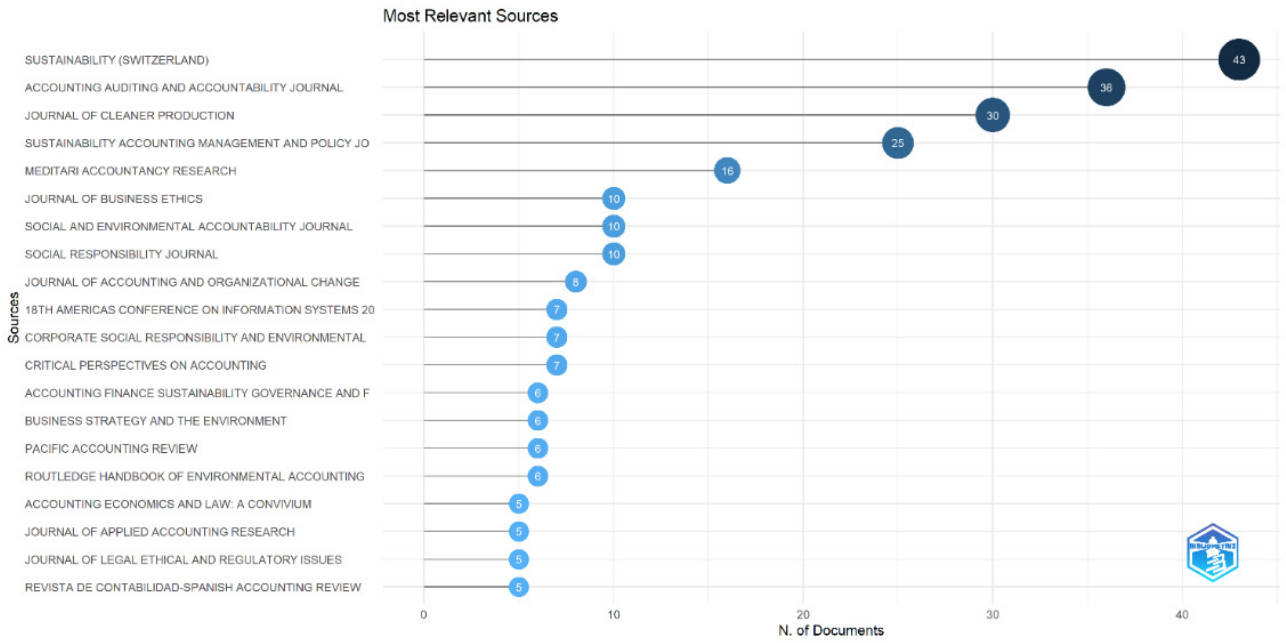


Figure 10. Most Relevant Sources

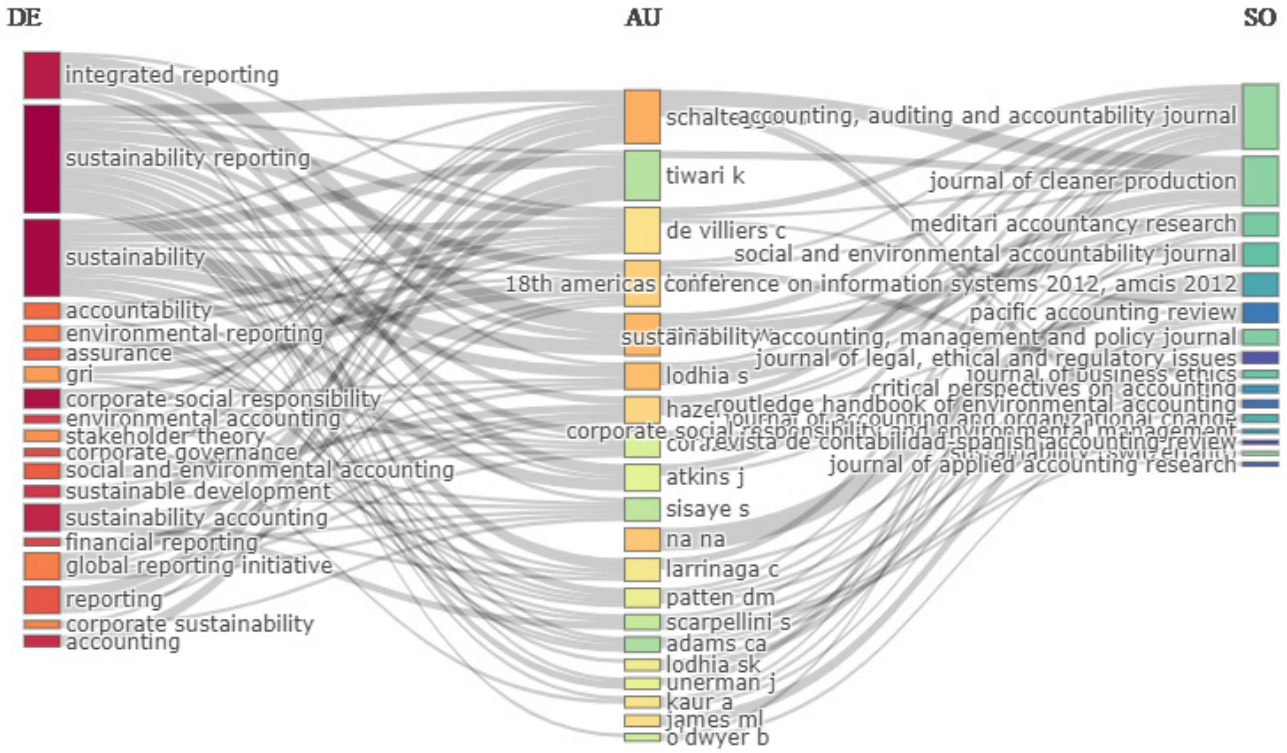
Source: authors' elaboration using R software.

As Figure 10 shows, the most articles are found in the previously mentioned journals: Sustainability (Switzerland) (43), the Accounting, Auditing and Accountability Journal (36), the Journal of Cleaner Production (30) and the Sustainability Accounting, Management and Policy Journal (25).

Sankey diagrams: Three field plots

A Sankey diagrams is a visualization tool that is used to show the flow from one set of values to another. This diagram combines two characteristics: the line shows the relationship between objects, while the width of the line represents its strength, a quantitative indicator of the relationship. Sankey diagrams provide a visual emphasis on the main transmission flows in the system and are useful in finding the dominant "contributions" to the overall flow.

The tripolar section in Biblioshiny is used to visually assess the relationship between sources, countries, affiliation, keywords, lead authors, and cited sources (Kumar et al. 2021). Figure 11 shows the results of the analysis of the communication network between keywords, authors and journals in this field.



Abbreviations. DE – author keywords; AU – authors; SO – publication name (or source)

Figure 11. Three-fields plot

Source: author's elaboration using R software.

Figure 11 shows the relationship between the keyword (left), author (middle), and source (right). Scholars such as Schaltegger, Tiwari, and De Villiers were found to have predominantly used the following keywords: integration reporting, sustainability reporting, sustainability, accountability, and environmental reporting. They published in the following publications: the Accounting, Auditing and Accountability Journal, the Journal of Cleaner Production, Meditari Accountancy Research, and the Social and Environmental Accountability Journal.

Conclusion

The bibliometric method of analysis of scientific papers based on the international scientometric database Scopus was used to establish current trends in the development of sustainability reporting. The query results for the period 2011–2021 were processed

using the VOSviewer and R (bibliometrix package) computer programs. There was an increase in scientific interest in the topic, which is manifested in an increase in the number of scientific papers, especially since 2016, amounting to a total of 625 publications.

The study of subject areas in terms of keywords indicates that in recent years, special attention has been paid to the study of sustainable development, sustainability, decision-making, sustainability reporting, accountability, environmental impact, climate change, corporate social responsibility, and more. A more specific analysis of the most cited articles on the subject has shown an emphasis on sustainable development reporting, taking into account climate and environmental issues. The analysis made it possible to establish that significant scientific achievements on this topic were made by Prof. Stefan Schaltegger, Olivier Boiral, Charl De Villiers, Jeffrey Unerman, Leonardo Rinaldi, and Brendan O'Dwyer, among others. These authors have mainly published their papers in the following journals: Sustainability (Switzerland), the Accounting, Auditing and Accountability Journal, the Journal of Cleaner Production and Sustainability Accounting, and the Management and Policy Journal.

As a result of the analysis, it was possible to establish that the following papers have the highest number of citations and have made a significant contribution to solving the pressing issues on the topic: "Seeking legitimacy for new assurance forms: The case of assurance on sustainability reporting" by O'Dwyer, Owen, and Unerman; "Integrated Reporting: Insights, gaps and an agenda for future research" by De Villiers, Rinaldi, and Unerman; and "The International Integrated Reporting Council: A story of failure" by Flower.

Based on the geographical structure of the authors who have researched the problems of reporting on sustainable development, the following countries should be distinguished: The United Kingdom (England), the USA, Australia, Germany, Spain, and Italy. Researchers from Central and Eastern Europe (mainly Poland, the Czech Republic, Romania, Croatia, Hungary, and Lithuania) have researched this issue somewhat less. However, they also have quite a lot of experience, which made it possible to follow the process of disclosing information about investments in reports from sustainable development (Staszkiewicz and Werner 2021), trace companies' financial sustainability (Pasek-ová et al. 2017), implement aspects of sustainable development in the reporting system (Vallišová, Černá, and Hinke 2018), establish trends and regularities in the development of knowledge of reporting on sustainable development in the public sector (Stefanescu 2021), investigate the quality of social information disclosed in non-financial reports (Peršić and Lahorka 2018), investigate the sustainability of companies based on the importance of marketing communications in business (Jianu, Ţurlea, and Guşatu 2016), and increase business transparency through corporate social reporting (Dagilienė, Leitonienė, and Grenčikova 2014).

The results of the study are aimed at helping researchers better understand the state of research on sustainability reporting. In addition, the literature and conclusions presented in this article provide researchers with a broader vision of the topic and make it more open. In the future, researchers may focus on problem areas to explore further. In addition, the usefulness of this study is that it provides an opportunity to summarize and generalize the work on the topic during previous periods, allowing other scholars to use the results as a starting point for their research.

Acknowledgments

This study was based on two scientific topics: "Accounting in the context of sustainable economic development" (code of R&D work – OA–16) and "Formation and distribution of information flows between the subjects of the accounting system of the enterprise" (code of R&D work – OA–20).

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Trendy raportowania zrównoważonego rozwoju: systematyczna analiza sieciowa literatury

Sporządzanie i składanie raportów zrównoważonego rozwoju jest kluczowym obszarem reformy sprawozdawczości korporacyjnej w świetle realizacji celów zrównoważonego rozwoju. W ostatnich latach znacząco wzrósł udział firm, które składają raporty dotyczące zrównoważonego rozwoju i społecznej odpowiedzialności biznesu. Dlatego ważne jest badanie definicji aparatu

pojęciowego. Artykuł ma na celu zbadanie struktury ilościowej i jakościowej przepływu dokumentacji czasopism naukowych, głównych obszarów badań i trendów rozwojowych. Przedstawiono w nim również wyniki systematycznego przeglądu publikacji dotyczących raportowania zrównoważonego rozwoju.
W pracy wykorzystano analizę bibliometryczną czasopism naukowych pochodzącą z bazy Scopus dla lat 2011–2021. Prace naukowe wybrane za pomocą słowa kluczowego „raportowanie zrównoważonego rozwoju" zostały wyeksportowane do przetwarzania w programach komputerowych VOSviewer i R (pakiet bibliometryczny). Na podstawie wyników analizy ilościowej wyodrębniono 625 publikacji, z których większość stanowiły artykuły naukowe. Główne obszary badań nad sprawozdawczością w zakresie zrównoważonego rozwoju w rachunkowości to zrównoważony rozwój, stabilność, podejmowanie decyzji, sprawozdawczość w zakresie zrównoważonego rozwoju i odpowiedzialność.
Badanie pozwoliło również zidentyfikować autorów i szkoły badawcze, które wniosły największy wkład w ten temat, oraz zdefiniować klastry geograficzne w kontekście ściśle współpracujących ze sobą krajów całego świata i najwyżej ocenianych czasopism.
Oryginalność tego opracowania polega na tym, że pomaga stworzyć ramy koncepcyjne. Powinno być przydatne dla zdefiniowania zakresu przyszłych badań i ma na celu zapewnienie nowego jakościowo wglądu w rolę sprawozdawczości w zakresie zrównoważonego rozwoju. Artykuł stanowi okazję do wypełnienia luk w badaniach jakościowych dotyczących sprawozdawczości w zakresie zrównoważonego rozwoju. Główne wnioski płynące z tego artykułu pomogą badaczom poszerzyć swoją wiedzę w tym zakresie poprzez retrospektywną analizę wyników badań.

Słowa kluczowe: raportowanie zrównoważonego rozwoju, rachunkowość, CSR, analiza bibliometryczna, analiza sieciowa

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The Motives for Issuing Exchangeable Bonds in the Privatization of State-Owned Enterprises

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Abstract

Using a unique sample of exchangeable bond issues carried out in seven countries since the 2000s, this paper investigates the role of hybrid debt in the privatization of state-owned enterprises (SOEs) via government-controlled investment vehicles. This research shows that so far, sixteen series of exchangeable bonds amounting to approx. USD 25 billion were issued to privatize ten SOEs in the telecommunication, energy, basic materials, industrials, healthcare, and utilities sectors in Europe and Asia. Moreover, in some cases, the privatization of SOEs by means of exchangeables can prove to be a more favorable alternative to traditional methods of selling shares directly on the capital market, for example, via IPOs or SPOs (during periods of deep undervaluation of privatized companies or of high stock market volatility). First, shares can be sold at a later date and at a higher price. Second, the impact on the stock market price of an SOE may be less disruptive to shareholders. Third, the entire privatization process tends to be more flexible for issuers in that they can perceive exchangeables as a source of relatively cheap, long-term external capital while keeping control over the privatized company until the potential conversion of debt by bondholders.

Keywords: state-owned enterprises, privatization, equity-linked securities, exchangeable bonds

JEL: G32, G34, G38, L33

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Introduction

Privatization, defined in the simplest way as the government divestiture of state-owned enterprises (SOEs), has been the subject of intensive research by academics and policymakers over the past three decades. Its primary aim is to reduce the government's role as a dominant stakeholder in the domestic economy and to increase the importance and involvement of the private sector. According to the most current OECD statistics, privatization revenues have more than doubled over the last decade, from around USD 110 billion in 2008 to USD 266 billion in 2016 (OECD 2019).

In the last twenty years, SOEs have been among the largest and fastest-growing multinational enterprises. However, in-depth research in this area is limited and depends heavily on the definition of SOEs adopted in each study (Capobianco and Christiansen 2011). Nevertheless, Kowalski et al. calculated in 2013 that one in ten of the 2,000 largest globally-listed companies of 2011 were state-owned. The IMF's estimates show that this share has risen to 20% in the past decade, and the assets of SOEs worldwide are nowadays worth $45 trillion, which is more or less half the global GDP (IMF 2020). SOEs are gaining importance primarily in emerging market economies, while in developed economies, their significance has remained stable. In OECD countries, state-owned enterprises usually operate in sectors identified as strategic for the national economy, such as energy, rail transport, finance, and telecommunications (OECD 2020).

Several studies documenting smaller productivity and value destruction in state-owned firms provide arguments for reducing public ownership and changing corporate governance in SOEs (Harrison et al. 2019). Such action may primarily support the business management process and positively affect their financial results (Djankov and Murrell 2002; Brown, Earle, and Telegdy 2004; 2016; Estrin et al. 2009). SOEs significant inefficiency and poor performance can be explained by various factors, including strong political interference in the decision-making process of political-oriented managers (Shleifer and Vishny 1994; Boycko, Shleifer, and Vishny 1996; Sheshinski and López-Calva 2003) or inadequate monitoring of management, which incentivizes them to follow their own objectives (Vickers and Yarrow 1991).

On the other hand, some recent studies indicate that privatization enhances corporate social responsibility (CSR) performance and leads to increased CSR investments (Boubakri et al. 2019). However, this observation has not been proven in all countries (Khan et al. 2021). Moreover, privatization can be beneficial from a state perspective. Revenues from privatization can supply state budgets and help reduce budgetary deficits (Megginson and Netter 2001), as well as advance the development of domestic financial sectors and capital markets (Boutchkova and Megginson 2000). However, it should be noted that an excess of state ownership beyond a certain point can contribute to a reduction

in firm-level stock liquidity (Boubakri et al. 2020). Privatization is a highly politically sensitive process exposed to potential corruption and abuse, owing to its involvement in the transfer of productive assets from state to private hands. It must therefore be carried out very carefully and requires politicians to thoroughly analyze all factors that can significantly impact the privatization process and enhance the country's economic growth (Estrin and Pelletier 2018).

Privatization can be carried out: (1) By the SOEs themselves involving their own internal structures and resources; (2) Through the divestment of shares directly by the state; or (3) By selling corporate assets owned by the state indirectly via government-controlled investment vehicles.

There are three main methods of privatization that depend on, among other factors, the size of the SOEs, current market conditions, financial market maturity, the degree of competitiveness of privatized economic sectors, the domestic legal systems, and political context (Estrin et al. 2009; OECD 2019). The first method embraces trade sales carried out through private placement or by trade sale auctions. They both involve selling shares to favored bidders or offering tranches of shares in already listed SOEs to groups of preferred private investors. The second method is based on management or employee buy-outs (MBOs or EBOs), which involves selling shares to legal entities controlled by management or staff. The third way encompasses the sale of shares on the capital market through initial and secondary public offerings (IPOs and SPOs), accelerated book building (ABB), or by issuing hybrid debt, which can be converted or exchanged for SOE shares. A common purpose of such issues is simply to dilute state ownership in SOEs.

The privatization of SOEs using hybrid debt instruments, such as bonds with warrants, convertible bonds, and exchangeable bonds, is particularly interesting from an academic point of view. Due to the discernible gap in the literature, special attention should be paid to the divestments carried out through exchangeable debt. This instrument is usually analyzed from the perspective of private entities (Ghosh, Varma, and Wollridge 1996; Danielova, Smart, and Boquist 2010; Danielova 2011), ignoring its role in the privatization of state-owned companies. Few theoretical articles focused on specific case studies on the privatization of SOEs (Kaźmierczak and Marszałek 2013). In fact, they do not find the motives behind the issuing of exchangeable debt in privatization, nor do they indicate the advantages of this instrument compared to traditional methods of disposing of state ownership, such as IPOs, SPOs, or trade sales. It is also not clear how exchangeables help managers to improve the operational efficiency of state-owned enterprises by gradually increasing the participation of private investors. All previous conclusions were primarily drawn from an extrapolation of the results from studies on other forms of hybrid debt, such as convertible bonds used by private entities and not for privatization purposes. In light of this consideration, it can be assumed that privatization through exchangeable debt may be carried out to gradually privatize and sell

a minority block of shares among small investors (Ruozi and Anderloni 1999), especially in a period of deep undervaluation and large fluctuations in the stock market (OECD 2019). However, all these suppositions call for empirical verification.

The intention of this paper is to fill in the above-mentioned research gap. It aims to identify motives for issuing exchangeable debt in the privatization of SOEs from the perspective of corporate finance management and indicate possible advantages of this approach over the traditional ways of selling state ownership. Analysis of the unique research sample, which comprises sixteen exchangeable issues carried out in seven countries since the 2000s, led to answers for three key questions: 1) How common are exchangeable issues for privatization purposes over the last two decades? 2) What motivated the public party to use hybrid debt instruments as a favorable alternative to traditional ways of selling shares of state-owned firms? 3) How are the exchangeable issues that are used to privatize SOEs designed?

By addressing these research questions, the paper contributes to the literature in several ways. First, its main findings are in the line with mainstream research on the use of hybrid debt instruments. Second, it provides insight into potential reasons for issuing exchangeable debt during privatization. Third, it complements knowledge on issuing exchangeable bonds among business entities and supports managers in corporate finance management.

The rest of the paper is organized as follows. A literature review is provided in Section 2, while Section 3 describes the data collection and the sample selection process. Section 4 presents the analyses and discusses the results, and Section 5 concludes the paper.

Literature review

The unconventional construction of hybrid instruments makes them a useful tool when divesting private entities. Knowledge about them is scarce due to the relatively low popularity of exchangeable bonds when privatizing SOEs in the public sector. The only article on the use of exchangeable debt in privatization includes a description of the mechanism of state property divestment of SOEs based on specific case study examples in different countries (Kaźmierczak and Marszałek 2013).

Privatization by means of hybrid debt instruments can take various forms. First, state ownership can be disposed of through debt-equity swaps. It involves the exchange of sovereign bonds or bank loans for ownership rights to equity, helping governments to reduce their foreign debt burdens[1] (Ganitsky and Lema 1988; Ramamurti 1992; Bowe and Dean 1993; Mil-

1 Exemplified by debt conversion programs in Latin American countries in the late 1980s and early 1990s.

man 1996). Second, it can be done by privatization bonds, which are sovereign bonds that give bondholders the priority to convert them into shares of privatized enterprises[2] (Khosrowshahi 1997). Third, privatization can be carried out directly by privatized companies by issuing bonds with warrants or convertible bonds that can be converted for their shares. They can take the form of going-public bonds. These instruments are issued prior to a listing of privatized companies on a stock exchange, and bondholders have the right to convert them for shares during the IPO at a predetermined price (Lieberman and Kirkness 1998). Fourth, privatization can be carried out by exchangeable bonds via government-controlled investment vehicles, such as dedicated state agencies, sovereign wealth funds, development banks, and government-owned investment funds (Kaźmierczak and Marszałek 2013).

Exchangeable debt is a hybrid instrument similar to convertible bonds. The main difference is that exchangeables can be exchanged for a company's existing shares owned by the issuer, not for the shares of an issuing company, as in the case of convertibles. There are a number of arguments that point to the advantages of share disposal using hybrid debt instead of the ordinary sale of common stock on the capital market. Most of them may be crucial for the privatization of SOEs.

First, issuing exchangeable debt can be more cost-effective for the issuers because they avoid the complex and time-consuming procedure of issuing SOEs' shares through IPOs or SPOs (Barber 1993; Gentry and Schizer 2003; Kleidt 2006). Second, the announcement of exchangeable debt offers may be associated with a less negative price response of the privatized firms' stock than the response when the ordinary sale of equity on the public capital market is announced (Ghosh, Varma, and Wollridge 1990; Barber 1993).[3] Third, by issuing exchangeable bonds, the issuer may avoid issuing undervalued shares of a privatized company and selling them at a higher price at a later date (OECD 2019). Fourth, issuing exchangeable bonds does not affect the ownership structure of the issuer because the bonds can be converted into common shares of its subsidiary. As a result, the issuer does not need to recognize gains on the sale of shares and can capture all dividends paid by the underlying company until the conversion of debt (Barber 1993). Fifth, due to the embedded conversion option, the exchangeable bonds may constitute a source of cheaper medium- and long-term financing for the issuers (Lieberman and Kirkness 1998).

A simplified scheme of privatization through exchangeable bonds is shown in Figure 1. The process typically begins with the issuing of bonds that are exchangeable for SOE

2 As seen in Morocco in the mid–1990s.

3 Possibly due to the repurchase guarantee embedded in the exchangeable debt offering. The issuing firm guarantees that it will keep the stock of underlying firmstock if its value falls below the value of the straight bond component of the exchangeable offering (Barber 1993, p. 57). However, other analyses reveal that exchangeable offerings convey unfavorable information about the underlying firms to the market and may be interpreted as the beginning of restructuring process (Amman, Fehr, and Seiz 2006; Kleidt 2006; Danielova and Smart 2012).

shares, usually by a government-controlled investment vehicle. Bonds are subscribed mostly by institutional investors. Depending on the strategy, the proceeds from the issue remain with the SPV, are transferred to the SOE, or are redirected to the state budget. At maturity (or earlier if the bonds have an embedded call option that allows investors to convert debt into equity before maturity), investors decide to exchange bonds for SOE shares and become shareholders in the privatized company.

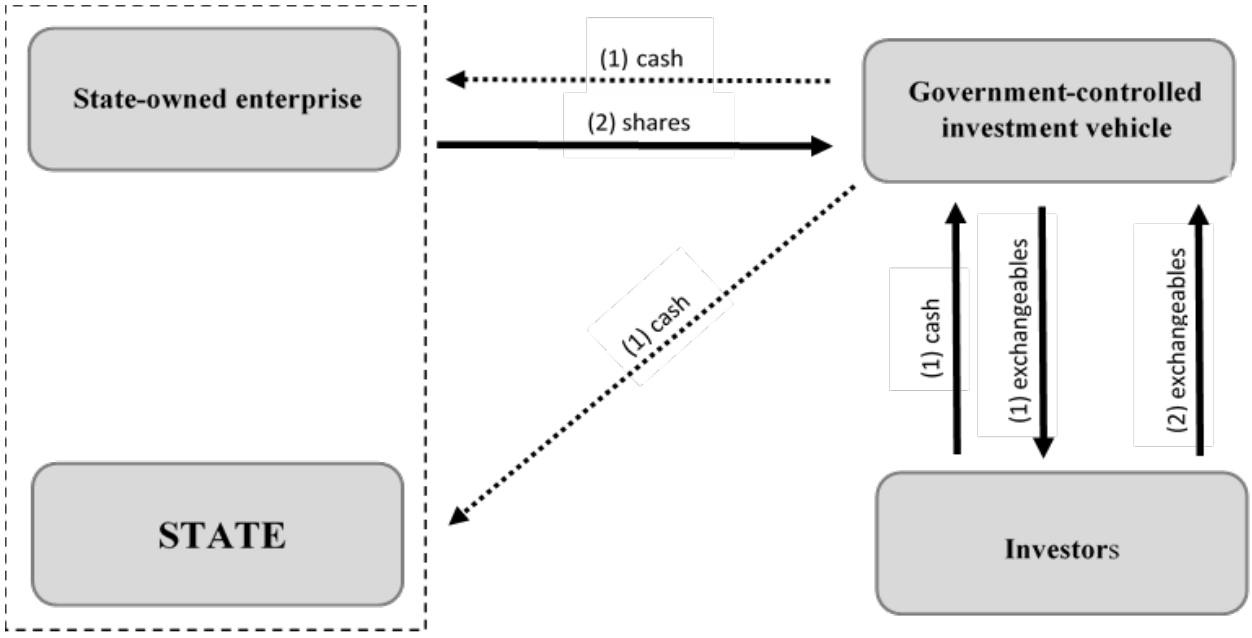

Figure 1. Privatization process with the use of exchangeable bonds

Source: own elaboration.

Data collection, sample selection, and methodology

A unique database was compiled of all identified issues of exchangeable bonds utilized in privatizations since the beginning of the 2000s. It was done manually using companies' annual reports, market disclosures, and press releases. The study concentrates on exchangeable issues conducted only through government-controlled investment vehicles (or their subsidiaries). Any equity exits not related to privatization were not included in the sample. Attention was focused exclusively on exchangeable debt issues (i.e., exchangeable bonds, exchangeable notes, and exchangeable certificates). Therefore, any types of debt-equity swaps, sovereign bonds exchanged for ownership rights in SOEs, and convertibles issued by state-owned companies for their own equity, were excluded from the analysis. After implementing these restrictions, the final sample encompasses sixteen exchangeable issues carried out in the privatization of companies from seven countries that operate in seven different economic sectors.

The empirical research was divided into three parts. In part one, the geographical and sectoral characteristics of exchangeables issued during privatizations since the 2000s were analyzed. Part two focuses on the issuers of equity-linked securities in search of motives for issuing debt exchangeable for ownership in SOEs. Part three examines major features of exchangeable bond issues, including maturity, coupons, and conversion premiums, to find common features of exchangeables issued for privatization purposes.

Analysis, results, and discussion

Table 1 presents an overview of the global market of exchangeable bonds used in privatizations since the beginning of the 2000s. Sixteen series of exchangeable bonds were issued in four countries in Europe (Austria: 2; Germany: 5; Hungary: 3; and Portugal: 3) and three countries in Asia (Singapore, Malaysia, and Papua New Guinea) (Table 1, column 2).

Table 1. An overview of the global exchangeables market in privatizations since the 2000s

Issue date	Country	Privatized company	Economic sector	Amount in currency
2003	Austria	Voestalpine AG	Basic materials	245,200,000 EUR
2003	Austria	Telekom Austria AG	Telecommunication	325,000,000 EUR
2003	Germany	Deutsche Post AG	Industrials	1,150,000,000 EUR
2003	Germany	Deutsche Telekom AG	Telecommunication	5,000,000,000 EUR
2004	Hungary	Gedeon Richter Ltd.	Healthcare	639,000,000 EUR
2004	Singapore	Singapore Telecom. Ltd.	Telecommunication	1,250,000,000 USD
2005	Germany	Deutsche Post AG	Industrials	1,100,000,000 EUR
2005	Portugal	EDP SA	Utilities	572,800,000 EUR
2006	Malaysia	Telekom Malaysia Bhd	Telecommunication	750,000,000 USD
2007	Portugal	EDP SA	Utilities	1,015,150,000 EUR
2008	Germany	Deutsche Telekom AG	Telecommunication	3,300,000,000 EUR
2009	Germany	Deutsche Post AG	Industrials	750,000,000 EUR
2009	Hungary	Gedeon Richter Ltd.	Healthcare	833,300,000 EUR
2009	PNG*	Oil Search Ltd.	Energy	1,168,000,000 AUD
2010	Portugal	Galp Energia SA	Energy	885,650,000 EUR
2013	Hungary	Gedeon Richter Ltd.	Healthcare	903,800,000 EUR

* PNG – Papua New Guinea.
Source: own elaboration.

Telecommunication companies comprised the largest group of the ten SOEs privatized by means of exchangeable debt (Deutsche Telekom AG, Singapore Telecommunications Ltd., Telekom Austria AG, and Telekom Malaysia Bhd). Other firms operated in the following sectors: energy (Galp Energia SGPS SA and Oil Search Ltd.), basic material (Voestalpine AG), industrial (Deutsche Post AG), healthcare (Gedeon Richter Ltd.), and utilities (EDP SA) (Table 1, column 4).

The total value of exchangeable bonds issued since the 2000s amounted to nearly USD 25 billion (Table 1, column 5). This could be considered a modest contribution considering that the total value of privatization revenues reached USD 266 billion in 2016 (OECD 2019). Four-fifths of issues were attributed to Europe, all denominated in Euro. Asian firms opted mostly for US dollar issues. Only one issue was denominated in Australian dollars.

Table 2 summarizes all exchangeable bond issuers from the research sample. Almost half of exchangeables were issued by state agencies involved in public asset management or privatization programs (i.e., the Hungarian National Asset Management (MNV) and its predecessor, the Hungarian Privatization and State Holding Company (APV), both in Hungary; Parpública in Portugal; the Independent Public Business Corporation (IPBC) in Papua New Guinea, and the Austrian Industrial Administration Limited-Liability Company (ÖIAG) in Austria). The second group of issuers constitutes investment agencies and sovereign wealth funds (or their subsidiaries), and special purpose entities (i.e., Temasek Holdings in Singapore and Khazanah Nasional in Malaysia). Finally, one issue was carried out by a development bank (i.e., Kreditanstalt für Wiederaufbau, KfW in Germany).

Table 2. The issuers of exchangeable bonds for privatization purposes since the 2000s

Issuer		Privatized company
APV/MNV* (Hungary)	Privatization agency/national asset management agency	Gedeon Richter
IPBC (Papua New Guinea)	Sovereign wealth fund	Oil Search
KfW (Germany)	Development bank	Deutsche Post, Deutsche Telekom
Khazanah Nasional** (Malaysia)	Sovereign wealth fund	Telekom Malaysia
ÖIAG (Austria)	Privatization agency	Telekom Austria, Voestalpine
Parpública (Portugal)	National asset management agency	EDP, Galp Energia
Temasek Holdings (Singapore)	Investment Agency	Singapore Telecommunications

* MNV is the successor of APV; ** Khazanah Nasional carried out the privatization of Telekom Malaysia through its SPV – Rafflesia Capital.
Source: own elaboration.

In-depth analysis shows that almost all exchangeable bonds were sold to international and institutional investors that operate in domestic markets (such as investment companies, banks, asset managers, insurance companies, and pension funds). They were then listed on stock exchanges (in Luxembourg, Frankfurt, Lisbon, Singapore, and Hong Kong). Only one issue was taken up by an industry investor to raise capital for investment purposes of the state.[4] A few issues were aimed at retail investors outside the domestic market.[5] Finally, private investors (i.e., current employees) subscribed to one issue to keep the shareholder structure due to the strategic importance of the privatized SOE for the state.[6]

The diversity of strategies applied by governments makes it possible to identify possible motives behind the issuance of exchangeable debt in the privatization of state-owned companies. Most exchangeable bond issues carried out for privatizations were highly innovative for the local capital markets. For instance, the Austrian ÖIAG placed the first exchangeable debt issuance in the Austrian market. The German KfW, issued in 2005, was the first foreign currency exchangeable bond offered by a non-Japanese issuer to Japanese household investors (commonly called Uridashi bonds). In 2006, Malaysia's Khazanah Nasional prepared the first offering of Shariah-compliant exchangeable debt in the world (exchangeable sukuk). These examples may indicate that the decision to issue exchangeable bonds was made with great deliberation, taking into account a variety of circumstances, including market conditions and periods of increased demand for high-quality credit in combination with very liquid underlying shares (which makes it possible to obtain attractive pricing of debt instruments used in such situations). Therefore, the issuance of exchangeables can perfectly complement the entire privatization process in addition to IPO, SPO, or block sales. From this point of view and after reviewing the terms and conditions of exchangeable issues presented in Table 3, four main rationales for the use of exchangeable debt can be distinguished.

Table 3. Terms of issue of exchangeable bonds issued for privatization purposes since the 2000s

Privatized company	Maturity (years)	Coupon (%)	Conversion premium (%)
Deutsche Post (2003)	4	0.500	30.0
Deutsche Post (2005)	4	0.500	12.0
Deutsche Post (2009)	5	1.500	35.0
Deutsche Telekom (2003)	5	0.750	38.0
Deutsche Telekom (2008)	5	3.250	27.5

4 Papua New Guinea, where exchangeables issued by IPBC were subscribed by the International Petroleum Investment Company of Abu Dhabi (IPIC).

5 Such as the exchangeables issued by KfW in Japan in 2005.

6 See the privatization of voestalpine AG in Austria in 2003.

Privatized company	Maturity (years)	Coupon (%)	Conversion premium (%)
EDP (2005)	5	2.690	43.0
EDP (2007)	7	3.250	45.0
Galp Energia (2010)	7	5.250	25.0
Gedeon Richter (2004)	5	1.000	54.0
Gedeon Richter (2009)	5	4.400	32.0
Gedeon Richter (2013)	5.5	3.375	35.0
Oil Search (2009)	5	5.000	72.4
Singapore Telecom.(2004)	5	0.000	4.8
Telekom Austria (2003)	3	1.125	35.0
Telekom Malaysia (2006)	5	1.250	19.0
Voestalpine (2003)	3	1.500	27.0
Mean	5	2.2	33.4

Source: own elaboration.

First, the issuance of exchangeables enables the issuing company to get a higher price for the shares sold as a result of debt conversion. Thus, they are commonly used when privatized entities are severely undervalued[7] or during high volatility of stock markets due to uncertainty.[8] This is a probable reason why the average premium for the sample of exchangeables exceeds 30%. It represents the upper limit of an average conversion premium for convertible debt estimated from 20 to 30% (Das 2003). What is more, to assure a relatively high price for common stock, issuers often give bondholders the right to convert exchangeables into SOE equity only in the last years before maturity.[9] To maintain balance, they often add a call option that allows the early redemption of bonds with no obligation to convert them into equity if privatization ultimately becomes undesirable. Sometimes they even offer cash in exchange for giving up conversion.[10]

Second, issuers may use exchangeable bonds due to privatization plans that assume a careful and gradual exit from the privatized entities without causing a drop in their share price following the sale of a large block of shares to external investors.[11] This argument is supported by the outcomes that indicate that underlying shares that exchange-

7 Exemplified by the privatization of the state postal and telecommunication services in Austria and Germany in 2003.

8 See for reference the privatizations of EDP and Galp Energia in Portugal.

9 For example, the privatization of the EDP in 2005 in Portugal.

10 As with the privatization of Gedeon Richter in Hungary in 2013.

11 Illustrated by the privatization of Gedeon Richter in 2004 in Hungary and Telekom Malaysia Bhd. in Malaysia in 2006.

able bonds can be converted into constitute nearly 6% of the outstanding share capital of the privatized companies.

Third, the issuance of exchangeable bonds may be perceived by issuers as relatively cheap and long-term external capital which can directly supply state budgets,[12] fund state investment projects,[13] or finance the principal business of the issuing companies.[14] These observations are supported by an average maturity of sample exchangeables of five years and an average coupon equal to 2.2% (median: 1.5%). This is approximately twice as low as the average government bond interest rate in corresponding years. The difference is most pronounced in Germany (3.0–4.0% for 10Y government bond yields vs. 0.5–3.0% for exchangeables), Austria (approx. 4.0% vs. 1.0–1.5%), Hungary (6.0–9.0% vs. 1.0–4.5%), and Portugal (3.5–5.5% vs. 2.5–5.0%).

Fourth, by issuing exchangeables, the issuers can keep all dividends from privatized subsidiaries until conversion and maintain a real impact on their operational activity. However, confirmation of this thesis requires further in-depth qualitative research.

Finally, every third exchangeable issue from the sample (amounting to approx. USD 10 billion) was carried out to refinance maturing bonds that had not been converted into shares in the privatized companies. There are many indications that, in some cases, issuers did not even want the issue to end in conversion. Their main intention was to remain a shareholder in privatized SOEs and continue to exercise their ownership rights in accordance with state economic interests.[15]

Following the results of the reasearch, the effects of privatizing SOEs through exchangeable bonds cannot be assessed unambiguously. First of all, more than half of the issues from the sample did not result in the conversion of debt into equity, which seemed to be the primary aim of the issuers in the majority of cases[16]. The conversion failure was mainly caused by unfavorable market conditions, which effectively discouraged bondholders from exchanging bonds for shares of privatized entities.[17] On the other hand, the complete success of the privatization strategies based on hybrid debt can be seen in Austria, Papua New Guinea, and Germany[18]. Hence, further in-depth research in this area is necessary.

12 Resembling the privatized companies in Germany and Portugal.

13 As in Papua New Guinea.

14 As in Malaysia or Singapore.

15 For example, the privatization of Gedeon Richter in 2009 and 2013.

16 For example, Deutsche Telekom AG and Galp Energia SA.

17 See the privatization of EDP SA.

18 Privatizations of, consecutively, voestalpine AG, Telekom Austria AG, Oil Search Ltd. and Deutsche Post AG.

The issuance of exchangeable bonds for the privatization of SOEs was previously discussed in Russia. Such a plan was considered for the privatization of VTB Bank in 2002–2003 (they were going to be five-year bonds exchanged for 10–20% of VTB's shares), but it ultimately ended up with an ordinary sale of shares in the financial market. The idea of issuing exchangeable bonds was then revisited in 2011–2013 for the privatization of Alrosa and Sberbank, but this ended in fiasco again (Pronina 2011). The issuance of hybrid debt instruments for the privatization of state-owned enterprises was also considered in Poland by the Treasury Ministry in 2007–2009 (Bujnicki 2017) and 2012 (Zatoński 2012). However, despite initial plans, their widespread use in the Polish financial market has not occurred.

Conclusions

The issuance of bonds that are exchangeable for shares in state-owned enterprises carried out via government-controlled investment vehicles is a privatization method that is used in different parts of the world. However, this topic has hardly been addressed in previous research. Therefore, the purpose of this article was to fill the research gap and contribute to the literature with new research insights into the little-known mechanism for using exchangeable bonds during privatization via financial markets. Using a unique research sample that comprised sixteen exchangeable issues carried out in seven countries since the 2000s, the article identified key motives for the issuance of exchangeable debt in the privatization of SOEs through dedicated state entities. It also explained why states use hybrid debt instruments as a more favorable alternative to traditional ways of disposing of state ownership, such as IPOs, SPOs or trade sales. The main conclusions to be drawn from this article are as follows.

First, the total value of exchangeable bonds issued for privatization purposes since the 2000s, which amounts to almost USD 25 billion, very strongly contrasts with the more than USD 250 billion of total privatization revenues earned only in 2016, according to the latest OECD data. More specifically, over the last twenty years, sixteen series of exchangeables were issued to privatize ten SOEs in Europe and Asia (i.e., Austria, Germany, Hungary, Portugal, Singapore, Malaysia, and Papua New Guinea) that operate in various sectors from telecommunication and energy to basic materials, industrials, healthcare, and utilities (i.e., Austria Telekom, voestalpine, Deutsche Telekom, Deutsche Post, Gedeon Richter, Galp Energia SGPS, EDP, Singapore Telecommunications, Telekom Malaysia, and Oil Search).

Second, government-controlled investment vehicles that intermediated in the privatization of SOEs through exchangeable debt included state agencies involved in privatization programs, investment agencies, sovereign wealth funds, and development banks (i.e., MNV in Hungary, Parpública in Portugal, IPBC in Papua New Guinea, ÖIAG in Austria, Temasek Holdings in Singapore, Khazanah Nasional in Malaysia, and KfW in Germany).

Third, most exchangeable issues were highly innovative for the local capital markets (e.g., the first Shariah-compliant exchangeable debt issued in Malaysia or the first exchangeable debt issuance in Austria). Moreover, many of them were then listed on major world exchanges (i.e., in Luxembourg, Frankfurt, Lisbon, Singapore, and Hong Kong). Exchangeables were mostly sold to domestic and international institutional investors (such as investment companies, banks, asset managers, insurance companies, and pension funds). Only a few were aimed at retail investors in or outside a domestic market.

Lastly, the analysis indicates that in some cases, selling SOE shares through exchangeable bonds can be more beneficial for the stakeholders than disposing of them directly on the capital market through IPOs, SPOs or trade sales. Such situations may include, among others, periods when privatized companies are severely undervalued or there is high volatility in stock markets due to extraordinary uncertainty. This presumption has been initially confirmed by the observations that by using exchangeable bonds: (1) Shares may be sold at a higher price (due to a 30–50% conversion premium embedded in the analyzed exchangeables); (2) The impact on the stock market price of the privatized company may be less disruptive to shareholders (the underlying shares into which exchangeable bonds can be converted constitute a modest portion of outstanding share capital); (3) The entire privatization process tends to be more flexible (the state keeps control over the privatized company, receives all dividends paid until conversion of hybrid debt, and can cease the privatization at any time by exercising a call option attached to exchangeables); and (4) The issuance of exchangeable bonds constitutes a relatively cheap and long-term external capital for the issuers, which can finance their business or contribute to the state budget (an average coupon of exchangeables is twice as low as the average government bond yields in corresponding years).

The findings of this paper relate to research in corporate finance examining the motives that drive hybrid debt issues. The article is perhaps the first to provide a comprehensive analysis of using exchangeable bonds for privatization and lays the groundwork for further research on equity-linked securities in the privatization of SOEs. Looking forward, it would first be useful to examine whether the decision to issue exchangeable bonds is related to periods when privatized companies are severely undervalued, and there are extraordinary fluctuations in the stock market. This would demonstrate whether exchangeable bonds are considered the most appropriate instrument for privatization in specific market conditions. Consequently, it would then be necessary to investigate how the SOE share price fluctuates in the short, medium and long terms after the announcement of an exchangeables issue for shares of the privatized company. This would answer how investors view the use of hybrid bonds for privatizations (i.e., whether they provide positive or negative information about a privatized company).

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Motywy emisji obligacji wymiennych w procesach prywatyzacyjnych przedsiębiorstw państwowych

Na podstawie unikalnej próby obligacji wymiennych wyemitowanych w siedmiu krajach w XXI wieku w artykule przeanalizowano rolę hybrydowych instrumentów dłużnych w procesach prywatyzacyjnych przedsiębiorstw państwowych. Z przeprowadzonego badania wynika, że dotychczas wyemitowano szesnaście serii obligacji wymiennych o łącznej wartości ok. 25 mld USD w celu prywatyzacji dziesięciu przedsiębiorstw w Europie i Azji, działających w sektorach: telekomunikacyjnym, energetycznym, materiałów podstawowych, przemysłowym, opieki zdrowotnej i użyteczności publicznej. Ponadto wykorzystanie obligacji wymiennych w celu prywatyzacji przedsiębiorstw państwowych może w niektórych przypadkach stanowić korzystniejszą alternatywę dla tradycyjnej oferty sprzedaży akcji prywatyzowanych spółek na rynku kapitałowym (np. w okresach niedowartościowania akcji lub dużych wahań indeksów giełdowych). Po pierwsze, emitenci mogą dokonać sprzedaży akcji prywatyzowanych przedsiębiorstw w późniejszym czasie i po wyższej cenie. Po drugie, emisja obligacji wymiennych może mieć mniej negatywny wpływ na notowania giełdowe prywatyzowanej spółki. Po trzecie, proces prywatyzacji może być postrzegany jako bardziej elastyczny przez samych emitentów, ponieważ mogą oni wykorzystywać środki z emisji długu hybrydowego jako źródło tańszego i długoterminowego kapitału zewnętrznego oraz zachowywać kontrolę nad prywatyzowaną spółką do czasu ewentualnej konwersji obligacji przez obligatariuszy.

Słowa kluczowe: przedsiębiorstwa państwowe, prywatyzacja, hybrydowe instrumenty dłużne, obligacje wymienne

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Energy Subsidies and their Implications for CO_2 Emissions in the Visegrad Group Countries

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Abstract

The aim of the article is to present a review of the literature on energy subsidies and the scale and structure of subsidies for energy production in the Visegrad Group countries. It also presents the most important results of an investigation into the relationship and impact of fossil fuel subsidies on CO_2 emissions based on a linear regression model. Due to the availability of comparable statistical data, the survey was limited to the period 2015–2020. The analysis does not provide a clear confirmation of the negative impact of the amount of subsidies (from the current or previous year) on the level of CO_2 emissions.

Keywords: CO_2, fossil fuel, subsidies, V4 countries

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Introduction

Government subsidies for energy consumption and production, including fossil fuels – and the social, environmental, and fiscal consequences of fossil fuels – have been analysed in many economic studies. By affecting the final price levels for producers and consumers, such subsidies cause the simultaneous overproduction and increased consumption of energy products relative to the market situation without such subsidies. The debate on subsidising fossil fuels and electricity production intensified after the 2009 G20 Pittsburgh Summit. The leaders reiterated the commitment to "Rationalize and phase out over the medium-term inefficient fossil fuel subsidies that encourage wasteful consumption. As we do that, we recognize the importance of providing those in need with essential energy services, including through the use of targeted cash transfers and other appropriate mechanisms. This reform will not apply to our support for clean energy, renewables, and technologies that dramatically reduce greenhouse gas emissions" (G20 Information Centre 2009). Since then, the reduction and reform of economically inefficient and environmentally harmful fossil fuel subsidies have become a major issue on the political agenda of many governments worldwide. It was also reflected in the plan of action adopted by the UN in 2015, *Transforming our world: the 2030 Agenda for Sustainable Development,* where, among 17 Sustainable Development Goals, Goal 12c stated: "Rationalize inefficient fossil-fuel subsidies that encourage wasteful consumption by removing market distortions, in accordance with national circumstances, including by restructuring taxation and phasing out those harmful subsidies, where they exist, to reflect their environmental impacts" (United Nations 2015).

In the context of the international debate on climate change and the transition to a low-emissions economy, attention must be drawn to the efforts made by the European Union (EU), where decarbonisation and the Climate Policy are becoming more important in the energy policy. The ultimate goal is to achieve climate neutrality in the aspect of CO_2 emissions by 2050 through renewable energy sources, energy efficiency, and reduced greenhouse gas emissions. Furthermore, the European Commission (EC) has undertaken to phase out inefficient fossil fuel subsidies by 2025, with the first annual monitoring report, *Member States' progress towards phasing out energy and more specifically, fossil fuel subsidies in the EU*, published in 2020, according to the requirement of the *Regulation on the Governance of the Energy Union and Climate Action* (European Commission 2020a). Nevertheless, Member States continue subsidising energy sources, explaining that such measures are necessary for the transition towards a low-emissions economy and to improve the security of supplies, or price competitiveness, which is often contrary to the adopted climate goals.

Due to the high degree of dependence on energy resources imported from Russia, questions about the pace of energy transformation and the issue of the EU's energy security have become particularly important following Russian aggression on Ukraine. Russia is the country of origin of 25% of oil, 45% of natural gas, and 44% of hard coal imported

by the EU. Central and Eastern European countries are more dependent on Russian oil than Western European countries (Lipiński, Maj, and Miniszewski 2022). Apart from diversifying resource supplies and further developing renewable energy sources, it may be necessary to strengthen the EU's strategic security by reducing the demand for energy by changing consumer behaviour.

Although the transition to low-emission energy sources has been the subject of many studies, energy subsidies are not widely described in the literature on the subject. The article fills this research gap. It is structured as follows. First, there is a literature review, and then the scale and structure of energy production subsidies in the Visegrad Group (V4)[1] are presented. Finally, an attempt will be made to identify the dependencies and impact of fossil fuel subsidies on CO_2 emissions based on the linear regression model. Due to the availability of comparable statistical data, the research was limited to the period 2015–2020, with the analysis performed using R software, version 4.1.2.

Literature review

For many years, state intervention has been visible in the energy sector. Governments used subsidies to improve the security of supplies, reduce air pollution and greenhouse gas emissions, increase competition, and ensure social protection and employment security (Koplow 1996). However, opinions on the efficiency of those measures vary (OECD & IEA 2021). Furthermore, political priorities and technological capacities change over time. General energy subsidies should meet fundamental social, economic, and environmental goals. Lower energy prices allow low-income households to use various electrical devices and appliances to heat their homes. Thus, they achieve a higher living standard, which would be impossible without such support. Support for producers aims to reduce energy generation costs, help investments, and stimulate production capacity. It can also help them develop new types of energy media, including renewable energy sources.

The state also supports producers that use natural energy for manufacturing technologies. Subsidies for energy and fuel production often also serve to keep jobs and reduce unemployment, particularly in the coal mining sector in many countries rich in this resource. Removing subsidies for coal mining would often mean shutting down unprofitable mines, the loss of jobs, and the deterioration of the trade balance as a result of increased imports. Various forms of subsidies for producers and investors support the search for new energy sources and the development of production, particularly in the early phase of implementation. It also serves to improve the natural environment by encouraging energy production that involves lower emissions of harmful substances into the air.

1 An informal regional cooperation between the Czech Republic, Hungary, Poland, and Slovakia.

Governments also tend to support the development of transmission and transport infrastructure, as well as measures related to liquidating old and inefficient production plants and waste management. Significant state funds are also devoted to energy consumers to encourage them to undertake actions aimed at energy savings and lower fuel consumption. However, energy subsidies often do not allow the intended social and economic goals to be achieved effectively. Subsidies for household energy consumption result in higher-income consumers, who consume more energy than the average household, being the main beneficiaries. Consequently, although higher-income households consume more energy in absolute terms, the share of energy-related expenditures in total expenditures is higher in poorer households. Subsidies for producers, in turn, are not favourable to reducing energy-consuming production and replacing old plant with new low-energy equipment.

International discussion still lacks a consistent universal definition of energy subsidies or a harmonised reporting mechanism (Koplow 1993; Myers and Kent 2001). Budget subsidies are transfers that appear in domestic accounts as governmental expenditures. Examples include cash transfers to energy producers, consumers, and similar entities, as well as low-interest loans or loans with interest rates reduced by the government. Off-budget subsidies, in turn, include tax reliefs and exemptions, preferential market access, regulatory support mechanisms, and preferential access to natural resources (van Beers and Moor 1999; van Beers et al. 2007).

By regulating domestic prices and keeping them below global market prices, governments can support the consumption of particular energy resources. They can also decide to subsidise production, for example, by imposing minimum prices above the market level. In such a case, producers increase the supply and accelerate the shortage of particular energy resources while public budgets are used to cover the surpluses. Both types of political interventions above can exist simultaneously and form a thick network of distortions causing significant fiscal drainage. Through overproduction or excess consumption, subsidies for both producers and consumers may degrade the natural environment (Moor and Calamai 1997; Moor 2001).

Various institutions are also involved in the classification, cataloguing, and analysis of energy subsidies, and definitions of energy subsidies applied by the various organisations to estimate the scale materially differ from one another. Non-uniform definitions thus lead to large differences in the estimated volumes of support (IRENA 2020).

The International Energy Agency (IEA) defines energy subsidies as "any government action that concerns primarily the energy sector that lowers the cost of energy production, raises the price received by energy producers or lowers the price paid by energy consumers" (IEA 2014). The subsidy amount is the difference between the reference price and the price paid by end customers. If it is positive, the product is considered subsi-

dised. For energy importers, the reference price is deemed as the import price paid by the nearest international energy hub, plus the costs of transport and distribution plus VAT. For energy exporters, it is defined as the export price less costs of transport and distribution plus VAT. Such an approach is questioned by many energy exporters and by OPEC, who believe that the reference price should be determined based on generation costs, not the export price (IEA, OPEC, OECD and World Bank 2010).

The OECD defines support as a measure "that provides a benefit or preference for fossil-fuel production or consumption" (OECD 2015). By affecting the final price levels for producers and consumers, energy subsidies cause simultaneous overproduction and excessive consumption of energy products relative to the market situation in the absence of such subsidies. The final result depends on price-related factors of the flexibility of supply and demand for particular energy products. The definition of support applied by the OECD is broad. It covers all forms of budgetary support, including direct transfers and tax reliefs or exemptions that provide benefits or preference for fossil-fuel production or consumption, both on absolute terms and compared to other types of activities or products.

The financial support covered by the OECD listing creates a burden for governmental budgets in the form of increased expenditures or decreased income. The listing does not cover most subsidies for consumption, which is the prevailing form of energy subsidy in developing countries. The OECD has identified over 550 governmental policy measures applied by its members that have been considered fossil fuel support. The volume of energy subsidies estimated by the OECD is the lowest among all international institutions that deal with estimation, which results from the adopted definition. This is because listings drafted by the OECD cover some sorts of funds (not covered by estimates by other organisations) that do not affect consumption price levels, such as benefits for low-income households, benefits for the liquidation of old plants generating energy products, or support of research and development activities (OECD 1997; 1998).

The International Monetary Fund (IMF) applies a more complex definition of energy subsidies. It differentiates between subsidies for producers and consumers, as well as pre-tax and post-tax subsidies. The definition of pre-tax subsidies is comparable with the one applied by the IEA. We deal with consumption subsidies if the price paid by consumer companies (supplier consumption) or households (end-customer consumption) is lower than the costs of generation, transport, and distribution. On the other hand, we deal with production subsidies when the selling price is higher than the costs, plus transport and distribution margins. In international trading, the reference price level is formed by international market prices plus the costs of transport and distribution. For energy products traded domestically, the reference price is adopted at a level that covers generation costs (Clements et al. 2013).

According to the IMF methodology, pre-tax energy subsidies correspond to the definition adopted by IEA; namely, they are the difference between the international market prices and the prices paid by end customers. Post-tax energy subsidies account for external costs that can be attributed to fossil fuel consumption, such as global warming and pollution, as well as its negative impact on human health, the degradation of the environment, and traffic intensity. Such phenomena negatively affect the quality of life and are not accounted for in production costs. However, they generate social costs and require various actions on the part of governments. Such social costs are referred to as "post-tax subsidies" or "hidden energy subsidies." While pre-tax subsidies are popular mainly in developing countries, post-tax subsidies occur on a large scale in both developing and developed countries. Listings of energy subsidies drafted by the IMF are the most complete and cover the greatest number of countries compared to listings by other international institutions.

As already mentioned, comparing energy subsidies is difficult as each institution follows its own calculation methodology. Estimates of energy subsidy values differ considerably depending on the analysing institution and the adopted definition of subsidies. Some institutions apply an overly broad definition, including popular instruments such as accelerated depreciation or reduced VAT rates. The diversity of published statistics is not, however, detrimental to the importance of the global issue of vastly applied energy subsidies. Through excessive consumption of energy products, such subsidies negatively affect the global climate and human health. However, the subsidies can also positively affect the development of new technologies that promote energy generation from renewable resources. Public aid allows the implementation of projects that would be impossible in market conditions. It supports the achievement of strategic goals, such as reducing harmful greenhouse gas emissions.

Energy subsidy statistics prepared by various international organisations are not always continuous. The high labour involved in compiling the data means that the statistics are often published with a significant delay. Additionally, they are not always unavailable for all years, sometimes provided biannually (Taylor 2020).

Recently, various international institutions and scientists from many research centres have analysed the scale and effects of subsidising energy products, in particular, fossil fuels. This is related to measures to reduce global CO_2 emissions and mitigate negative climate change. Research on subsidising fossil fuel and electricity generation intensified after the Pittsburgh G20 Summit in September 2009. All measures in this area accelerated after 2015 and the global adoption of the main assumption of the Paris Agreement, i.e., limiting global warming to "well below 2°C."

Encouraged by the ambitious commitment of the Paris Agreement, the EU decided to be even more active. As early as November 2018, the EC presented its own vision of a climate-neutral EU while analysing all the major sectors, particularly the energy sector,

and possible transformation paths. The transition from a 20% reduction in CO_2 emissions to be achieved by 2020 under the energy and climate package from 2008 to an almost complete reduction has become the main challenge for the EU countries. It means a reduction of approximately 114–157 Mt CO_2 emissions each year.

In 2019, the European Council appeared to make more of an effort to fight climate change, addressing the Commission to accelerate works on the EU's climate neutrality based on its international commitments under the Paris Agreement (European Commission 2019). On 1 December 2019, the EC published a communication on the *European Green Deal*. The proposed EU growth strategy should transform the EU into a climate-neutral, just, and prosperous society with a modern, resource-efficient, and competitive economy (European Commission 2020a). The EU's new, very climate-oriented goals focused principally on energy transformation. Therefore, it was agreed that fossil fuel subsidies must be subject to strict control. On the other hand, green subsidies, namely benefits aimed at developing the industry, promoting the consumption of clean types of energy, limiting the consumption of traditional fossil fuels, and counteracting the unfavourable effects of climate change, should function as a tool to transform the energy sector.

In 2020, the EC published its first annual monitoring report of subsidies, "Member States' progress towards phasing out energy and more specifically, fossil fuel subsidies in the EU" (European Commission 2020a).

The recently adopted European Climate Law (European Parliament 2021) cements Europe's goal to become an emission-free continent by 2050, conforming to the goals of the Paris Agreement. According to the new regulation, further efforts are required to ensure a socially fair phasing out of environmentally harmful energy subsidies, in particular, fossil fuels, which are contrary to the goal. Furthermore, the G7 leaders, including EU leaders, committed to phasing out direct governmental support for energy-intensive fossil fuels (G7 2021). The proposal regarding the Revision of the Energy Taxation Directive (Council Directive 2021) supports phasing out obsolete tax breaks and incentives for fossil fuel use while promoting cleaner fuels and supporting the achievement of the EU's ambitious targets for reducing greenhouse gas emissions.

Type and size of energy subsidies in the EU

According to the Regulation on the *Governance of the Energy Union and Climate Action* (SWD(2019) 212 final), the EC drafts annual monitoring reports on Member States' progress towards phasing out fossil fuel subsidies. The first report was published in 2020 and covers the period of 2015–2019 (COM(2020) 950 final). The report relies on direct

data collected from Member State sources and the information contained in the National Energy and Climate Plans (NECPs). Our analysis uses the report from 2021 (COM(2021) 950 final). However, some data aggregated for 2020 require confirmation and, additionally, that year was special due to the supply and demand shock caused by the COVID–19 pandemic. Therefore, it was decided that 2019 should serve as the principal point of reference to assure a fuller and more reliable image.

Although in 2020, renewable energy sources exceeded fossil fuels in the EU's energy mix for the first time (38% electricity, 37% fossil fuels, and 25% nuclear energy), Member States still spent 56 billion euros on fossil fuel subsidies in 2019, with 15 Member States spending more on fossil fuels than on renewable energy sources (RES). Analyzing the evolution of energy subsidies in the EU points to financial support in 2019 totalling 176 billion euros. In 2020, the total energy subsidy in the EU remained stable at 177 billion Euros. Subsidies on measures related to energy efficiency, however, continued to grow (by 5%) compared to 2019. Fossil fuel subsidies in 2019 totalled 0.4% of GDP on average, although there are clear differences regarding total subsidy amount vs GDP. The highest expenditures on fossil fuels vs GDP were recorded for Hungary (1.21% of GDP), while Malta spent just 0.03% (Figure 1). In Czechia, Slovakia, and Poland, total fossil fuel subsidies were equivalent to 0.62%, 0.45%, and 0.31% of GDP, respectively, although one must point to the scale of coal subsidies in Poland and Slovakia (0.2% of GDP).

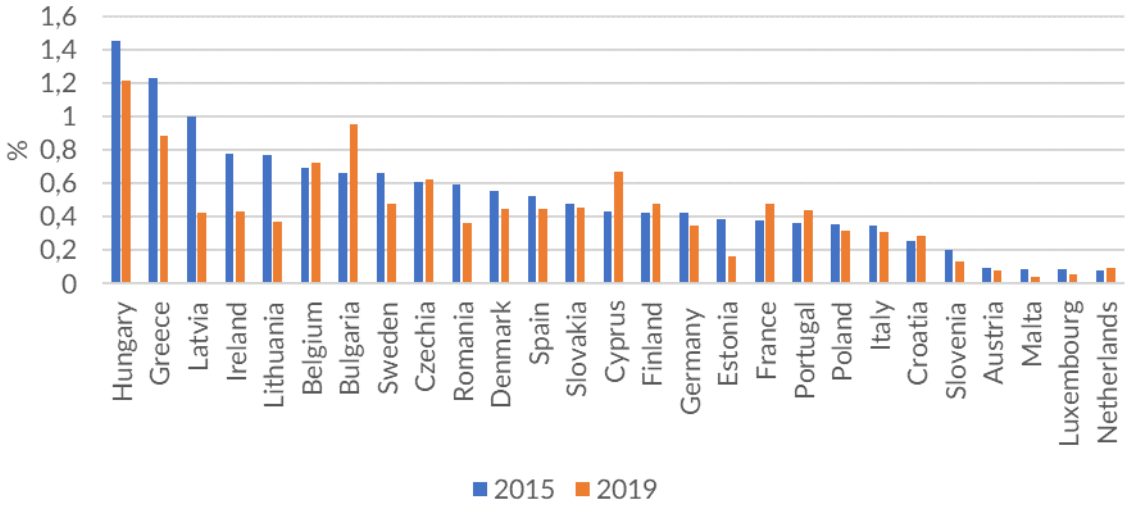


Figure 1. Fossil fuel subsidies in the EU Member States as a per cent of GDP, 2015 and 2019

Source: own study based on European Commission (2020b); Eurostat (2022).

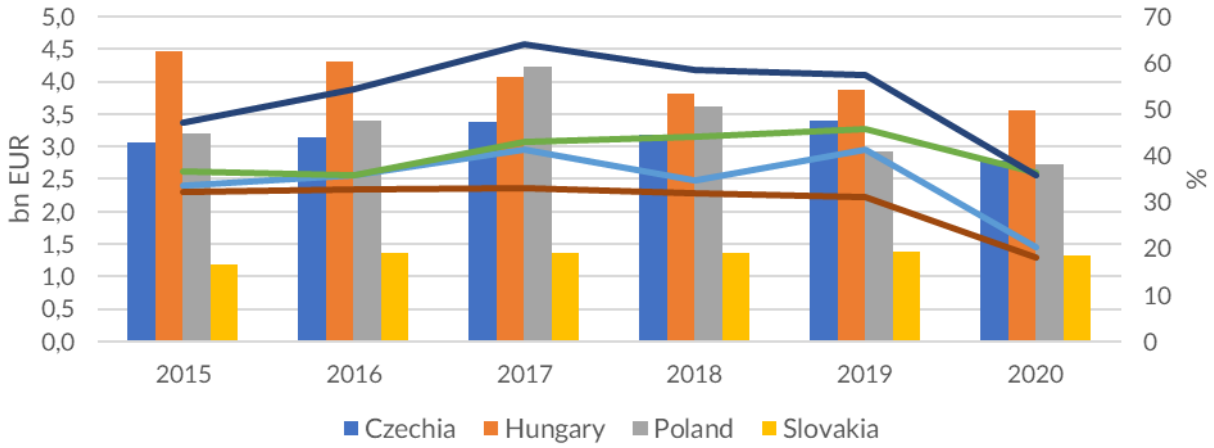
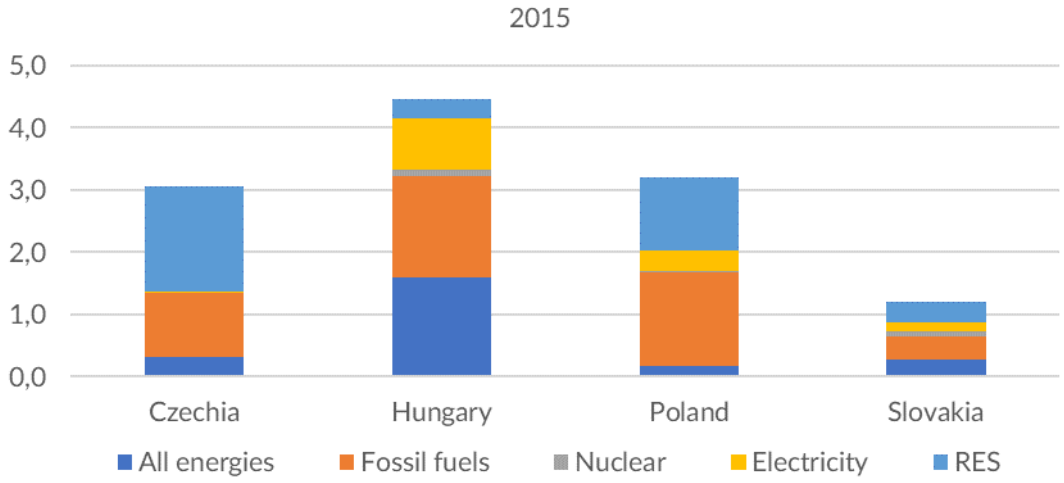


Figure 2. Energy subsidies (line, left axis) and the share of fossil fuel subsidies in total energy subsidies (columns, right axis) in V4, 2015–2020

Source: own study based on European Commission (2020b).

While focusing on V4 countries, attention should be drawn to the tendency regarding subsidy volumes and the share of fossil fuel subsidies in total energy subsidies. The data have been aggregated in Figure 2. In Hungary and Poland, subsidy volumes have been reduced by 13% and 9%, respectively, compared to 2015. The reverse is true in Czechia and Slovakia, i.e., there was an increase of 11% and 16%, respectively. While focusing on the share of subsidies for energy from conventional sources, there is a relatively constant proportion between 2015 and 2019, followed by a reduction in all economies in 2020. Nevertheless, between 2015 and 2020, Poland spent twice as much on aid to conventional energy sources than the remaining energy sources (54%), compared to Hungary (40%), Czechia (35%), and Slovakia (30%).



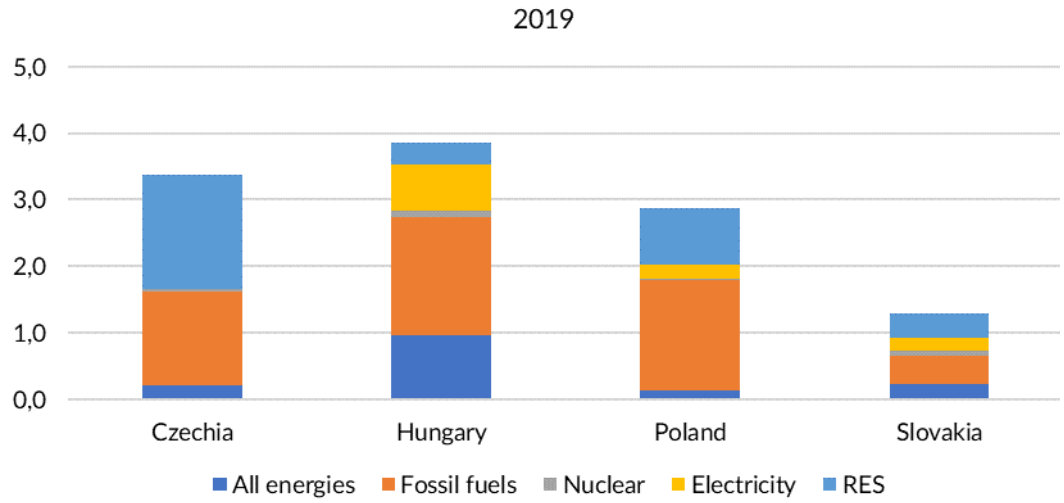
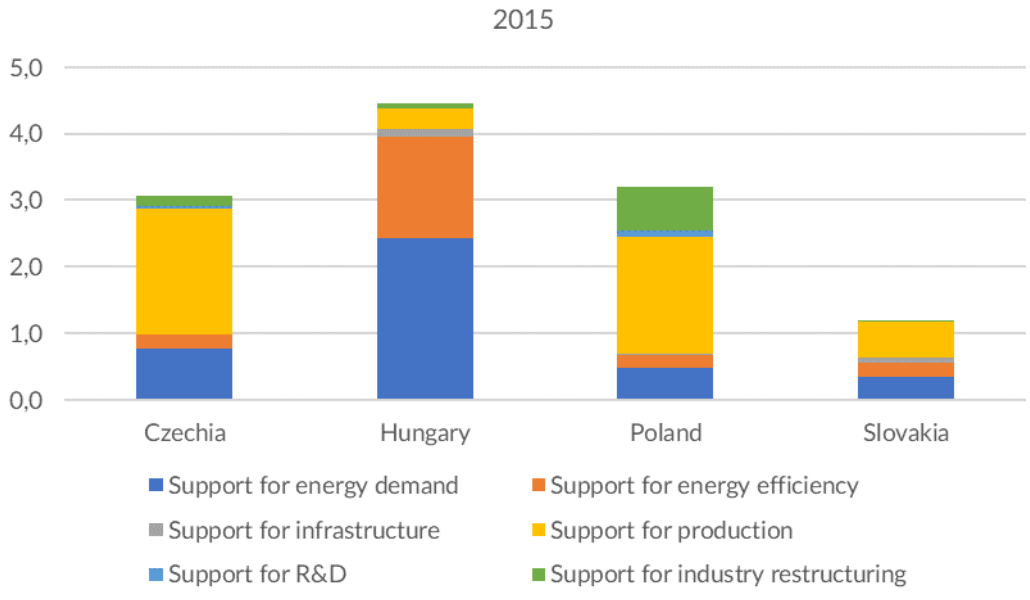


Figure 3. Energy subsidies (€2018 bn) by energy carrier in V4 countries, 2015 and 2019

Source: own study based on European Commission (2020b).

The volume of subsidies in 2019, broken down by energy media, shows that the support for renewable energy sources (Figure 3) constituted 50% in Czechia, 8.7% in Hungary, 29% in Poland, and 27% in Slovakia. Furthermore, when comparing the amount of support given in 2015, Czechia, Hungary, and Slovakia recorded growth of 2%, 10%, and 13%, respectively, while Poland recorded a decrease of 29%.

The trends are also confirmed by the types and orientation of energy subsidies. In the Czech and Slovak economies, the subsidy structure presented in Figure 3 is dominated by subsidies that support production. In Hungary, most funds were intended to support demand, while in Poland, the proportions between the support for production and consumption, as well as industry reconstruction, remain at a similar level.



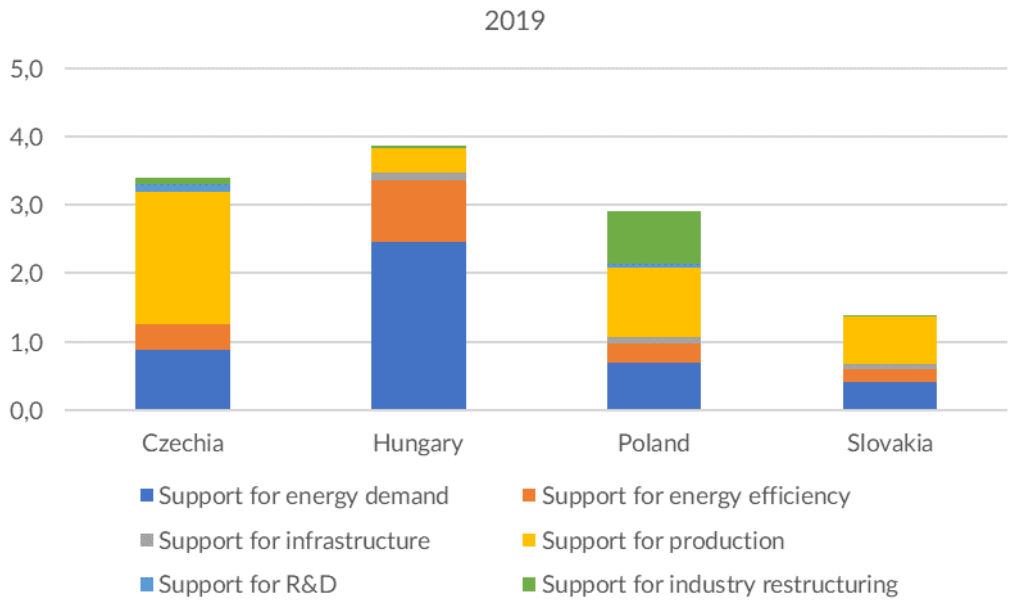


Figure 4. Energy subsidies (€2018 bn) by type in V4 countries, 2015 and 2019

Source: own study based on European Commission (2020b).

Subsidies to improve energy efficiency, however, constituted a smaller share in total expenditures: from 10% in Poland to 23% in Hungary.

Research methodology

Assuming that energy subsidies have significant implications for the pace of the EU's energy transformation by affecting the energy consumption levels and the types of fuels used, we seek the dependencies and impact of fossil fuel subsidy volumes on CO_2 emissions in the V4 countries. To assess the relationship between a dependent variable and an independent variable, a linear regression model is used.

Table 1. Fossil fuel subsidies in V4 countries, 2015–2020 (€2020 bn)

	2015	2016	2017	2018	2019	2020
Czechia	1.0282	1.1293	1.4009	1.1049	1.4093	0.5678
Hungary	1.6363	1.5440	1.7453	1.6873	1.7702	1.2973
Poland	1.5144	1.8492	2.7084	2.1233	1.6705	0.9807
Slovakia	0.3800	0.4491	0.4504	0.4387	0.4270	0.2387

Source: own study based on European Commission (2020b).

Table 2. Fossil CO_2 emissions in V4 countries, 2015–2020 (Mt CO_2)

	2015	2016	2017	2018	2019	2020
Czechia	107.728	109.155	110.015	108.840	105.107	92.082
Hungary	47.325	48.185	50.712	50.402	50.437	49.405
Poland	306.053	317.068	330.422	330.801	312.917	292.562
Slovakia	34.525	35.523	37.549	37.525	34.651	31.871

Source: own study based on Crippa et al. (2021).

In 2020, fossil fuel subsidies in the V4 countries were noticeably lower than in previous years (by more than half). The scale of emissions is also lower, although the difference is not as drastic (Table 1 and Table 2). It is thus worth considering both models that account for 2020 and excluding that year. It is interesting how subsidies from the previous year affect emissions in a given year. As a consequence, the analysis includes models with a time shift by a year (lag) and without it, namely showing how emissions in a given year are affected by subsidies from a given year. The relatively small amount of available and comparable data, i.e., six time points, makes it impossible to measure the impact of subsidies from a previous year and subsidies from a given year in one hierarchical model. Thus, four models were obtained:

- a model without a lag and including 2020,
- a model with a time lag and including 2020,
- a model without a lag and excluding 2020,
- a model with a time lag and excluding 2020.

Each is a linear model that defines the relationship between the dependent variable and the explanatory variable. The model without a lag and including 2020 is expressed as:

$$E_t = \alpha + \beta S_t + \varepsilon, \tag{1}$$

where: *Et* is the emissions volume, *St* – the volume of subsidies in year t, α is the intercept, and β is the model parameter. We also assume that random error is characterised by normal distribution: $\varepsilon \sim N\left(0,\sigma^2\right)$.

In turn, the model with a time lag and including 2020 is expressed as follows:

$$E_t = \alpha + \beta S_{t-1} + \varepsilon, \tag{2}$$

where: *Et* is the emissions volume in year t, and *St–1* is the volume of subsidies in the previous year (t = 2016, 2017, …, 2020; we omit 2015 due to the absence of data from the previous year). Other definitions are identical as in the model without a lag and including Models excluding 2020 have an analogical structure, but here we accounted for t = 2015, 2016, …, 2019 and t = 2016, 2017, …, 2019, respectively. All models include the β parameter, which shows the impact of subsidies on emissions.

Results and discussion

In all four models for the Czech economy, p > 0.05 was obtained, which means that the dependence is of no statistical importance (Table 3). Additionally, three tests were performed for each model:

- the Shapiro-Wilk test to check the assumption that ε is indeed characterised by a normal distribution,
- the Durbin-Watson test to check that no autocorrelation is present, i.e., whether ε from one year depends on ε from the previous year,
- the Breusch-Pagan test for heteroscedasticity of ε, i.e., whether it is variable in time.

Table 3. Models estimation for the Czech economy

Trait	Parameter	95%CI		p*
Model without a lag and including 2020				
Energy subsidies (bn euro)	17.554	4.554	30.554	0.057
Model with a lag and including 2020				
Energy subsidies in the previous year (bn euro)	– 23.792	– 63.033	15.449	0.32
Model without a lag and excluding 2020				
Energy subsidies (bn euro)	– 2.59	– 14.293	9.114	0.694
Model with a lag and excluding 2020				
Energy subsidies in the previous year (bn euro)	1.781	– 16.578	20.14	0.867

p – univariate linear regression; *statistically significant (p < 0.05).
Source: own study.

The assumptions of the model are met when test results are of no statistical importance, i.e., when the p-value remains above 0.05. When diagnosing the models, we must also point out the problem of breaching the assumptions in the test for the model with the time lag and including 2020 and the model without the lag and excluding 2020 (Table 4).

Table 4. Model diagnostics for the Czech economy

Test	Shapiro-Wilk test	Durbin-Watson test	Breusch-Pagan test
H0	Normality of errors	No autocorrelation	Homoscedasticity
Without lag, with 2020	p = 0.135	p = 0.186	p = 0.912
With lag, with 2020	p = 0.999	p = 0.037*	p = 0.026*
Without lag, without 2020	p = 0.963	p = 0.075	p = 0.032*
With lag, without 2020	p = 0.356	p = 0.103	p = 0.397

p – univariate linear regression; *statistically significant (p < 0.05).
Source: own study.

The first and the last models allow us to state that in the Czech economy, CO_2 emissions do not depend on subsidies either from the present or the previous year.

Table 5. Models estimation for the Hungarian economy

Trait	Parameter	95%CI		p*
Model without lag and including 2020				
Energy subsidies (bn euro)	2.912	– 4.316	10.139	0.474
Model with lag and including 2020				
Energy subsidies in the previous year (bn euro)	– 1.361	– 14.314	11.591	0.85
Model without lag and excluding 2020				
Energy subsidies (bn euro)	13.498	1.604	25.393	0.113
Model with lag and excluding 2020				
Energy subsidies in the previous year (bn euro)	0.221	– 18.839	19.281	0.984

p – univariate linear regression; * statistically significant (p < 0.05).
Source: own study.

With the Hungarian economy, as in the previous example, all four models yielded p > 0.05, confirming no statistical importance (Table 5).

At this phase of the analysis, there is a problem with the model without lag and including 2020, as well as the test regarding the model with lag and excluding 2020 (Table 6). All models, however, lead to the same conclusion. However, based on the model with lag and including 2020, as well as the model without lag and excluding 2020, we can state that the emission levels do not depend on subsidies from either the present or the previous year.

Table 6. Model diagnostics for the Hungarian economy

Test	Shapiro-Wilk test	Durbin-Watson test	Breusch-Pagan test
H0	Normality of errors	No autocorrelation	Homoscedasticity
Without lag, with 2020	p = 0.036*	p = 0.022*	p = 0.966
With lag, with 2020	p = 0.053	p = 0.088	p = 0.453
Without lag, without 2020	p = 0.303	p = 0.14	p = 0.458
With lag, without 2020	p = 0.037*	p = 0.215	p = 0.584

p – univariate linear regression; * statistically significant ($p < 0.05$).
Source: own study.

Table 7. Models estimation for the Polish economy

Trait		95%CI		p*
Model without lag and including 2020				
Energy subsidies (bn euro)	23.763	15.57	31.957	0.005
Model with lag and including 2020				
Energy subsidies in the previous year (bn euro)	17.303	– 15.068	49.673	0.372
Model without lag and excluding 2020				
Energy subsidies (bn euro)	20.659	8.52	32.798	0.045
Model with lag and excluding 2020				
Energy subsidies in the previous year (bn euro)	7.941	– 14.694	30.576	0.563

p – univariate linear regression, * statistically significant ($p < 0.05$).
Source: own study.

In the model without lag and including 2020, the p-value amounts to 0.005; therefore, the statistical dependence of variables has been confirmed. The regression parameter (β) totals 23.763; therefore, each further billion euros increases emission by an average of 23.763 Mt. In turn, in the model with the lag and including 2020, the p-value points to dependence of no statistical significance, i.e., subsidies from the previous year do not affect CO_2 emissions.

According to the calculations in Table 7, the model without the lag and excluding 2020 points to a dependence of statistical significance ($p < 0.05$). The regression parameter (β) totals 20.659; therefore, each further billion euros increases emissions by an average of 20.659 Mt. This is similar to the inclusion of 2020, although the impact of subsidies is slightly lower and much less significant here. As in the model with the lag and including 2020, and in the model with the lag and excluding 2020, the calculated dependence is

of no statistical significance ($p > 0.05$). Thus, here subsidies from the previous year also do not affect emissions in the current year.

While moving to model diagnostics (Table 8), we must point out the p-value for the model with lag and including 2020 ($p = 0.049$, i.e., exactly the threshold value), which means that it must be treated with caution.

Table 8. Model diagnostics for the Polish economy

Test	Shapiro-Wilk test	Durbin-Watson test	Breusch-Pagan test
H0	Normality of errors	No autocorrelation	Homoscedasticity
Without lag, with 2020	p = 0.65	p = 0.75	p = 0.158
With lag, with 2020	p = 0.963	p = 0.049*	p = 0.204
Without lag, without 2020	p = 0.192	p = 0.665	p = 0.49
With lag, without 2020	p = 0.965	p = 0.217	p = 0.905

p – univariate linear regression; * statistically significant ($p < 0.05$).
Source: own study.

Finally, therefore, according to the model without lag and excluding 2020, as well as the model with lag and excluding 2020, subsidies from a given year increase emissions in that year, while subsidies from the previous year do not have an impact. The data from 2020 break the model assumptions, which is why they have not been included here. This means the situation is worth observing.

Table 9. Models estimation for the Slovak economy

Trait	Parameter	95%CI		p*
Model without lag and including 2020				
Energy subsidies (bn euro)	22.687	10.053	35.321	0.024
Model with lag and including 2020				
Energy subsidies in the previous year (bn euro)	24.533	– 63.068	112.135	0.621
Model without lag and excluding 2020				
Energy subsidies (bn euro)	33.792	– 10.357	77.941	0.231
Model with lag and excluding 2020				
Energy subsidies in the previous year (bn euro)	21.871	– 30.434	74.176	0.499

p – univariate linear regression, * statistically significant ($p < 0.05$).
Source: own study.

Calculations for the model without lag and including 2020 (Table 9) allow us to state that the dependence is statistically significant ($p < 0.05$). The regression parameter (β) totals 22.687; therefore, each further billion euros increases emissions by an average of 22.687 Mt. In turn, in the other three models in Table 9, the dependence is of no statistical significance ($p > 0.05$). Furthermore, excluding 2020 in the model without the lag completely changed the conclusion from the analysis of the model that includes 2020.

Table 10. Model diagnostics for the Slovak economy

Test	Shapiro-Wilk test	Durbin-Watson test	Breusch-Pagan test
H0	Normality of errors	No autocorrelation	Homoscedasticity
Without lag, with 2020	p = 0.644	p = 0.595	p = 0.075
With lag, with 2020	p = 0.097	p = 0.013*	p = 0.972
Without lag, without 2020	p = 0.326	p = 0.546	p = 0.123
With lag, without 2020	p = 0.053	p = 0.224	p = 0.498

p – univariate linear regression; * statistically significant ($p < 0.05$).
Source: own study.

When diagnosing the models, there is again an issue regarding the model with the lag and 2020, as was the case with Poland (Table 10). Finally, according to the models that exclude 2020, emissions are independent of subsidies from the current and previous year. We must point out that the data from 2020 break the model assumptions, which is why they have not been accounted for. The situation is thus worth observing, particularly since including 2020 significantly changes the result of the analysis.

Concluding remarks

The literature provides evidence that fossil fuel subsidies are not only a burden for public budgets, exhausting the limited fiscal resources, but that they also distort the costs and prices that affect decisions made by many manufacturers, investors, and consumers, thus instilling the use of older technologies and more energy-intensive production methodologies. Fossil fuel subsidies thus undermine the efforts to mitigate climate change and hinder effective energy transformation.

The research into the scale and structure of subsidies for conventional energy sources reveals that, in all four countries, they remained at a constant level between 2015 and 2019. However, the data for 2020 point to significant limitations of both total energy subsidy volume and the share of fossil fuel subsidies (except for Slovakia).

While answering the research question regarding the dependence and impact of fossil fuel subsidies on CO_2 emissions, conclusions were drawn regarding the linear model coefficients. However, the data gathered do not constitute strong proof for the accuracy of the hypothesis. Nor do they confirm the impact of subsidy volume (from either the current or previous year) on CO_2 emission levels. The conclusion, although significant from the application point of view, must be treated with caution. The problem is important and requires further statistical observation as this research relied on a relatively short range of data due to the availability of comparable statistical data.

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Subsydia energetyczne i ich konsekwencje dla emisji CO_2 w krajach Grupy Wyszehradzkiej

Celem artykułu jest przedstawienie przeglądu literatury na temat subsydiów energetycznych, skali i struktury dopłat do produkcji energii w krajach Grupy Wyszehradzkiej. Zaprezentowano też najważniejsze wyniki próby zbadania zależności i wpływu subsydiów do paliw kopalnych na emisje CO_2 na podstawie modelu regresji liniowej. Ze względu na dostępność porównywalnych danych statystycznych badanie ograniczono do okresu 2015–2020. Przeprowadzona analiza nie stanowi jednak mocnego dowodu na jednoznaczne potwierdzenie negatywnego wpływu wysokości dotacji (z roku bieżącego lub poprzedniego) na poziom emisji CO_2.

Słowa kluczowe: CO_2, dotacje, kraje V4, paliwa kopalne

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Innovative Clusters of Global Trade Leadership

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Abstract

The formation of a new global system and systemic global interdependence has generated new competitiveness factors for market participants, determining their appropriate strategic behavior to ensure a highly competitive position and leadership. Therefore, the purpose of the study is to identify the countries of intellectual leaders in the global market and the factors that influence the positions that countries achieve in terms of leadership. The following research methods were used: multifactor regression models, cluster analysis, and comparative analysis. Based on the authors' methodology for assessing countries' intellectual leadership, the clustering of countries in the global economy is determined. The evaluation algorithm was based on three levels: 1) resources, 2) the intermediate results of intellectual activity, and 3) the final results of overall progress.
Using a multifactor regression model and cluster analysis, four clusters of countries were identified according to key indicators of intellectual leadership. For each cluster, the specialization

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of the two countries in terms of merchandise exports was analyzed: cluster 1 – the United States and Germany; cluster 2 – Israel and Italy; cluster 3 – Brazil and Ukraine; cluster 4 – China and South Korea. Each country is assigned an index of economic complexity, and the change in position of each country within a cluster over ten years is noted.
An important goal is to understand the determinants of the leadership of countries in each geographic region.
The analysis is based on the cluster analysis carried out in previous publications. The clustering of countries was carried out based on the dynamics of macroeconomic indicators over the past 15 years.

Keywords: Index of economic complexity, intellectualization, clustering of countries, commodity exports

JEL: I23, I25

Introduction

The formation of a new global system based on knowledge and information has been accompanied by rapid change and significant stratification of the competitive environment. Systemic global interdependence has generated new competitive factors for the market participants, determining their appropriate strategic behavior to ensure a highly competitive position and leadership. It has become a key component of public economic policies and effective management and a subject of special interdisciplinary research. Reorientation to innovative development is a key feature of the current stage of development of the world economy, and it is the basis of the Fourth Industrial Revolution.

The goal of economic followers is to develop non-linear innovations, which are characteristic of the most developed economies of the world. Forming a global innovation space is a complex process that accompanies the current stage of development of the global economy. The fourth industrial revolution determines the further orientation and activation of technology in production, robotics, and network technologies, among others. Only innovation-oriented economies are highly competitive in these conditions, and the role of intellectual development factors is changing accordingly. Classically, factors of the intellectualization of the economy are education and science; however, education ceases to be the only driving force for the development of society (OECD 2011). Characteristics of the modern market include the offshoring of the labor market, a change in the structure of production, the development of opportunities through technology and network, and the active export of services. Expanding the scope of intellectual leadership as a way to ensure competitiveness in the knowledge economy in this aspect is seen as managing the changing business environment.

The modern understanding of leadership is based on its perception as a multifaceted, multilevel, factorial, and functionally determined phenomenon. When there are qualitative technological changes, in particular, super dynamic digital transformations, the networkization of economic systems, socialization and greening, global success, and the constant progress of business organizations, countries and regions are served, first of all, by intellectual leadership. In the 21st century, a new composition of its resource, scientific and technological, market, and civilizational imperatives is being formed, which is most fully reflected in the sustainability and inclusiveness of economic development, structural dynamics, and the global competitive disposition of countries. At the same time, the world is in a pre-paradigmatic state, which is determined by separate theories of intellectual leadership research and how it is implemented, in the absence of a comprehensive conceptual justification.

In the scientific literature, one of the most pressing issues is the theoretical and methodological understanding of the essence of innovation and its drivers, and the role of knowledge, education, and technology in ensuring the economic progress of society. In the 1950s, Solow substantiated the model of exogenous economic growth on the basis of the Cobb–Douglas production function and the Harrod-Domar Keynesian model of economic growth (Solow 1956). In the future, research will begin to consider in more detail the various aspects of the main factors (labor, capital, land) and scientific and technological progress.

The 21st century is marked by the emergence of radically new technologies and trends in informatization, digitalization, networking, and more. In the new context, the study of economic growth factors aims to identify more segments in dependencies that explain the impact of ICT (information and communication technology) on the dynamics and scale of economic development. Jorgenson and Vu (2005) described the impact of investment in information technology (IT) on the level of development of the world's largest economies, it is determined that the development of technology has led to rapid economic growth between 1989 and 2003. In a later study, Jorgenson and Vu (2010) analyzed the period 1989–2008. Oliner and Sichel (2000) demonstrated that productivity growth in the US since the 1990s has been associated with an investment in ICT. ICT capital comprised 1.1% of the 4.8% output growth rate from 1996–1999. Colecchia and Schreyer (2002) compared the impact of ICT capital on economic growth in nine OECD countries. Although they found significant differences in ICT investment, it grew rapidly in all countries.

Skorupinska and Torrent-Sellens (2017) showed that the rates of return on digital investment are relatively much higher than those on investment in other physical components. Meanwhile, Hong (2017) showed that in South Korea, private ICT R&D (Research and development) investment had a stronger relationship with economic growth compared to public ICT R&D investment. However, Kretschmer (2012) showed that as-

sessing the impact of ICT very much depends on the methodology. Nevertheless, over the last two decades, an increase in ICT by 10% translated into higher productivity growth, from 0.5 to 0.6%.

Yeganegi and Najafi (2022) analyzed the impact of innovations in certain industries on the level of economic development of the country, in general, and the specialization of countries. Vicente (2022) looked at the innovative development of countries and clusters. Meanwhile, Hanzhi and Wang (2022) researched individual economies, the determinants of their development and the prerequisites for specialization.

This article's purpose is to identify the key factors and prerequisites for the formation of leadership of particular countries through economic and mathematical modeling. Thus, an important *goal* seems to be to understand the determinants of the leadership of countries in each region of the world.

Method of analysis. The analysis is based on the cluster analysis that was carried out in previous publications. It was conducted based on the dynamics of macroeconomic indicators over the past 15 years.

Added value. Based on the analysis, the determinants of the leadership of the countries in the regions were determined, the prerequisites of the leadership of the countries in each of the regions were characterized, and the possibilities of further development of these countries in the regions and in the global economic space were determined.

Results

The economic development of countries, its determinants, factors of the greatest influence are an urgent issue of the study of economic science. Studies of scientists and authors in previous works testify to the significant impact, for example, of the intellectualization of economic activity on the overall development of the country (Kalenyuk et al. 2022). However, it requires a study to determine the features of development and its key determinants in different countries, which differ in the structure of the economy, features of economic activity, etc.

Determining the country's opportunities for development in the conditions of international division of labor, specialization, and the formation of global production and logistics networks remains an important issue. The determination of these prerequisites should be based on statistical data that allow the identification of the country's specialization factors. It was done on the basis of the clustering of countries by individual indicators. A total of forty countries and forty-four indicators have been selected over ten years, which makes it possible to assert the mathematical validity of clustering results. The author's methodology is based on the identification of key development factors at three levels: 1) resource level (accu-

mulated logistical, financial, human, and intellectual potential); 2) the level of intermediate results of intellectual activity (scientific-educational, technological, infrastructural, production, service, market); 3) the level of final results of the general progress (dynamics of general economic indicators, positions in world ratings and indices, etc.). It also makes it possible to conduct a complex estimation and comparison of the basic functional zones of the studied phenomenon and to follow the development experience of innovative systems of the intellectual leader states (Kalenyuk and Tsymbal 2021).

Intellectual leadership is quite complex in definition and structure, so assessing it requires a systematic approach, based on the characteristics of intellectual activity. Our approach is that intellectual leadership today should be determined by levels that characterize certain stages of intellectual activity and have their own characteristics. There are three levels of such stages: 1) resources, 2) intellectual performance, and 3) end results. For the sake of simplicity, this study will only consider country or national economy from all possible subjects (e.g., country, region, industry, institution, corporation, etc.).

The resource level is characterized by the availability of basic intellectual resources. Their presence and potential characterize the general ability of the country (or any other entity) to conduct intellectual activity. Although the availability of intellectual resources is an important condition for leadership, it does not mean actual leadership. More realistically, it may manifest itself at the next level, which characterizes the results obtained by the country. The level of results of intellectual activity involves evaluating specific results: patents, licenses, know-how, and publications, among others. The end results concern not only purely intellectual activity, but activity in general – the whole economy or society. The next step in the evaluation should be to identify key indicators at each of these levels. In our opinion, only such a systematic approach to assessing each of these levels using several indicators makes it possible to characterize the intellectual activity and assess the overall competitive position of different actors. Therefore, all indicators for assessing intellectual leadership consider either the potential of intellectual resources or the results of intellectual activity.

A multifactor regression model and cluster analysis were used to produce four clusters of countries with common characteristics and socio-economic development trends in key (static and dynamic) indicators of intellectual leadership (Table 1). This technique allowed us to analyze the impact of intellectualization indicators on GDP in each cluster.

Table 1. The results of clustering countries by indicator of intellectualization

Cluster 1	Cluster 2
Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Iceland, Ireland, Japan, Luxembourg, Netherlands, Norway, Sweden, Switzerland, Great Britain, USA	Czech Republic, Greece, Israel, Italy, New Zealand, Portugal, Slovenia, Spain
Cluster 3	**Cluster 4**
Brazil, Chile, Colombia, Estonia, Hungary, Latvia, Lithuania, Mexico, Poland, Russian Federation, Slovakia, Turkey, Ukraine	China, Hong Kong, India, South Korea, Singapore

Source: compiled by the author.

As a result of the analysis, it was determined that all clusters differ significantly in the set of countries in terms of the level of socio-economic development and the features of economic activity. The first cluster unites countries that have a high level of economic development and demonstrate consistently high dynamics. The second cluster includes countries with stable economies and a high level of socio-economic development, covering mainly the European region. The countries of the third cluster are more geographically diverse and show relatively low rates of development. The grouping of countries into cluster 4, which includes Asian countries that have certain features of general business conduct, are characterized by extremely dynamic rates of growth in a short period of time, seems interesting. The clustering made it possible to find common features of the development of the cluster countries, and it became the basis for identifying key development factors and prerequisites for achieving leadership positions globally, regionally, or sectorally.

The paper examines the export specialization of individual countries within each cluster, as well as the level of economic complexity of the products they export. The analysis used UN trade statistics (United Nations 2018), as well as information from the Center for International Development at Harvard University (The Atlas of Economic Complexity n.d.).

When specializing, countries belonging to the same cluster have significant common features in their export profile and have reached a similar level of economic complexity. To analyze the specialization of countries from each cluster, two countries were selected that best demonstrate the peculiarities of cluster development (The objective 2022). We will consider features of the countries of the first cluster on the example of the USA and Germany. The commodity exports of both countries are dominated by high-tech goods (machinery and transport equipment, chemical products, cars, electronic integrated circuits, and medicines, among others) (Table 2).

Table 2. Merchandise exports of USA and Germany, 2019

SITC*	Merchandise exports by SITC	USA		Germany	
		billion US$	%	billion US$	%
Total	All commodities	1,644.276	100.0	1,493.095	100.0
0 + 1	Food, animals + beverages, tobacco	111.957	6.8	78.108	5.2
2 + 4	Crude materials + anim. & veg. oils	77.353	4.7	24.998	1.7
3	Mineral fuels, lubricants	199.591	12.1	33.128	2.2
5	Chemicals	224.279	13.6	230.999	15.5
6	Goods classified chiefly by material	137.472	8.4	175.458	11.8
7	Machinery and transport equipment	534.875	32.5	715.426	47.9
8	Miscellaneous manufactured articles	165.843	10.1	171.380	11.5
9	Not classified elsewhere in the SITC	192.907	11.7	63.598	4.3

* SITC – Standard international trade classification.
Source: compiled by the United Nations (2020).

The United States is still the world leader in innovation, although today, most innovation goes to products made abroad. The loss of manufacturing jobs in the United States, especially to China's advantage, is not just a focus on producing cheap consumer goods using cheap labor. Over the past six years, the share of Chinese exports of products classified as high-tech goods has grown to more than 27%, while in the US, it is less than 18%.

A comparison of the development of countries' leadership in terms of the Economic Complexity Index (ECI), which considers the complexity and diversification of the country's exports, determined sufficient proximity of countries within one cluster. Thus, for the United States, this figure reached 1.55, and for Germany, it reached 2.09, one of the best results in the world. The positions of these countries in the ranking of economic complexity are quite close. In 2018, Germany ranked 4th out of 133 countries, and the United States was 11th (Table 3).

Table 3. Index of economic complexity, 2018

Country	Index of economic complexity	Ranking	
		2018 y. (from 133 countries)	Change over 10 years
1st cluster			
Germany	2.09	4	– 2
USA	1.55	11	+1

Country	Index of economic complexity	Ranking	
		2018 y. (from 133 countries)	Change over 10 years
2nd cluster			
Italy	1.44	14	+3
Israel	1.2	20	+3
3rd cluster			
Ukraine	0.37	44	0
Brazil	0.21	49	– 1
4th cluster			
South Korea	2.11	3	+8
China	1.34	18	+6

Source: The Atlas of Economic Complexity (n.d.).

Thus, countries in the same cluster have a fairly close position on indicators of economic proximity. If we consider the countries of the 2nd cluster, which include Italy and Israel, in 2018, they were in the second ten of the 133 countries in the ranking. Italy ranked 14th on the ECI with 1.44; its rating improved by three places over the previous ten years. The Israeli economy reached 20th place with an index of 1.2 The dynamics of change are the same as Italy's, as their rank also improved by three points.

Israel is characterized by a fairly high share of machinery and transport equipment (26.9% of total exports of goods in 2018). In Italy, it is dominated by merchandise exports (35.9%). According to the SITC, approximately the same share in Italian exports is occupied by products of the "Chemicals" group (13.2%), "Goods classified mainly by materials" (17.8%), and "Various manufactured products" (17.9%). The Top 10 Italian exports include medicines, cars, engine parts, and shoes (The Atlas of Economic Complexity n.d.). In Israeli exports, a significant place is taken by goods belonging to the "Chemicals" group (24.7%), "Goods classified mainly by materials" (29.1%), and "Various manufactured goods" (17.9%). The main commodity items of Israeli exports are processed and unprocessed diamonds, medicines, electronic integrated circuits, and medical equipment and instruments.

Table 4. Merchandise exports of Israel and Italy, 2019

SITC	Merchandise exports by SITC	Israel		Italy	
		billion US$	%	billion US$	%
Total	All commodities	58.489	100.0	532.684	100.0
0 + 1	Food, animals + beverages, tobacco	1.789	3.1	45.669	8.6

SITC	Merchandise exports by SITC	Israel		Italy	
		billion US$	%	billion US$	%
2 + 4	Crude materials + anim. & veg. oils	0.870	1.6	8.277	1.6
3	Mineral fuels, lubricants	1.201	2.1	15.368	2.9
5	Chemicals	15.599	26.7	75.635	14.2
6	Goods classified chiefly by material	14.724	25.2	90.231	16.9
7	Machinery and transport equipment	16.563	28.3	180.683	33.9
8	Miscellaneous manufactured articles	7.738	13.2	98.376	18.5
9	Not classified elsewhere in the SITC	0.004	0.0	18.446	3.5

Source: compiled by the United Nations (2020).

The third cluster of countries, which comprises mostly countries from Central and Eastern Europe, is considered on the example of Bulgaria and Ukraine. Both have rather low ratings of economic complexity and did not show significant progress in this area between 2008 and 2018. Thus, Ukraine, with an index of economic complexity of 0.33, ranks 47th, while after ten years, its positioning had worsened by 4 points. Bulgaria's economy is more complex than Ukraine's – its ECI was 0.52, putting it 42nd in the ranking, and it improved its position by three points.

In contrast to the countries of the previous clusters, the specialization of both countries is dominated by products with a low degree of processing. For Bulgaria, the leading exports are petroleum oils, other than crude. The SITC product group "Raw materials + oils of animal and vegetable origin" of Bulgarian exports is 7.7%, and "Food, animals + beverages, tobacco" is 12.8%. Ukraine's main export list in 2019 included sunflower seeds, semi-finished products of cast iron and non-alloy steel, corn, iron ore and concentrates, and flat-rolled hot-rolled iron. The SITC commodity groups "Food, Animals + Beverages, Tobacco" and "Raw Materials + Oils of Animal and Vegetable Origin" covered almost half of Ukrainian exports of goods (49.9%) in 2019. The group "Goods classified mainly by materials" comprised a significant volume of exports of both Ukraine and Bulgaria (28.7% and 19.9%, respectively) (Table 5). Chemical products occupy a smaller weight in the exports of the countries of this group compared to the previous group. In particular, war-related products account for 10.8% of the structure of Bulgarian merchandise exports, and only 3.7% of Ukrainian merchandise exports.

Table 5. Merchandise exports of Bulgaria and Ukraine, 2019

SITC	Merchandise exports by SITC	Bulgaria		Ukraine	
		billion US$	%	billion US$	%
Total	All commodities	33.415	100.0	47.335	100.0
0 + 1	Food, animals + beverages, tobacco	4.281	12.8	12.195	25.8
2 + 4	Crude materials + anim. & veg. oils	2.582	7.7	11.407	24.1
3	Mineral fuels, lubricants	3.181	9.5	0.861	1.8
5	Chemicals	3.611	10.8	1.729	3.7
6	Goods classified chiefly by material	6.646	19.9	13.603	28.7
7	Machinery and transport equipment	7.674	23.0	5.307	11.2
8	Miscellaneous manufactured articles	4.432	13.3	2.041	4.3
9	Not classified elsewhere in the SITC	1.008	3.0	0.192	0.4

Source: compiled by the United Nations (2020).

The peculiarities of the countries that were classified in the 4th cluster are their significant export specialization in machinery and transport equipment, as well as significant progress in increasing the economic complexity of national economies. We consider South Korea and China as examples of countries in the 4th cluster. South Korea ranks third in the world in terms of economic complexity (its ECI value is 2.11). Over the ten-year period, it rose eight places in the ranking, ahead of even Germany today. During the same period, China rose six places, with an ECI of 1.34 (18th place).

Machinery and transport equipment dominate by a large margin in both countries' exports. For China, the share of machinery in the country's exports is 48%. Meanwhile, in South Korea, it accounted for 57.5% in 2019 (Table 6). China's main export items were radio and television transmitters, television cameras, digital cameras and video recorders; computers; electronic integrated circuits; parts and accessories for office equipment, special equipment; semiconductor devices; phones. South Korea's exports were represented by the following commodity items: electronic integrated circuits; refined petroleum oils; cars; ships, boats; engine parts; parts and accessories for office equipment special equipment; liquid crystal devices, lasers; other optical instruments and instruments (United Nations 2020).

Thus, the study confirms common features in the specialization of countries within the cluster, as well as the achievement by countries of similar levels of economic complexity and diversification of export goods.

Table 6. Merchandise exports of China and South Korea, 2019

SITC	Merchandise exports by SITC	China		South Korea	
		billion US$	%	billion US$	%
Total	All commodities	2,494.230	100.0	542.172	100.0
0 + 1	Food, animals + beverages, tobacco	69.990	2.8	7.827	1.4
2 + 4	Crude materials + anim. & veg. oils	18.345	0.7	42.179	1.2
3	Mineral fuels, lubricants	46.628	1.9	73.997	7.8
5	Chemicals	167.699	6.7	73.997	13.6
6	Goods classified chiefly by material	408.746	16.4	68.640	12.7
7	Machinery and transport equipment	1,212.092	48.6	310.027	57.2
8	Miscellaneous manufactured articles	564.619	22.6	32.144	5.9
9	Not classified elsewhere in the SITC	6.112	0.2	0.934	0.2

Source: compiled by the United Nations (2020).

Recently, the number of scientific and technical workers has grown rapidly and, accordingly, the positions in the field of high technologies of those countries that previously belonged to the third world are strengthening. As already mentioned, in previous decades, developing countries managed to achieve certain results in economic development. The Asian market is already strategically important for many American exporters, especially producers of expensive consumer goods and means of production, as Japan and Europe experience a decline in high-tech developments.

During the 1990s and the 2000s, US exports to Singapore, Taiwan, and Hong Kong doubled. Today, these countries are a larger import market for the United States than any European country. In the high-tech market of Asia, the cost of R&D is increasing, but the situation today is not clear. For example, in China, the world's third-largest smartphone maker, Huawei Technologies, and the world's largest PC maker, the Lenovo Group, are already raising R&D spending significantly; the same is happening in Malaysia. The Hong Kong & Shanghai Banking Corporation predicts that by 2030, China will account for more than half of world trade in high-tech goods. Hong Kong and the United States will remain in second and third place, albeit with smaller market shares, and South Korea will overtake Singapore as the fourth largest exporter of high-tech goods. According to the latest report on the evaluation of high-tech innovation, which is a critical factor in China's innovation development and economic growth, they have made significant progress.

Conclusions

The clustering of countries indicates that countries united by the level of socio-economic development and economic growth rates have a certain specialization, which becomes both a prerequisite for and a consequence of accelerating economic development. In addition, the analysis indicates that countries in the same cluster have similar indicators of the complexity of economic activity and a similar structure of production of goods and export-import activity.

The countries of the first cluster are characterized by the highest indicators of socio-economic development, and they generally export mainly goods with a high degree of processing and level of added value. The countries of the second cluster, which includes some Central and Eastern European countries (including Slovenia and the Czech Republic), occupy an intermediate position between the first and third groups. In many parameters, they are close to the countries of the first cluster, but machines and equipment in their exports have a significantly lower weight than the countries of the first group. The countries of the second cluster specialized in producing low-technology products, especially food and raw materials. However, the countries of this cluster have potential based on products, machinery, and transport equipment, which can be a substratum for creating economic growth.

The countries of the third cluster, which unite the Central and Eastern European countries and the Baltic countries, mainly specialize in goods with a relatively small degree of processing and have low indicators of the complexity of the economy. The countries of the fourth cluster, which unites Asian countries, occupy a unique position. They have high indicators of economic complexity, specialize in high-tech exports, and are focused on goods with a high level of added value and ICT. The key feature of the countries of the fourth cluster is significant growth rates of economic indicators and specific development strategies. The criteria for the development of countries identified with the mathematical model, as well as the clustering based on the indicator of international specialization in the export profile, confirms the economic proximity and similarity of the economic structure of those countries.

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Innowacyjne klastry światowych liderów handlu

Powstanie nowego systemu globalnego i systemowej współzależności globalnej wygenerowało nowe czynniki konkurencyjności dla uczestników rynku, określające ich strategiczne zachowania służące zapewnieniu wysoce konkurencyjnej i wiodącej pozycji. Dlatego celem badania była identyfikacja krajów będących intelektualnymi liderami na rynku globalnym oraz czynników wpływających na pozycję głównych krajów. Zastosowano następujące metody badawcze: modele regresji wieloczynnikowej, analizę skupień oraz analizę porównawczą. Na podstawie autorskiej metodologii oceny przywództwa intelektualnego krajów dokonano grupowania krajów w gospodarce światowej. Algorytm oceny opierał się na trzech poziomach: 1) zasobach, 2) pośrednich wynikach aktywności intelektualnej oraz 3) ostatecznych wynikach ogólnego postępu.
Korzystając z modelu regresji wieloczynnikowej i analizy skupień, zidentyfikowano cztery klastry krajów wyodrębnione na podstawie kluczowych wskaźników przywództwa intelektualnego. Dla każdego klastra przeanalizowano specjalizację obu krajów w obszarze eksportu towarów: klaster 1 – Stany Zjednoczone i Niemcy; klaster 2 – Izrael i Włochy; klaster 3 – Brazylia i Ukraina; klaster 4 – Chiny i Korea Południowa. Każdemu krajowi przypisano wskaźnik złożoności gospodarczej i zarejestrowano zmianę pozycji każdego kraju w klastrze w ciągu dziesięciu lat.
Ważnym celem jest zrozumienie uwarunkowań przywództwa krajów w każdym regionie geograficznym.
Badania opierają się na analizie skupień przeprowadzonej we wcześniejszych publikacjach. Klasteryzacja krajów została przeprowadzona na podstawie dynamiki wskaźników makroekonomicznych w ciągu ostatnich 15 lat.

Słowa kluczowe: indeks złożoności gospodarczej, intelektualizacja, klasteryzacja krajów, eksport towarów

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Global and European Foreign Trade during the COVID–19 Pandemic

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Abstract

The article aims to answer the following questions: 1) How has the European Union's international trade developed in terms of goods and geography in the last two years, and to what extent has it been resilient to the effects of the COVID–19 pandemic? 2) To what extent has the ambitious path to the development of the digital economy, including the particularly dynamic development of e-commerce in recent years, contributed to reducing the negative effects of the COVID–19 pandemic?

The results of the research show that the global economy experienced a huge decline in trade in goods and services during the COVID–19 pandemic: World trade in goods fell by 7.4% in 2020, which means that global exports amounted to USD 17.6 trillion, i.e., USD 1.4 trillion less than in the previous year. It was the largest annual decline since the 2009 recession, when trade fell by 22%. However, a much stronger decline was recorded in world trade in services, which in 2020 shrank by 20% compared to 2019. During the COVID–19 pandemic, the dynamic development of global e-commerce was noted. According to the data presented in the UNCTAD report of May 3, 2021, global e-commerce increased to USD 26.7 billion. Business-to-business (B2B) sales dominate in e-commerce. E-commerce accounts for 30% of the world's gross domestic product (GDP) and covers both business-to-business (B2B) and business-to-consumer (B2C) sales.

Keywords: European Union, international trade, e-commerce, digital economy, Digital Europe, Digital Compass

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Introduction

The effects of the COVID–19 pandemic have become very severe for many sectors of the global and European economies in recent years. This is indicated by the results of analyses and assessments of the International Monetary Fund (IMF), the United Nations Conference on Trade and Development (UNCTAD), and the European Commission (EC). Fundamental here is the latest IMF forecast from January 2022. The world economy and most of its regions started 2022 (International Monetary Fund 2022b) with a weaker position in terms of the achieved economic growth rate than expected in 2021 (International Monetary Fund 2021).

However, data on world trade in goods are slightly more optimistic. An UNCTAD report from December 2021 (UNCTAD 2021c) showed that in that year, the value of global trade in goods and services increased by approximately USD 5.2 trillion compared to 2020. The report showed that the value of global trade in goods exceeded the pre-COVID–19 level by 15%, but in the services sector, performance was weaker as the trade value has not yet reached pre-pandemic levels. On the other hand, good results of the increase in trade intensity were recorded during the pandemic in e-commerce in both its forms, i.e., Business to Business (B2B) and Business to Customer (B2C). It was related to the intensive development of the digital economy at the European level and especially at the global level.

However, according to the IMF, the economic damage caused by the conflict in Ukraine from March 2022 will contribute to a significant slowdown in global economic growth in 2022 and a substantial increase in inflation. Fuel and food prices have risen sharply, hitting vulnerable populations in low-income countries the hardest. Global growth is expected to slow down from an estimated 6.1% in 2021 to 3.6% in 2022 and 2023. After 2023, global growth is projected to decline to around 3.3% in the medium term. War-induced increases in commodity prices and rising price pressures led to an inflation forecast of 5.7% for 2022 in developed economies and 8.7 percent in developing and emerging economies (International Monetary Fund 2022a).

This article aims to try to answer the following questions:

1. What major changes have occurred in global and European trade in goods and services during the COVID–19 pandemic?
2. To what extent does the ambitious path to the development of both circular and digital economies in the global and European economy – including the particularly dynamic development of e-commerce in recent years – contribute to reducing the negative effects of the COVID–19 pandemic?

Table 1. Latest *World Economic Outlook* projections

Real GDP, annual percent change	2021	2022	2023
World Output	6.1	3.6	3.6
Advanced Economies	5.2	3.3	2.4
United States	5.7	3.7	2.3
Euro Area	5.3	2.8	2.3
Germany	2.8	2.1	2.7
France	7.0	2.9	1.4
Italy	6.6	2.3	1.7
Spain	5.1	4.8	3.3
Japan	1.6	2.4	2.3
United Kingdom	7.4	3.7	1.2
Canada	4.6	3.9	2.8
Other Advanced Economies	5.0	3.1	3.0
Emerging Market and Developing Economies	6.8	3.8	4.4
Emerging and Developing Asia	7.3	5.4	5.6
China	8.1	4.4	5.1
India	8.9	8.2	6.9
ASEAN–5	3.4	5.3	5.9
Emerging and Developing Europe	6.7	–2.9	1.3
Russia	4.7	–8.5	–2.3
Latin America and the Caribbean	6.8	2.5	2.5
Brazil	4.6	0.8	1.4
Mexico	4.8	2.0	2.5
The Middle East and Central Asia	5.7	4.6	3.7
Saudi Arabia	3.2	7.6	3.6
Sub-Saharan Africa	4.5	3.8	4.0
Nigeria	3.6	3.4	3.1
South Africa	4.9	1.9	1.4
Memorandum			
Emerging Market and Middle-Income Economies	7.0	3.8	4.3
Low-Income Developing Countries	4.0	4.6	5.4

Note: For India, data and forecasts are based on the fiscal year, with FY 2021/2022 starting in April 2021. For the April 2022 WEO, India's growth projections are 8.9 percent in 2022 and 5.2 percent in 2023, based on the calendar year.
Source: International Monetary Fund (2022a, p. 6).

The European Union's new trade policy towards third countries

In times of the digital revolution, geographic barriers and distances are becoming less important, which has a huge impact on the economy and society worldwide. It also means new opportunities for trade, including for European Union (EU) SMEs and consumers, thanks to the global e-commerce market, estimated at over EUR 12 trillion. Compliance costs tend to be higher for small businesses than for large businesses when trading cross-border. However, e-commerce gives even small internet businesses the ability to access customers from all over the globe. As the largest exporter of services in the world, the EU can benefit from e-commerce. However, in the age of the digital economy, new types of trade barriers have emerged. Some of them concern companies for which trading in digital channels is their primary activity. The collection, digitization, storage, processing, and transfer of data (including economic, financial, statistical, and scientific information) have become an integral part of modern business models, including in manufacturing companies. These data are vital for the development of global value chains.

Consequently, the importance of the free flow of data across borders for Europe's overall competitiveness has increased. Regulatory cooperation, mutual recognition, and the harmonization of standards are the best tools to solve the problems of the digital economy. Many of these issues are addressed in the Digital Single Market Strategy, but only in the EU context. European companies still face significant barriers around the world, such as non-transparent rules, state interference, and unjustified data localization and storage requirements. Data security is of paramount importance to all companies that process data. Digital infrastructure, encryption, and common standards are also important for global value chains, so these issues also fall within the scope of trade policy.[1]

On February 18, 2021, the EC published *Trade Policy Review – An Open, Sustainable and Assertive Trade Policy*, which presents a new balanced, open, and assertive European Union trade policy (*Trade Policy Review…* 2021, see also European Commission 2021c). In it, the EC sees sustainable development as an element of the necessary green transformation of economies, which will have to be reflected at the global level, i.e., within the World Trade Organization (WTO) and at the level of other trade organizations. The EU is also working with individual WTO members to implement parallel environmental initiatives related to the circular economy.

The WTO also has a vital role in supporting the Sustainable Development Goals of Decent Work and Gender Equality, which are extremely important both outside and within the EU. In relation to decent work, the WTO supports the analysis and exchange of experience on how

1 https://trade.ec.europa.eu/doclib/docs/2016/january/tradoc_154149.pdf (accessed: 2.05.2022).

trade policy can contribute to social development, how stronger protection of workers' rights is beneficial for growth and development, and how to ensure that both within and outside the EU the benefits of trade liberalization will reach all workers and disadvantaged communities. This action can be supported by continued and more active cooperation between the WTO and the International Labor Organization. The EU is also cooperating internationally to further integrate this social dimension of globalization into the work of the WTO. Concerning gender equality, the EU can play a leading role in raising awareness of the importance of ensuring that a gender mainstreaming approach is at the heart of trade policy. It can be achieved through initiatives such as the Declaration of the WTO Ministerial Conference on the trafficking and economic empowerment of women, organized in Buenos Aires in December 2017 (*Gender Equality in EU's foreign and security policy…* 2021).

The EU also intends to prioritize the engagement in dialogue with African countries on the WTO's reform agenda, in particular by intensively supporting the building of the African Continental Free Trade Area. In this context, the EU supports obtaining observer status in the relevant WTO bodies by the African Union (AU). The EC ensures that it will continue to engage in discussions with China and India on specific aspects of the WTO's reform agenda. China's GDP per capita has increased tenfold since its accession to the WTO, and it also became the largest exporter to the WTO in just two decades (European Commission 2021a).

In the face of new internal and external challenges, particularly the new, more sustainable development model set out in the EU Green Deal Strategy and the European Digital Strategy, the EC believes that there is a need for a new approach to trade policy. The policy should help achieve internal and external policy goals and promote more sustainable development in line with the commitment to achieve the United Nations' *Sustainable Development Goals* (SDGs) by 2030. An important task of trade policy is also to play a positive role in recovering from the COVID–19 pandemic and building the ecological and digital transformation of the European economy.

Global uncertainty fueled by political and geo-economic tensions is now increasing. Globalization, technological development, and the creation of global value chains have dichotomous effects on economies and societies. On the one hand, they led to enormous gains in labor productivity, stimulating sustained trade-based economic growth in many parts of the world and helping lift millions of people out of poverty. On the other hand, these changes sometimes had a strong disruptive effect, which increased income inequality and left some individuals and communities behind. What was meant to be transitional adjustment costs sometimes resulted in the ongoing deterioration of living standards, employment opportunities, wages, and other working conditions. In many cases, governments insufficiently responded to economic adjustments and insufficiently mitigated their adverse effects. It sparked calls for deglobalization, and there are increasing particular and isolationist reactions.

The rapid growth in the importance of China, which shows global ambitions and follows a separate state-capitalist model, has fundamentally changed the world's economic and political order. This situation poses an increasing challenge to an established global economic governance system and helps ensure a level playing field for European companies that compete globally and nationally. Accelerating climate change, biodiversity loss, and environmental degradation, combined with tangible examples of their devastating effects, have made green transformation a decisive goal of our time. The *European Green Deal*, as a new strategy for the EU's sustainable development, facilitates the change of economic policy to better respond to the challenges of the 21st century. Its overarching goal is to transform towards a climate-neutral, environmentally sustainable, resource-efficient, and resilient economy by 2050, aiming to reduce greenhouse gas emissions by at least 55% by 2030 and protect, preserve, and enrich the EU's natural capital. As such, this strategy is to be a driving force for the growth of competitiveness, leading to a gradual but profound transformation of the member states' economies, which will significantly impact the trade structure.

Green transformation must go hand in hand with social justice. In many parts of the world, severe deficits in decent work persist in global supply chains, ranging from severe violations of the freedom of association to poor working conditions.[2] Depriving workers of their fundamental rights puts pressure on worsening social conditions around the world and fuels people's disillusionment with globalization and open trade. Digital transformation is not only a key factor in enabling sustainable development. In light of Europe's entry into the digital decade, supporting its transformation in this direction is a priority at both internal and external policy levels, including for trade policy and its instruments.[3]

At the same time, the nature of trade is systematically changing. In the future, it will be more based on innovation, supported by the protection of intellectual property, and trade in services and products based on respecting intellectual property rights will play an increasingly important role compared to traditional trade in goods. Services not only directly contribute to the value chain (financial services, telecommunications, IT, transport, and logistics), but, even more importantly, they are incorporated into manufactured products. The servitization of the economy and the advancement of digital technologies create well-paid and high-quality jobs and fuel economic growth.[4]

2 According to estimates by the International Labour Organization (ILO), there are still some 25 million victims of forced labor and 152 million victims of child labor, and 2.78 million workers worldwide die each year from work-related accidents or illnesses. See: International Labour Organization 2017a; 2017b.

3 For more on this topic, see Wysokińska and Witkowska 2021, pp. 102–122 and 128–133.

4 The EU's position in the world trade in services is high. Before the Pandemic, the EU's share was 32%, and in trade in goods, about 29%. In the EU's commodity structure of sold production of technologically advanced goods, almost 50% are commodity groups that are the basis for the development of digitalization, such as electronics and telecommunications, scientific and research apparatus, computer and office machinery manufacturing (see Wysokińska and Witkowska 2021, p. 139).

The EU is also the world's largest provider of Aid for Trade.[5] The COVID–19 pandemic has increased the need to fully implement the 2017 EU Aid for Trade Strategy. The EU's strategic interest is to foster greater integration into the world economy of vulnerable developing countries, many of which are geographically adjacent to Europe. The EU's strength lies in its openness and the attractiveness of a single internal market. Its openness and commitment on the international stage make it a credible supporter of international cooperation, multilateralism, and a rule-based order, which in turn are crucial to the EU's interests. The EU works with its partners to ensure that universal values are respected, particularly in promoting and protecting human rights. It includes core labor standards, social protection in line with the European Pillar of Social Rights, gender equality,[6] and the fight against climate change and biodiversity loss. Strengthening the resilience and sustainability of the EU economy and its supply chains is a pillar of its pursuit of open strategic autonomy.

Intense global competition in the digital sphere will change the configuration of global economic relations, and trade policy will play a significant role in achieving the EU's digital transformation goals. European businesses depend on digital services, and this dependency will only increase. Data is vital for many businesses, and it is also an essential part of EU supply chains. Digital technologies provide the productivity gains needed to maintain the competitiveness of the economy, also leading to the transformation of traditional industrial sectors where European companies will need to improve their competitive position. At the same time, the digital transformation and the emergence of new technologies are essential for Europe from a security point of view. The EC believes that the emergence of new digital technologies, including artificial intelligence, should be considered on a global scale by setting more ambitious global standards and rules.

Supporting the Digital Agenda for Europe is a priority of the EU's trade policy. It should ensure EU leadership in digital trade and technology, notably by promoting innovation. The EU should continue to play a leading role in digital standards, particularly when it comes to data protection, where the EU General Data Protection Regulation is often seen as a source of inspiration (European Commission 2020a; 2020b; Regulation (EU) 2016/679... 2016).

Data will be crucial for the EU's future. Regarding cross-border data transfers and the ban on data localization requirements, the EC has announced that it will

5 Aid for Trade aims to support developing countries in using trade as a lever for poverty reduction. Target 8.a under the Sustainable Development Goals in the resolution "Transforming Our World: 2030 Agenda for Sustainable Development" refers to increasing Aid for Trade, particularly for least developed countries (LDCs). Sustainable Development Goal 17 includes efforts to increase exports from developing countries, particularly LDCs.

6 See: European Parliament resolution of 23 October 2020 on Gender Equality in EU's foreign and security policy (2019/2167(INI)); *Gender Equality in EU's foreign and security policy…* 2021.

take an open but assertive approach based on European values and interests. It will strive to ensure that EU companies can benefit from an international free flow of data that is fully compliant with EU data protection and security and public order rules. In particular, the EU will continue to address unjustified obstacles to data flows while maintaining its regulatory autonomy in the area of data protection and privacy.[7]

Main trends in the world and European trade during the COVID–19 pandemic. The position of the three major players in world trade

According to the 2021 UNCTAD Report (UNCTAD 2021d), which presents the impacts of the COVID–19 pandemic in 2020, there was a decline in trade in goods and services in the global economy. Global trade in goods decreased by 7.4% in 2020, which means that global exports amounted to USD 17.6 trillion, i.e., USD 1.4 trillion less than in the previous year. It was the most significant annual decline since the 2009 recession, when trade fell by 22%. However, a much stronger decline was recorded in world trade in services, which shrank by 20% in 2020 compared to 2019. It was also the largest decline in trade in services since its inception (UNCTAD 2021b).

China, the EU, and the United States have been among the world's largest players in international trade since 2004, when China overtook Japan (Eurostat n.d., *The three largest global players…*; see also: Wysokińska and Witkowska, 2021, Chapter IV). The European Union, the United States, and China accounted for 43% of world trade in goods in 2020. In 2020, the total level of trade in goods (exports and imports) recorded for the EU was EUR 3,646 billion (excluding intra-EU trade), thus EUR 423 billion lower than for China but EUR 285 billion higher than for the US United. Due to the COVID–19 pandemic, there was a sharp fall in total trade in the EU (–10%) and the US (–9%), while in China, it increased by 2%. In the EU, the value of imports decreased (–12%, i.e., more than the value of imports, which fell –9%). The reverse was the case in the United States (–13% in exports, –6% in imports). In China, imports decreased by 1% while exports increased by 4%.

In 2020, the ratio of exports to imports (coverage ratio) was exceptionally high in favor of exports from Russia and China, which, in absolute terms, also had the highest annual trade surpluses. The United States had the largest deficit in 2020, continuing the trend seen throughout the last decade. By observing export and import flows, in 2020, the EU had the second-largest share in world exports and the third-largest share

7 Which is reflected in the title devoted to trade in the EU-UK Trade and Cooperation Agreement.

in imports of goods. The exports of goods from the EU accounted for 15.1% of world exports. With a share of 17.8%, China was ahead of the EU. The United States, with a 9.8% share, was in third place. However, in 2020 the United States had a larger share of world imports (16.2%) than the EU (13.1%) or China (13.8%) (Eurostat n.d., *The three largest global players…*; see also: Wysokińska and Witkowska, 2021, Chapter IV).

The chart below presents trends in international trade in EU goods (annual growth rates of exports and imports) between 2011 and 2020. It shows a strong downward trend in EU trade, both in exports and imports, from the third quarter of 2019 until the deep decline in turnover caused by the pandemic throughout 2020.

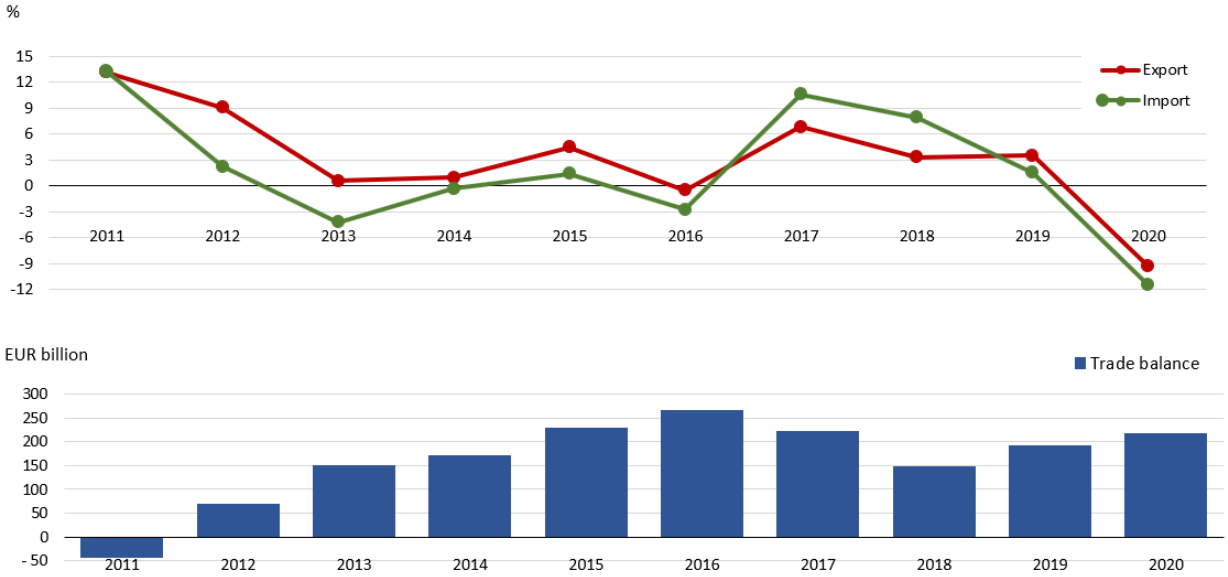

Figure 1. International trade in goods (annual growth rates)

Source: based on Eurostat (n.d., *EU trade in 2021 strongly…*).

Digital Europe – Digital Compass

The EC has outlined a vision of Europe's digital transformation by 2030. The program includes goals and key milestones, a common governance structure that includes a monitoring system to identify successes and gaps, and multi-country projects that allow integration of the EU, Member States, and private sector investments (European Commission n.d., *Europe's Digital Decade…*).

Europe's digital transformation vision is based on *Shaping Europe's Digital Future Strategy* (European Commission n.d., *Europe's Digital Decade…*). The strategy considers the enormous changes caused by the COVID–19 pandemic, which has significantly ac-

celerated the use of digital tools by showing their potential while exposing society's responses to new digital inequalities. The strategy also includes a system for monitoring the EU's progress against the key *UN Sustainable Development Goals* up to 2030.

The Digital Europe Program (DEP) was established for the duration of the Multiannual Financial Framework for 2021–2027. It is a newly created European program that supports the European Union's Digital Single Market strategy. Its main objectives are to support European industry and society, accelerate the digital transformation of the European economy, provide citizens, public administrations and businesses across the Union with the benefits of digitization, and increase Europe's competitiveness in the global digital economy while reducing the digital divide within the EU and strengthening its strategic autonomy in this area.

Thanks to the widespread implementation of digital technologies in the economy and society, the ***Digital Europe Program*** will positively impact the achievement of common European climate and environmental goals set out in the *European Green Deal*, mainly in terms of achieving climate neutrality by 2050.

The Digital Europe Program has five specific interrelated objectives that reflect the critical areas of the European Union's digital policy: Large-scale calculations, Artificial intelligence (AI), Cybersecurity and trust, Advanced digital skills, Implementation and optimal use of digital capacities, and Interoperability (European Commission n.d., *Digital Europe Programme*). Another of its important goals is the creation of a network of *European Digital Innovation Hubs* (EDIHs), i.e., centers to gather knowledge and competencies in the digital transformation of economic activity. Their task will be to support the digital transformation of both entrepreneurs and public administration entities. Among entrepreneurs, particular emphasis will be placed on the SME sector, where there is a significant need to increase the adoption of the latest digital solutions in the business. Intervention in this area will remove the risk of a decline in European and Polish SMEs' competitiveness and prevent them from losing their market position.

The main pillars of the EU's Digital Compass

The first pillar – a digitally skilled population. The primary target concerning digital skills is that at least 80% of the population have basic digital skills. Another target is to employ 20 million ICT professionals, taking into account gender equality.

The second pillar – sustainable digital infrastructure. This pillar proposes that all households be included in the 5G gigabit network. The goal is to create high-performance computing and data infrastructures in Europe by 2030 to strengthen Europe's infrastructure for the introduction of leading quantum technologies. By 2025, the EU plans to have the first quantum accelerated computer. Mechanisms for measuring the ener-

gy efficiency of data centers and electronic communication networks used by European companies will be introduced.

The third pillar – the digital transformation of enterprises. It is planned that 75% of enterprises in the EU will use cloud computing, big data, and artificial intelligence services. The aim is also to ensure that more than 90% of European SMEs reach at least a basic digital intensity. Europe is expanding its innovative scale-ups and improving these firms' access to finance, thus doubling the number of "unicorns" (i.e., USD 1 billion start-ups).

The fourth pillar – the 100% digitization of public services. It covers the provision of key online public services. Already, 80% of EU citizens use the European digital identity in the following areas: secure electronic voting, which allows greater public participation in democratic life; administration as a platform; comprehensive and easy access to public services with advanced capabilities, such as data processing, artificial intelligence, and virtual reality; the widespread implementation of a trusted, user-controlled digital identity, enabling every citizen to control their interactions and online presence (European Commission 2021b).

The policy agenda for achieving the digital goals is to enable the EC to work with the Member States to launch and shape multinational projects and international digital partnerships.

Global and European e-commerce during the COVID–19 pandemic

According to data presented in the UNCTAD report from May 3, 2021, global e-commerce increased to USD 26.7 billion. The COVID–19 pandemic had a significant impact on this result. Business-to-business (B2B) sales dominated e-commerce. The report estimates the value of global B2B e-commerce in 2019 at USD 21.8 billion, making up 82% of all e-commerce, including sales via online marketplaces and Electronic Data Interchange (EDI) transactions. The report also notes that the proportion of online shoppers making cross-border purchases increased from 20% in 2017 to 25% in 2019. According to the estimates in the report, a significant increase in e-commerce occurred due to traffic restrictions caused by COVID–19. They contributed to an increase in the share of online retail sales in total retail sales from 16% to 19% in 2020. It also shows that the pandemic particularly affected the decline in profits of companies offering services such as transportation and travel. It said that online retail sales increased significantly in several countries, with South Korea having the highest share in 2020, at 25.9%, compared to 20.8% a year earlier (see Table 2).

The rise in global e-commerce sales to USD 26.7 trillion in 2019 represents an increase of 4% compared to 2018, according to UNCTAD estimates. It includes B2B and B2C (business-to-consumer) sales and accounts for 30% of the world's GDP in 2020. Table 2 presents the shares of online sales in retail sales in selected economies from 2018–2020, indicating three countries with the highest and similar positions in 2020, i.e., South Korea, China, and Great Britain. The United States, Singapore, Australia, and Canada followed. Particularly noteworthy is the very large increase in the share in the 2018–2020 period achieved by the United Kingdom (8.4 pp), South Korea (7.7 pp), Singapore (7 pp), and China (6.5 pp) – see Table 2.

Table 2. Online retail sales, selected economies, 2018–2020

Economy	Online retail sales (USD billions)			Retail sales (USD billions)			Online share (% of retail sales)		
	2018	2019	2020	2018	2019	2020	2018	2019	2020
Australia	13.5	14.4	22.9	239	229	242	5.6	6.3	9.4
Canada	13.9	16.5	28.1	467	462	452	3.0	3.6	6.2
China	1,060.4	1,233.6	1,414.3	5,755	5,957	5,681	18.4	20.7	24.9
Korea (Rep.)	76.8	84.3	104.4	423	406	403	18.2	20.8	25.9
Singapore	1.6	1.9	3.2	34	32	27	4.7	5.9	11.7
United Kingdom	84.0	89.0	130.6	565	564	560	14.9	15.8	23.3
United States	519.6	598.0	791.7	5,269	5,452	5,638	9.9	11.0	14.0
Economies above	1,770	2,038	2,495	12,752	13,102	13,003	14	16	19

Source: UNCTAD, based on national statistics offices, UNCTAD (2020, p. 1).

According to the UNCTAD report, the COVID–19 pandemic also had mixed effects on leading B2C e-commerce companies. Data for the 13 largest e-commerce companies, 11 of which come from China and the United States, show a clear change in the platforms that offer services such as transport and travel (Table 3). They all experienced sharp declines in Gross Merchandize Value (GMV) and corresponding declines in the rankings. For example, Expedia fell from 5th place in 2019 to 11th place in 2020. Booking Holdings fell from 6th to 12th, and Airbnb, which launched its IPO in 2020, dropped from 11th to 13th. Despite the decline in the GMV of service companies, the total GMV for the 13 largest e-commerce B2C companies increased by 20.5% in 2020, more than in 2019 (17.9%). Shopify (up 95.6%) and Walmart (72.4%) reported particularly strong profits. Overall, GMV B2C for the top 13 companies amounted to USD 2.9 trillion in 2020 – see Table 3.

Table 3. Top B2C e-commerce companies by GMV, 2020

Rank by GMV		Company	HQ	Industry	GMV (USD billions)			GMV change (%)	
2020	2019				2018	2019	2020	2018–19	2019–20
1	1	Alibaba	China	E-commerce	866	954	1,145	10.2	20.1
2	2	Amazon	USA	E-commerce	344	417	575	21.0	38.0
3	3	JD.com	China	E-commerce	253	302	379	19.1	25.4
4	4	Pinduoduo	China	E-commerce	71	146	242	104.4	65.9
5	9	Shopify	Canada	Internet Media & Services	41	61	120	48.7	95.6
6	7	eBay	USA	E-commerce	90	86	100	– 4.8	17.0
7	10	Meituan	China	E-commerce	43	57	71	33.0	24.6
8	12	Walmart	USA	Consumer goods retail	25	37	64	47.0	72.4
9	8	Uber	USA	Internet Media & Services	50	65	58	30.5	– 10.9
10	13	Rakuten	Japan	E-commerce	30	34	42	13.6	24.2
11	5	Expedia	USA	Internet Media & Services	100	108	37	8.2	– 65.9
12	6	Booking Holdings	USA	Internet Media & Services	93	96	35	4.0	– 63.3
13	11	Airbnb	USA	Internet Media & Services	29	38	24	29.3	– 37.1
Companies above					2,035	2,399	2,890	17.9	20.5

Note: Alibaba year beginning April 1, Walmart year beginning February 1. GMV = Gross Merchandize Value (as well as Booking Value).
Source: UNCTAD based on company reports, UNCTAD (2020, p. 2).

Business-to-business sales dominate in e-commerce. The UNCTAD report estimates the value of global B2B e-commerce in 2019 at USD 21.8 trillion, representing 82% of all e-commerce, including sales via online marketplaces and electronic data interchange (EDI) transactions. The United States continued to dominate the entire e-commerce market, ahead of Japan and China (Table 4). B2C e-commerce sales were estimated at USD 4.9 billion in 2019, an increase of 11% compared to 2018. The three leading countries in terms of B2C e-commerce sales are China, the United States, and the United Kingdom. The European Union economies listed among the top 10 countries in the world (in terms of e-commerce B2C sales) are France, Germany, Spain, and Italy. Cross-border B2C e-commerce amounted to approximately USD 440 billion in 2019, an increase of 9% compared to 2018. For detailed data, see Table 4.

Table 4. E-commerce sales: Top 10 countries, 2019

Rank	Economy	Total e-commerce sales (USD billions)	Share of total e-commerce sales in GDP (%)	B2B e-commerce sales (USD billions)	Share of B2B e-commerce sales in total e-commerce (%)	B2C e-commerce sales (USD billions)
1	United States	9,580	45	8,319	87	1,261
2	Japan	3,416	67	3,238	95	178
3	China	2,604	18	1,065	41	1,539
4	South Korea	1,302	79	1,187	91	115
5	United Kingdom	885	31	633	72	251
6	France	785	29	669	85	116
7	Germany	524	14	413	79	111
8	Italy	431	22	396	92	35
9	Australia	347	25	325	94	21
10	Spain	344	25	280	81	64
10 above		20,218	36	16,526	82	3,691
World		26,673	30	21,803		4,870

Source: UNCTAD, based on national sources, UNCTAD (2020, p. 4).

The Annex presents the results of the 2020 Global B2C-E-commerce Index in 10 leading countries belonging to three groups of economies: 1) the best economies, 2) the Top 10 developing economies, and 3) the Top 10 emerging and transforming economies.

Conclusions

According to the statistics of international statistical institutions, data on world trade in goods and, to a lesser extent, trade in services are more optimistic than data on the world and regional GDP and Gross National Product (GNP) growth rates. The data presented in the December 2021 UNCTAD report shows that finally, in 2021, the value of global trade in goods and services increased by approximately USD 5.2 trillion compared to 2020 (after significant decreases in 2020 compared to 2019 – by 7.4% in global trade in goods and by 20% in trade in services). The report found that global trade in goods exceeded pre-COVID–19 levels by 15%, but for the services sector, the results were weaker as the value of this trade had not yet reached pre-pandemic levels.

China, the EU, and the United States have been among the world's most prominent players in international trade since 2004, when China overtook Japan. The European Union, the United States, and China accounted for 43% of world trade in goods in 2020.

Satisfactory results of the increase in trade intensity were recorded in the era of a pandemic, especially in e-commerce in both its forms, i.e., B2B and B2C. It was related to the intensive development of the digital economy at the European level and especially at the global level. Therefore, the dynamic growth of e-commerce in recent years has helped reduce the negative effects of the COVID–19 pandemic, especially at the global level. It is mainly because, for several years, an ambitious path to developing a circular and digital economy has been set at the global and European levels. Both the EC and global institutions have presented visions for the transformation of Europe and the world by 2030, within the framework of the Sustainable Development Goals, including, in particular, goals 7, 8, and 12–17.

A significant increase in e-commerce took place due to traffic restrictions caused by COVID–19, which contributed to an increase in the share of online retail sales in total retail sales from 16% to 19% in 2020, according to the estimates in the May UNCTAD report.

During the pandemic, the countries that achieved the highest position in 2020 were South Korea, China, and the United Kingdom, followed by the United States, Singapore, Australia, and Canada. Particularly noteworthy is the considerable increase in the share in the 2018–2020 period achieved by the United Kingdom (8.4 pp), South Korea (7.7 pp), Singapore (7 pp), and China (6.5 pp).

The three countries that recently achieved the best results for B2C e-commerce sales are China, the United States, and the United Kingdom. In the EU, France, Germany, Spain, and Italy achieved the best results.

B2B sales dominate in e-commerce. The UNCTAD report (UNCTAD 2021a) estimates the value of global B2B e-commerce in 2019 at USD 21.8 trillion, representing 82% of all e-commerce, including sales via online marketplaces and EDI transactions. The United States dominates the entire e-commerce market, ahead of Japan and China.

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ANNEX

Table A1. Top 10 economies in the UNCTAD B2C E-commerce Index 2020

2020 Rank	Economy	Share of individuals using the Internet (2019 or latest)	Share of individuals with an account (15+, 2017)	Secure Internet servers (normalized, 2019)	UPU postal reliability score (2019 or latest)	2020 Index value)	Index value change (2018–19 data)	Rank 2019
1	Switzerland	97	98	92	97	95.9	0.6	2
2	Netherlands	96	100	94	93	95.8	0.1	1
3	Denmark	97	100	100	81	94.5	0.1	6
4	Singapore	89	98	94	97	94.4	–0.3	3
5	United Kingdom	96	96	84	98	93.6	0.1	4
6	Germany	93	99	90	91	93.4	–0.1	9
7	Finland	95	100	88	91	93.4	–0.1	5
8	Ireland	88	95	92	98	93.4	0.7	7
9	Norway	98	100	84	88	92.6	–0.1	8
10	China, Hong Kong SAR	92	95	88	92	91.8	0.3	14

Source: UNCTAD (2021e).

Table A2. Top 10 developing economies in the UNCTAD B2C E-commerce index 2020

2020 Rank	Economy	Share of individuals using the Internet (2019 or latest)	Share of individuals with an account (15+, 2017)	Secure Internet servers (normalized, 2019)	UPU postal reliability score (2019 or latest)	2020 Index value)	Index value change (2019–20 data)	Rank 2019
4	Singapore	89	98	94	97	94.4	–0.3	3
10	China, Hong Kong SAR	92	95	88	92	91.8	0.3	14
18	South Korea	96	95	68	100	89.8	0.0	19
30	Malaysia	84	85	71	85	81.3	1.5	31
37	United Arab Emirates	99	88	61	64	78.2	0.0	28
42	Thailand	67	82	59	97	76.0	0.5	48
44	Iran	70	94	57	79	75.0	–1.5	45
49	Saudi Arabia	96	72	43	78	72.3	0.0	49

2020 Rank	Economy	Share of individuals using the Internet (2019 or latest)	Share of individuals with an account (15+, 2017)	Secure Internet servers (normalized, 2019)	UPU postal reliability score (2019 or latest)	2020 Index value)	Index value change (2019–20 data)	Rank 2019
50	Qatar	100	66	50	73	72.1	0.0	47
54	Oman	92	74	43	73	70.6	0.0	60

Source: UNCTAD (2021e).

Table A3. Top 10 emerging and transforming economies in the UNCTAD B2C E-commerce Index 2020, by region

East, South & Southeast Asia	West Asia	Africa	Latin America and the Caribbean	Transition economies
Singapore	United Arab Emirates	Mauritius	Costa Rica	Belarus
China, Hong Kong SAR	Saudi Arabia	South Africa	Chile	Russian Federation
South Korea	Qatar	Tunisia	Brazil	Serbia
Malaysia	Oman	Algeria	Dominican Republic	Georgia
Thailand	Turkey	Ghana	Colombia	Ukraine
Iran	Kuwait	Libya	Uruguay	North Macedonia
China	Lebanon	Kenya	Jamaica	Moldova
Mongolia	Bahrain	Nigeria	Trinidad and Tobago	Kazakhstan
Viet Nam	Jordan	Morocco	Peru	Azerbaijan
India	Iraq	Senegal	Argentina	Bosnia and Herzegovina

Source: UNCTAD (2021e).

Światowy i europejski handel zagraniczny w czasie pandemii COVID–19

Celem niniejszego rozdziału jest próba odpowiedzi na pytania: 1) „Jak pod względem struktury towarowej i geograficznej rozwijał się handel międzynarodowy Unii Europejskiej w ostatnich dwóch latach i w jakim stopniu był on odporny na skutki pandemii COVID–19?", 2) „W jakim stopniu ambitna droga do rozwoju gospodarki cyfrowej – w tym szczególnie dynamiczny rozwój handlu elektronicznego w ostatnich latach, przyczyniły się do niwelowania negatywnych skutków pandemii COVID–19?".
Rezultaty przeprowadzonych badań pokazują, że w dobie pandemii COVID–19 w gospodarce światowej miał miejsce ogromny spadek handlu towarami i usługami. Światowy handel towarami odnotował spadek o 7,4% w 2020 r., co oznacza, że globalny eksport wyniósł 17,6 bln USD, czyli o 1,4 bln USD mniej niż w poprzednim roku. Był to największy roczny spadek od recesji z roku 2009, kiedy handel obniżył się o 22%. Znacznie jednak silniejszy spadek odnotowano w światowym handlu usługami, który w 2020 r. skurczył się o 20% w porównaniu z 2019 r.
W okresie pandemii COVID–19 zanotowano natomiast dynamiczny rozwój globalnego handlu elektronicznego. Według danych zaprezentowanych w raporcie UNCTAD z 3 maja 2021 globalny handel elektroniczny zwiększył się do 26,7 mld USD. W handlu elektronicznym (e-commerce) dominuje sprzedaż *business-to-business* (B2B). Handel elektroniczny odpowiada za 30% światowego produktu krajowego brutto (PKB) i obejmuje zarówno sprzedaż między przedsiębiorstwami (B2B), jak i między przedsiębiorstwami a konsumentami (B2C – *business-to-customer*).

Słowa kluczowe: Unia Europejska, handel międzynarodowy, handel elektroniczny, gospodarka cyfrowa, Cyfrowa Europa, Cyfrowy Kompas

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The Convergence of Factors That Affect the Dairy Product Market: A Comparative Analysis of European Union Countries

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Abstract

The European Union is a large producer of milk and dairy products. It is also a significant market for the consumption of dairy products, which is characterised by effective demand, and it significantly influences the markets of other food products. The main milk producers in the EU are Germany, France, Poland, the Netherlands, Italy and Spain. Intensive migration has contributed to additional demand for food products, in particular, dairy products. This provided the basis for the construction and calculation of a dynamic model of dairy production, the export of dairy products, and the coexistence with the existing population as the main consumers in the EU–27 countries and Great Britain between 2004 and 2020.

An additional research value is that based on the presentation of the analysis and modeling, the relationship between the growth in the demand for dairy products and the growth in the population is established. The reason for the large population in the countries of Central and Eastern Europe is intensive migration flows, which increase the demand for dairy products. The increase in volumes reduces the cost price, which contributes to the export of dairy products, and also contributes to the increase in the volume of production of dairy products. The resulting models made it possible to analyse the influence of population growth on the increase in production volume. At the same time, the dependence and influence of the export of dairy

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products on the increase in the volume of production of dairy products in the EU–27 and Great Britain countries is investigated.

The results of the mathematical modelling indicate unique opportunities to develop the dairy sector of individual EU–27 countries, i.e., the Czech Republic, the Netherlands, and Poland. These countries have a rational ratio of the influence of the population growth factor on the increase in the volume of dairy production and the optimal influence of the export of dairy products on the increase in the volume of dairy production.

Keywords: milk, dairy products, European Union, milk producers, consumers, export of dairy products, cost, price, profitability

JEL: F10, J11, Q11, Q17

Introduction

In the context of globalization, most countries around the world position themselves as open economies, the dynamics of which depend on building effective foreign economic relations between companies (Rosen et al. 2000; Robbins 2003). Economies adjust to more open markets by bringing their prices into line with global prices (Eskelinen et al. 2002). Exports and international competitiveness are crucial driving forces behind contemporary sectoral and economic development (Bojnec and Fertő 2019). National economies are embedded in a global system that generates mutual interdependence across countries. In this system, each country depends on the supply of consumer goods, intermediate products, and capital goods from its trade partners, and it relies on the trade partners to supply markets for its own products (Bayoumi, Coe, and Helpman 1996). Exports in an open economy are a tool to expand market space for branches and industries that are ready for intense international competition (Mahmood and Nishat 2004; Berger 2005; Demir, Kalayci, and Ertugan 2020; Gilpin 2020). The export base hypothesis is that a region's growth is led by export demand, given perfectly elastic factor supplies (Kilkenny and Partridge 2009). In accordance with the bilateral agreements, quotas are an additional element of trade liberalization (Putsenteilo, Klapkiv, and Kostetskyi 2018).

Given the existing natural, resource, social, economic and other factors, the agricultural sector is among the export industries in every country of the world that creates conditions for intensive integration into the world economy and food security (Mitchell 1985; Capalbo and Denny 1986; Melo and Robinson 1992; Barbier 2004; Qi and Wang 2007; Molenaar et al. 2015; Yu et al. 2017; Kyrgiakos, Vlontzos, and Pardalos 2021). Agri-food products are among the most popular on the market because they are a basic need for a person among the food ration, which is met in the first place.

In any territory, the supply of food is formed by a country's own resources through the production of agricultural products (Marsden, Banks, and Bristow 2000). It must fully cover the needs of the entire population living there. However, the planet's pop-

ulation is constantly growing, so the demand for food is also growing rapidly. Historically, when there have been food shortages or unavailability within A country, there is an urgent need to supply or purchase food on the world market.

Food demand has always been characterised by dynamism and a large volume of consumer requests (Thiele and Weiss 2003; Wang, Mao, and Gale 2008). It is also a key factor that directly affects food price formation (Henson and Traill 1993).

All countries are involved in the global food trade, as demand is constantly growing, mainly due to population growth, income growth and diversification of ways of nutrition (Liverman and Kapadia 2012; Stephens, Jones, and Parsons 2018). Therefore, international trade is of great importance for food security (Putsenteilo 2011).

According to research, the following factors commonly influence agri-food products on a global scale (Figure 1).

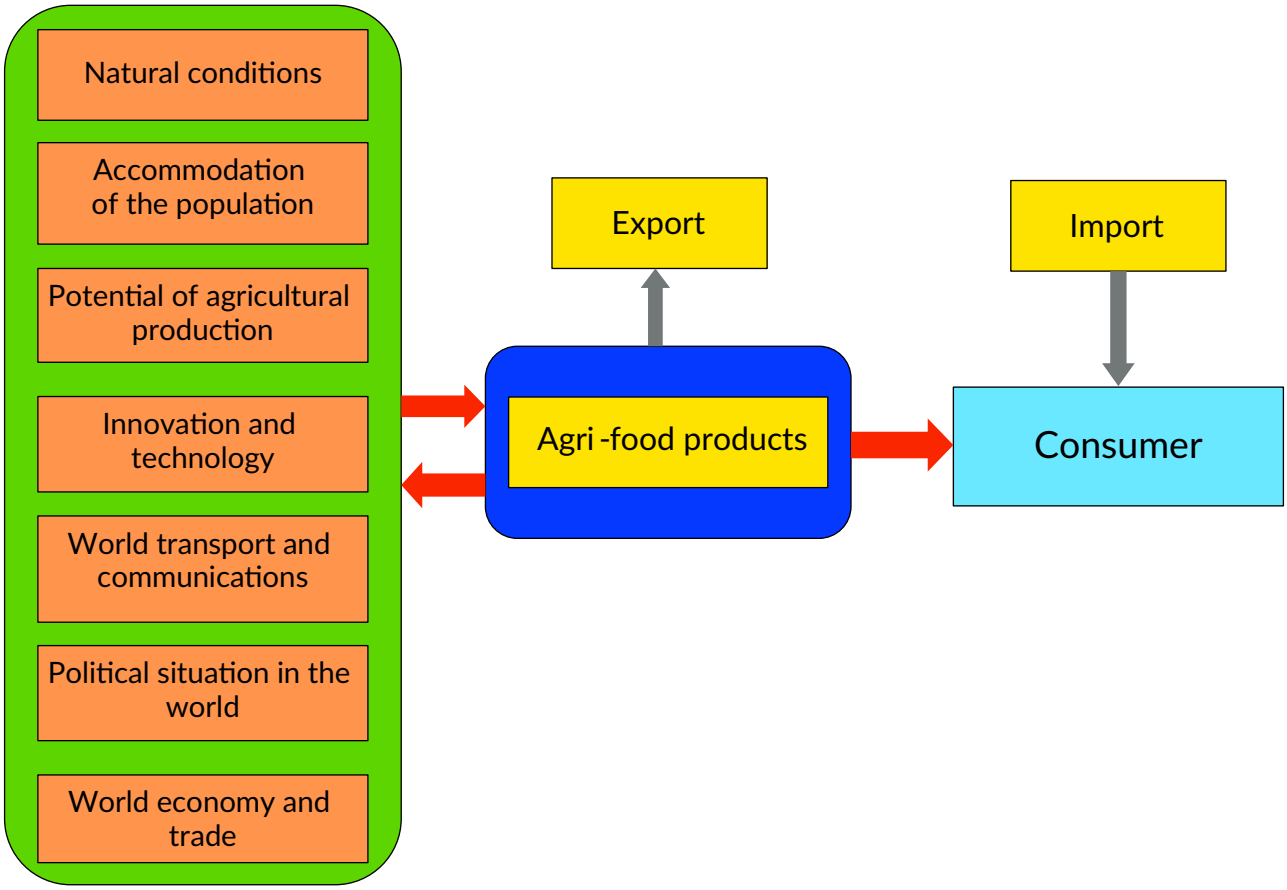

Figure 1. The factors that influence global agri-food products relations

Source: generated by the authors.

The development of the agricultural sector of the economy and its efficient functioning are determined primarily by the development of its institutions (Putsenteilo et al. 2020).

Material and methods

The EU is a large consumer market with more than 450 million inhabitants. It is characterised by effective demand – the average income is 1,900 euros per month (Eurostat 2001b). These factors make it very attractive to foreign companies, resulting in the intensification of competition in individual EU countries (Sadowski, Wojcieszak-Zbierska, and Beba 2021). However, companies from third countries face real challenges in entering EU agricultural markets (Chantreuil, Hanrahan, and Leeuwen 2011). Let us consider the dynamics and structure of the dairy market to better understand the competition in these markets.

Sales and market share data from all countries within the European Single Market (the European Union's 28 member states) have been included. The Euromonitor International Passport Global Market Information Database has the best available database for most of the selected countries and product markets. Euromonitor is the world's leading independent provider of strategic market research and collects volume sales databases from various sources, including trade associations, industry bodies, company financial reports, and official government statistics. These databases are validated by the food industry.

For this study, the databases were obtained for milk and dairy in the European Union (EU) at the most fine-grained level between 2004 and 2020.

The present study is secondary research mainly based on The Food and Agriculture Organization (FAO) database, Eurostat New Cronos, and the Bulletin of the IDF. Based on these data, we carry out statistical evaluations and illustrate the main tendencies in terms of production, trade and prices; finally, we analyse these trends. The FAO database provides the appropriate numbers for production, consumption, trade and prices. We have used these numbers to prepare figures and tables and analyse the changes over the years. We make relative numbers and examine the percentage changes in the different values. In addition, we try to reveal which causes contribute to the changes.

The main purpose of this study is to assess the production in the EU of butter, butter oil, cheeses, SMP (Skimmed Milk Powder), WMP (Whole Milk Powder), whey powder, casein, lactose, and cows' milk between 2004 and 2020. To achieve this goal, the Eurostat databases were selected. The advantage of these databases is their wide coverage (they cover all EU countries) and the only methodology for obtaining them. This makes it possible to compare EU countries.

Using multiple correlation analysis, we study the quantitative impact of factors on the results and establish the level of dependence of the performance indicator on each of the factors.

As the effective indicator Y, we choose "Products obtained", and as factors that influence the effective indicator, we use factors x_1, x_2 and x_3 – "Population"; "EXPORTS of Dairy Products to Third countries"; and "IMPORTS of Dairy Products from Third countries", respectively.

We assume that the relationship between factor indicators and performance is straightforward. To write such dependencies, one can use a linear function such as:

$$Yx = a_0 + a_1x_1 + a_2x_2 + ... + anxn.$$

In multiple correlation-regression models, even and partial correlation coefficients are calculated to measure the relationship density. Paired correlation coefficients show the density of the relationship between factors, and between factors and performance. The method of calculating and interpreting such coefficients is similar to the linear correlation coefficient for a one-factor (pair) connection. Constructing the regression equation is carried out for each study country separately.

Calculating paired correlation coefficients makes it possible to identify collinearity. Since it distorts the estimation of regression parameters, it must be eliminated. In this case, one of the factors must be excluded from the regression equation, which in a pairwise correlation gives a high linear coefficient that exceeds the absolute value of 0.7. Such a connection between two factors is called collinearity, and between several factors, it is called multicollinearity.

Determining the pairwise correlation coefficients takes into account the influence of other factors of the model. Partial correlation coefficients are calculated to abstract from their impact and to quantify the relationship between performance and factor indicators in their pure form. They show the level of influence of one factor on the result at influence of one factor at a fixed value on the result of others.

We find the calculated values of t-statistics for each pair of factors and the tabular value of t-statistics and compare them with each other.

$t_{12} > tkp$	Pair	X_1X_2	multicollinear
$t_{13} < tkp$	Pair	X_1X_3	non-multicollinear
$t_{23} > tkp$	Pair	X_2X_3	multicollinear
	Factor	X_3	excluded

Thus, as a result of the calculations, it can be concluded that it is necessary to remove factor X_3 (IMPORTS of Dairy Products from Third countries) from the equation, which indicates that there is no close relationship between factors X_1 and X_3, i.e. these factors are non-multicollinear. Then we build a standardised model with-

out taking into account the removed factor X_3. In order to be sure of the reliability of the connection equation and the expediency of its use for practical purposes, it is necessary to give a statistical assessment of its reliability. To do this, in addition to the coefficients of multiple correlation and determination, we use Fisher's criterion and the average error of approximation. The higher the multiple correlation coefficients, determination and Fisher's criterion, and the lower the standard error, the more accurately the relationship equation describes the relationship between the factors. When assessing the reliability of the relationship, the actual value of Fisher's test is compared with its tabular value. If the tabular value of the Fisher coefficient is greater than its actual value, this indicates that there is no relationship between the performance and factor indicators. Since $F_{\text{calculation}} > F_{\text{tab}}$, the reliability of the constructed mathematical model with reliability $P = 0.95$ can be considered adequate experimental data, and based on the accepted model, it is possible to carry out the economic analysis.

The Student's criterion is used separately to assess the reliability of each parameter of the equation. The result of the calculations is the construction of a multiple regression equation for each country separately, which reflects the dependence of Y on X_1 and X_2.

Analysing the parameters of the regression equation will allow us to draw a conclusion about the degree of influence of each of the two factors on the Y indicator – "Products obtained". For visual presentation, the results will be displayed Y and $Y_{\text{calculation}}$ in the form of charts for each EU country.

Results and discussion

Milk production is one of the important industries that provide the industry with raw materials and the population with biologically valuable food products (De Boer 2003; Blayney 2004; Marchand et al. 2012; Baldini, Gardoni, and Guarino 2017; Rotz et al. 2021). Milk has been known as nature's most complete food for millennia, and it currently plays an important role in people's diets across the world (Górska-Warsewicz et al. 2019). Milk and dairy products are nutrient-dense foods, supplying energy and high-quality protein with a range of essential micronutrients (especially calcium, magnesium, potassium, zinc, and phosphorus) in an easily absorbed form (Black et al. 2002; Bailey et al. 2010; Muehlhoff, Bennett, and McMahon 2013; Pfeuffer et al. 2018; Bechthold et al. 2019). Milk minerals are crucial for human health and development, as well as in dairy processes such as cheese-making and for all traits involving salt-protein interactions (Franzoi et al. 2017).

In Western countries, milk and dairy products are major components of the human diet, providing about 30% of dietary proteins and lipids and about 80% of dietary calcium (Fox 2003). Dairy products are an important part of most people's diets, and the benefits of calcium are widely advertised (Jelen and Lutz 1998; Girma, Tilahun, and Haimanot 2014). Therefore, dairy products are unlikely to be completely replaced (Maijala 2000; Bauman et al. 2006). Liquid (beverage) milk is a major food item in all developed dairying countries, representing 40% of total milk production (Fox 2003). However, the concentrations and properties of milk constituents are variable. Hence, the processability of milk and the properties of dairy products are inconsistent. However, much of this variability can be eliminated by modern technology, which exploits certain features of milk constituents (Boland and Singh 2019).

Given the crucial importance of the dairy sector in providing livelihoods, equity and food security for rural populations, quantifying the contribution of various factors to milk production growth is useful for reorienting dairy programs and development priorities (Dries and Swinnen 2004; Faye and Konuspayeva 2012).

Milk has certain features that distinguish it from other agricultural products and shape its production, processing and trade. In contrast to grains, milk is a bulky and heavy commodity requiring high-cost storage and transportation as it spoils quickly without cooling (Knips 2005). The production and consumption of milk as a food product is a chain of interrelated and interdependent stages of the overall process, the course of which depends on the state of the milk market, which is part of the agricultural market (Bourlakis et al. 2014; Landes et al. 2017; Kumar et al. 2019). Strategies for sustainable rural development focus on value chain creation by establishing and constantly searching for transparency, using tools such as traceability systems to establish trust and, ultimately, consumer willingness to pay for products of a higher added value. Despite various attempts to define what sustainability means, the concept is still imprecise in its definition (Luhmann, Schaper, and Theuvsen 2016). Today, the market for milk and dairy products is one of the largest food markets because it is quite large and active, has strong trends, and significantly affects other food markets (Dawson and Hubbard 1987; Serra and Goodwin 2003; Bouamra-Mechemache, Jongeneel, and Réquillart 2008; Hill 2017).

The composition of dairy product consumption varies across different regions, with liquid milk being the overall most important product by volume. However, processed dairy products have become more important with increasing incomes and living standards. In developed countries, there is a growing trend for high-value functional foods that require considerable research investments and sophisticated processing (Knips 2005).

The global increase in milk sales is associated with the growth in the world's population, as well as economic development, overall human well-being, and climate change (Guzmán-Luna et al. 2021). At the same time, the milk market has undergone significant trans-

formations in recent years, taking place against the background of changing consumer preferences and the elimination of global demographic balance (Blasko 2011; Gerosa and Skoet 2012). However, while milk sales are growing in developing countries, they are declining in developed countries (Duncan et al. 2013).

According to the latest outlook from the OECD-FAO, in the ten years between 2019 and 2028, global consumption of fresh and processed dairy products is expected to increase by 2.1% and 1.5% a year, respectively (Rusk 2019). Population growth in developing countries, together with the gradual economic development that has taken place, has forced milk producers to pay close attention to these markets (Delgado 2003). At the same time, in developed countries, the opposite effect is seen. There are declines in sales amid the widespread popularization of the idea of diet and healthy eating, which sees some people giving up milk and dairy products due to the presence of sugar in their ingredients (Armstrong et al. 2005; Pothoulaki and Chryssochoidis 2009; Sääksjärvi, Holmlund, and Tanskanen 2009; Nolan-Clark et al. 2011; Grout et al. 2020).

Factors in the growth in demand for milk and dairy products include population growth in the world, urbanization, increasing incomes in developing countries, and a high share of young people, among others. These demand factors will continue over the next 10–20 years. It will increase the demand for dairy products and, therefore, result in large volumes of milk being produced. This production, in turn, depends on two main factors: the number of cows and their productivity.

Prices for milk and dairy products on the world market, as well as any other product market under normal circumstances, are usually determined by domestic prices of major exporting countries, which, in turn, depend on production costs, government support for exports, and the season of the year (Cox and Chavas 2001). Thus, the market for milk and dairy products is a complex interconnected system of national markets in different stages of formation. At present, the way it functions is complicated by factors related to lower prices and intensified competition between exporters of dairy products.

The EU is a major producer of milk and dairy products, and they are integrated into a single market organization. Milk is produced in all EU countries and accounts for 12% of total agricultural output, estimated at around 155 million tonnes per year. The main producers are Germany, France, Poland, the Netherlands, Italy and Spain, which account for almost 70% of the production. While milk is produced in all member states, farm and herd sizes, yields, and types of farming vary widely across Europe, from free-range farming in Alpine areas to large specialised dairy farms in the northwest and centre of Europe (Augère-Granier 2018). The number of dairy cattle in the EU has been declining in recent years, as milk yield per cow has increased.

.As the dairy sector develops across the EU, differences in productivity, as well as technical factors, have diminished – less developed dairy producers are rapidly catching up

with those who were the first to restructure and modernize (Pappa, Illiopoulos, and Massouras 2019).

The EU is a major exporter of dairy products and the world's largest exporter of cheese and SMP. Exports of dairy products under certain quotas opened by third countries are carried out based on an export license issued. The European dairy industry processes about 135 million tons of raw milk into a wide range of products for both consumption and use in the production of many foods, feeds and pharmaceuticals. The dairy industry accounts for about 15% of the food industry in Europe (and about 13% of the total EU workforce). Various dairy products produced by the European dairy industry, such as liquid milk, cheese, fresh dairy products and butter, are an important contribution to the diet of EU consumers (Eurostat 2001b).

Part of the common agricultural policy, the EU's dairy policy consists of a range of instruments designed to support farmers and address market imbalances. In particular, it includes common market organisation, public intervention and private storage provisions, direct payments and rural development measures (Augère-Granier 2018). The growth of the world's population, as well as the popularity of dairy products, will be the main factors that will contribute to the export of dairy products from the EU–27 and maintain commodity prices. Cheese and skimmed milk powder will show the best export performance.

The study revealed a number of global trends in the dairy industry, such as the demand for dairy ingredients has higher growth compared to the demand for standard dairy products; in most countries, including the EU, profits from milk production do not exceed costs; the tendency to increase the demand for "non-dairy" products based on plant substitutes has led to the introduction of large enterprises that produces these lines of products. Some specific trends have also been identified. In particular, China's policy is aimed at increasing imports of the dairy industry, although the increase in national production is insignificant.

The largest producer of milk and dairy products in the EU is Germany, where the number of dairy herds exceeds 4 million cows. In terms of gross milk production, Germany ranks fifth in the world. It has 2% of the world's dairy cows and provides 5% of the world's milk. Germany's share of EU milk production is 20%. On average, there are 55.5 cows per farm in the country. Almost 70% of the dairy herd is represented by purebred breeds; the average annual yield per cow is 7352 kg (Eurostat 2001b).

The dairy industry accounts for a significant share of the total output of most countries. The last few years have seen an increase in milk production every year, despite the restraining policies of some countries in this direction. The trend of the world milk market will continue to grow. However, global trends in international trade in dairy products include a decrease in the number of large ex-

porters with an increase in the number of importing countries, as well as an increase in freshly exported products. EU policies on milk and dairy products, as in the United States, are aimed at balancing the interests of commodity producers and supporting exports.

The study of the experience of the dairy sector in developed countries allows us to identify the main development factors, which are expressed in the implementation of a comprehensive agricultural policy. It aims to consolidate dairy corporations through the pooling of assets and the acquisition of shares; improving the production, organizational and economic infrastructure of the milk and dairy products market; ensuring the balance of interests of the subjects of the dairy sector, i.e., milk producers, milk processors, trade, and consumers; introducing innovative technologies for dairy farms; providing marketing support and providing support for the organic dairy market.

In the coming years, growing EU and global demand are expected to support world dairy markets without hindering price fluctuations and market imbalances. Resilience and sustainability are keywords for the future of the sector. They can be achieved with innovation as a way to reconcile the need for farmers to earn a decent living, consumer demand for affordable and quality dairy products, and environmental/animal health requirements (Augère-Granier 2018). The EU dairy sector is characterised by unique market conditions, with a record gap between very high butter prices and prices at the level of interventions for skimmed milk powder. High demand for cheese, butter, cream and powders supports the price of milk.

The EU produces an average of about 164 million tonnes of milk annually, of which 153 million tonnes are supplied to milk processing plants. Until 2015, milk production in the EU was regulated by quotas. However, after renouncing the quotas, they returned to them, but in a different, voluntary form (Eurostat 2001b).

In 2020, EU farms produced 160.1 million tons of raw milk, which is 1.1% more than in 2019. It is estimated that 149.9 million tons were used by dairies together with skimmed milk to produce a variety of dairy products, as well as fresh products (Eurostat 2001b). Among other products, dairies produced 1.6 million tons of skimmed milk powder, 2.3 million tons of butter, 7.7 million tons of fermented milk products, such as yoghurt, 10.3 million tons of cheese, 24.0 million tons of drinking milk and by-product cheese production, 55.5 million tons of whey in 2020. EU dairy companies produced more of these products in 2020 than in 2019, and, with the exception of fresh products, more than in 2018. In 2020, 1.7% more butter was produced than in 2019, 2.6% more fresh drinking milk, and 3.0% more cheese (Eurostat 2001b).

Top dairy producers in the EU in 2020 (Figures 2–5).

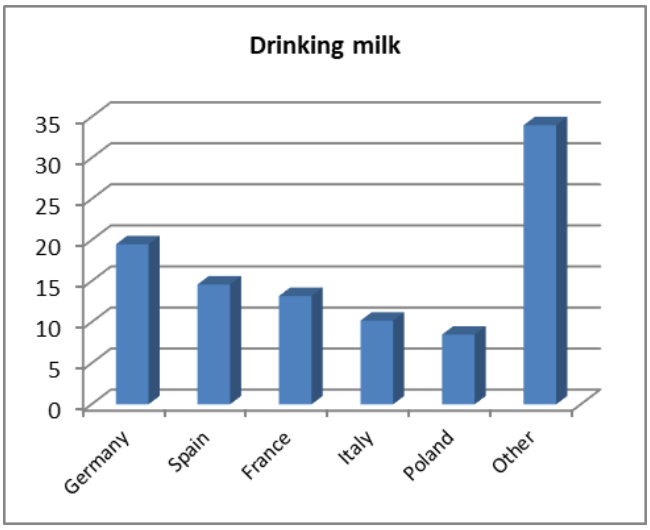

Figure 2. Producers of drinking milk in the EU, 2020

Source: Eurostat (2021a).

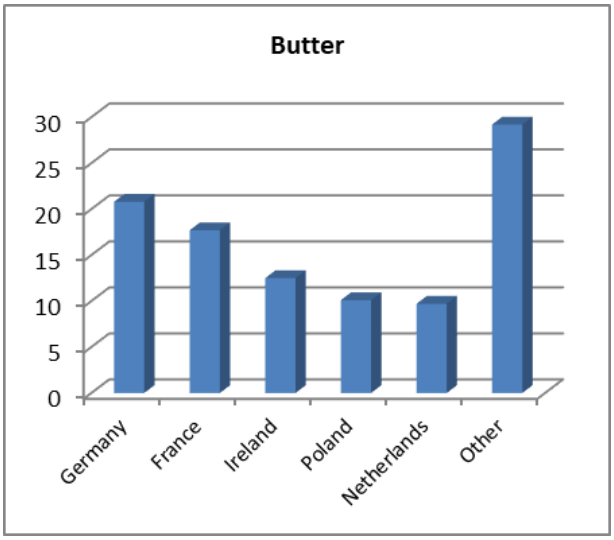

Figure 3. Producers of butter in the EU, 2020

Source: Eurostat (2021a).

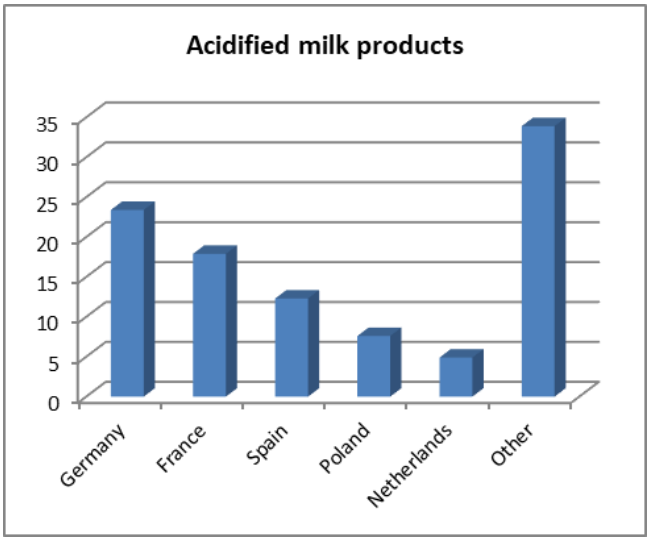

Figure 4. Producers of acidified milk products in the EU, 2020

Source: Eurostat (2021a).

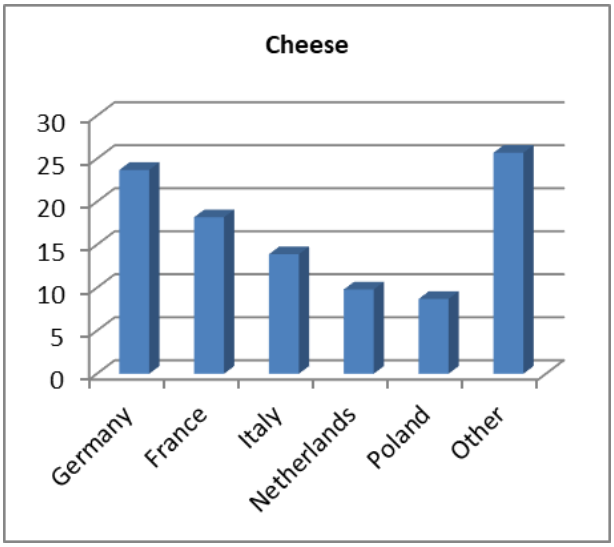

Figure 5. Producers of cheese in the EU, 2020

Source: Eurostat (2021a).

German dairies account for the highest share of EU production of all major fresh and manufactured dairy products, including drinking milk (19.3%), butter (21.0%), cheese (22.9%) and fermented milk products (23.7%) (Eurostat 2001b). The highest levels of dairy production were recorded in the most densely populated EU member states, although there were some exceptions. For example, Ireland ranks third in the amount of butter produced (12.4%), and the Netherlands is in fourth place in terms of cheese (9.7%) (Eurostat 2001b).

With the help of multiple correlation analysis, it is advisable to study the quantitative impact of factors on the results and establish the level of dependence of the per-

formance indicator on each factor. The analysis was conducted on the indicators of 28 countries of the EU between 2004 and 2020. As the effective indicator *Y*, we choose "Products obtained", and as factors that influence the effective indicator, we chose factors x_1, x_2 and x_3 – "Population", "EXPORTS of Dairy Products to Third countries", and "IMPORTS of Dairy Products from Third countries", respectively (Annex).

We assume that the relationship between factor indicators and performance is straightforward. To write such dependencies, one can use a linear function such as:

$$Yx = a_0 + a_1x_1 + a_2x_2 + ... + anxn.$$

The construction of the regression equation was carried out for each study country separately. All calculations below use the population of each of the 28 countries of the EU from 2004–2020.

As a result of the calculations, it was concluded that factor X_3 should be removed from the equation (IMPORTS of Dairy Products from Third countries), which indicates that there is no close relationship between factors X_1 and X_3, i.e. these factors are non-multicollinear.

Next, we built a standardised model without taking into account the removed factor X_3. To be sure of the reliability of the connection equation and the expediency of its use for practical purposes, it is necessary to give a statistical assessment of the reliability of the connection. To do this, in addition to the coefficients of multiple correlation and determination (R^2 = 73% – 83% range for the 28 countries of the EU), we used Fisher's criterion and the average error of approximation. Analysis of the parameters of the regression equation allows us to conclude about the degree of influence of each of the two factors on the indicator Y – "Products obtained". Studying the impact of milk production, milk exports, and population (growth), and their relationship between 2004 and 2020, allowed us to establish the following findings (Annex).

For example, the analysis of factor X_1 (population growth) by 1% leads to an increase in production in Sweden of 2.78%, in Greece – 2.81%, in Hungary – 2.95%, in Croatia – 2.96%, in Denmark – 3.43%, in Portugal – 3.65%, in Austria – 4.16%, in the Netherlands – 5.42%, in Poland –16.11%, and in Slovakia – 22.17%. Population growth by 1% in some EU countries has a minimum output (< 1.0%): Belgium, Bulgaria, Germany, Estonia, Ireland, France, Lithuania, Romania, Spain and Finland.

The analysis of partial coefficients of elasticity shows that factor X_2 has the greatest impact on the volume of dairy production: an increase in dairy exports by 1% gives an increase in production by 0.01% (Malta), 0.06% (Luxembourg), 0.09% (Croatia), 0.12% (Denmark), 0.16% (Cyprus), 0.19% (Estonia), 0.38% (Latvia), and 0.5% (Lithuania), but

11.83% (Germany). At the same time, an increase in production of more than 2% is observed in the following countries: Poland – 2.72%, Romania – 3.06%, UK – 5.39%, Spain – 6.78%, France – 8.14%, Italy – 8.78%, Germany – 11.83%.

To illustrate the results, we display Y and $Y_{calculation}$ in the form of charts for each EU country and the United Kingdom. The same dynamics were observed in all countries. As a result of the calculations, factor X_3 was excluded from the study of multicollinearity.

Conclusions

In the context of globalization, most countries position themselves as open economies. Their dynamics depend on building effective foreign economic relations between firms. Exports in an open economy are a tool to expand the market space for industries and manufacturers ready for intense international competition. In today's international trade relations, export-oriented firms and industries, by saturating domestic markets and filling certain segments of foreign markets, have the opportunity to compete not only through factors of intensive use but also through cost reductions due to scale, i.e. exports are a tool for efficiency economy and integration into the global food sector. As a result, both firms and national economies receive a growing economic effect.

The EU is a large consumer market with more than 450 million inhabitants, and it is characterised by effective demand. However, recent intensive migration has contributed to additional demand for food, including dairy products. This provided the basis for building and calculating a dynamic model of dairy production, dairy exports, and coherence with the existing population as the main consumer in the EU–27 and Great Britain between 2004 and 2020.

The models made it possible to analyse the influence of population growth on the increase in production. The dependence and impact of dairy exports on the growth of dairy production in the EU–27 and Great Britain were also studied. The empirical results indicate the unique opportunities for the development of the Czech Republic, the Netherlands and Poland in the indicators of the models. These countries have a rational ratio of the impact of population growth on the increase in dairy production and the optimal impact of dairy exports on the growth of dairy production.

The leaders in the production of drinking milk, butter, acidified milk, and cheese in Europe are Germany, France and Poland. Meanwhile, 8 of the top 10 world exporters of dairy products are in Europe: Germany, the Netherlands, France, Belgium, Italy, Denmark, Poland, and Ireland.

Thus, the world market of milk and dairy products in recent years has significantly expanded and diversified due to growing needs, geographical changes in trade flows, new consumers, and consumers' food preferences. The growth and change in trade in the world dairy market significantly depend on the level of the difference between domestic production of milk and dairy products and demand in individual countries, where there is a deficit against the background of rapid growth in consumption and population growth. The rapid demand for dairy products in countries with milk shortages is forcing exporting countries to re-evaluate and transform the capabilities of international markets. The export potential of the dairy industry is determined by domestic demand, raw materials and production base, market prices and the level of state support for production and export operations.

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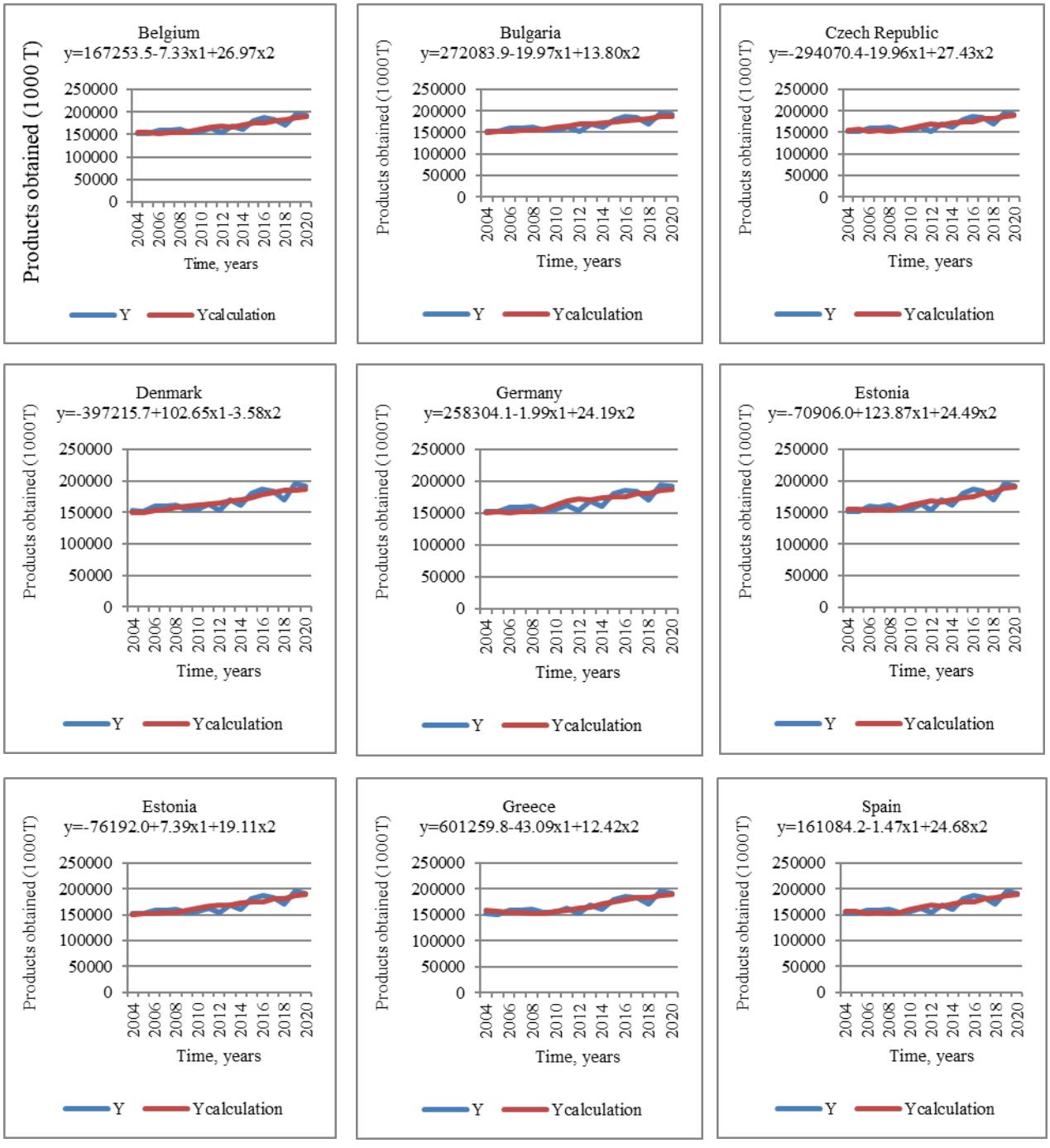
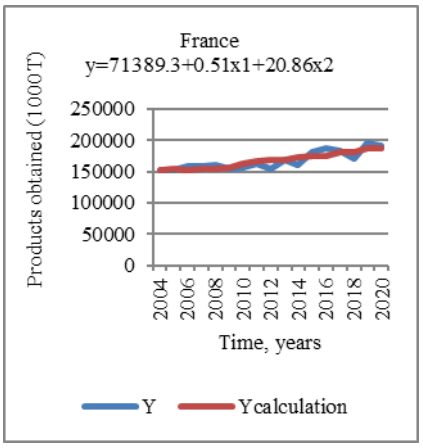
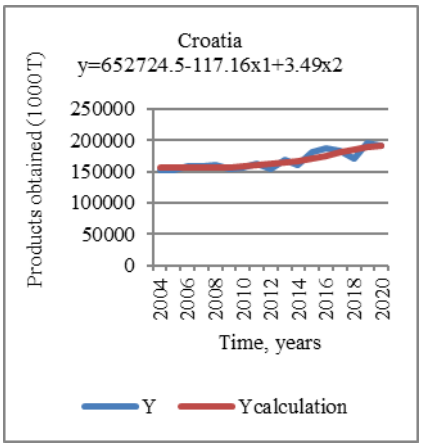
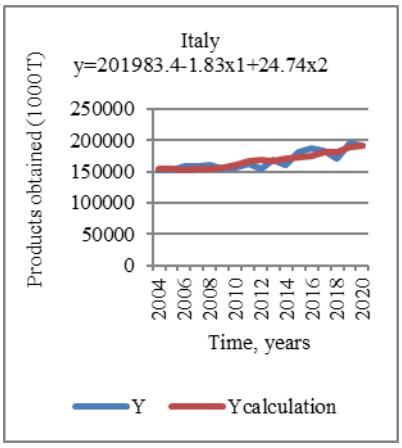
ANNEX

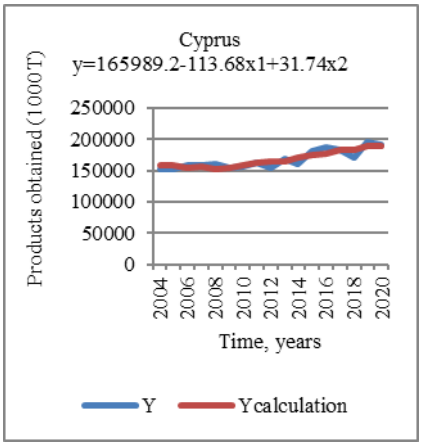
Quantitative impact of factors “Products obtained”, “Exports of Dairy Products”, and “Population” in the dairy industry of the EU–27 and Great Britain

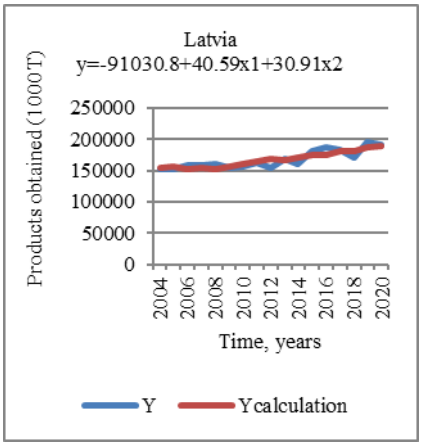


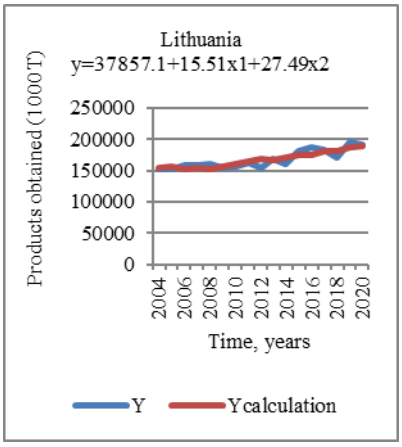

France
y=71389.3+0.51x1+20.86x2
Products obtained (1000T)
250000
200000
150000
100000
50000
0
2004 2006 2008 2010 2012 2014 2016 2018 2020
Time, years
Y
Ycalculation

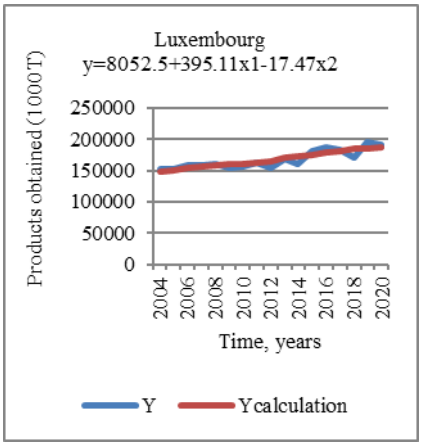

Croatia
y=652724.5-117.16x1+3.49x2
Products obtained (1000T)
250000
200000
150000
100000
50000
0
2004 2006 2008 2010 2012 2014 2016 2018 2020
Time, years
Y
Ycalculation

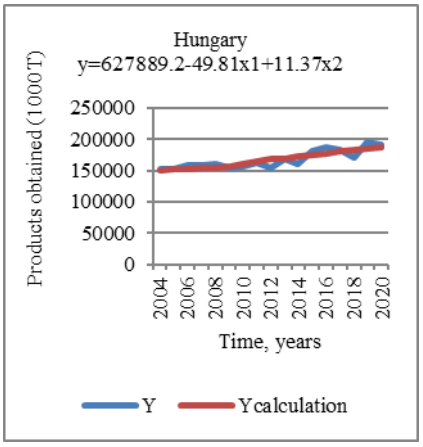

Italy
y=201983.4-1.83x1+24.74x2
Products obtained (1000T)
250000
200000
150000
100000
50000
0
2004 2006 2008 2010 2012 2014 2016 2018 2020
Time, years
Y
Ycalculation

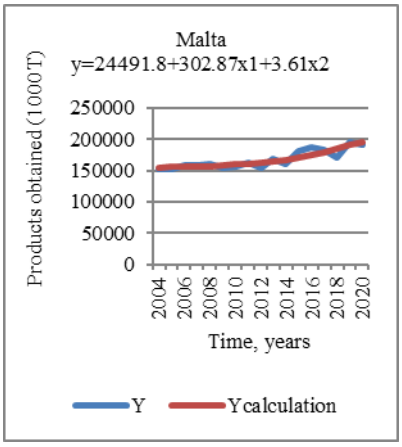

Cyprus
y=165989.2-113.68x1+31.74x2
Products obtained (1000T)
250000
200000
150000
100000
50000
0
2004 2006 2008 2010 2012 2014 2016 2018 2020
Time, years
Y
Ycalculation

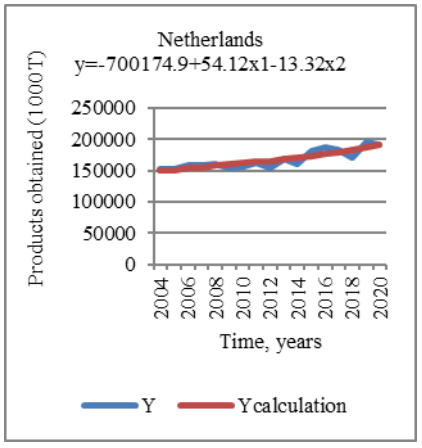

Latvia
y=-91030.8+40.59x1+30.91x2
Products obtained (1000T)
250000
200000
150000
100000
50000
0
2004 2006 2008 2010 2012 2014 2016 2018 2020
Time, years
Y
Ycalculation

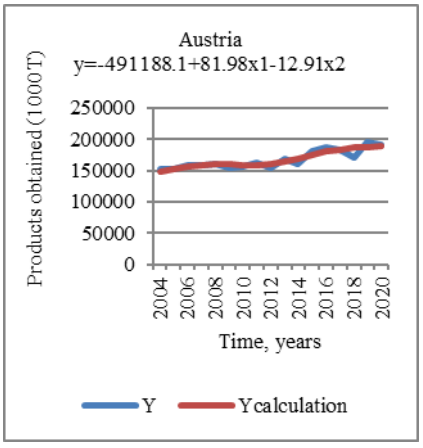

Lithuania
y=37857.1+15.51x1+27.49x2
Products obtained (1000T)
250000
200000
150000
100000
50000
0
2004 2006 2008 2010 2012 2014 2016 2018 2020
Time, years
Y
Ycalculation

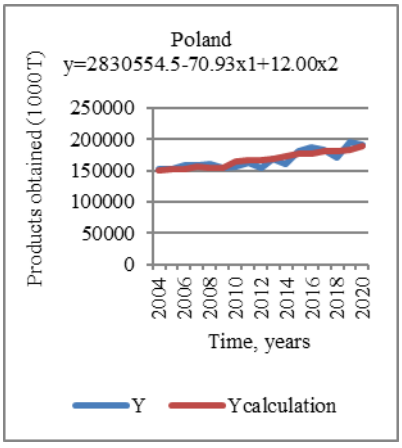

Luxembourg
y=8052.5+395.11x1-17.47x2
Products obtained (1000T)
250000
200000
150000
100000
50000
0
2004 2006 2008 2010 2012 2014 2016 2018 2020
Time, years
Y
Ycalculation

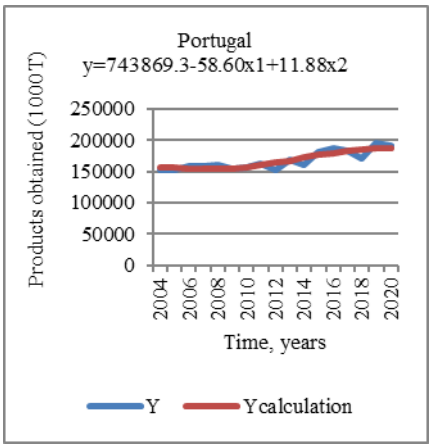

Hungary
y=627889.2-49.81x1+11.37x2
Products obtained (1000T)
250000
200000
150000
100000
50000
0
2004 2006 2008 2010 2012 2014 2016 2018 2020
Time, years
Y
Ycalculation

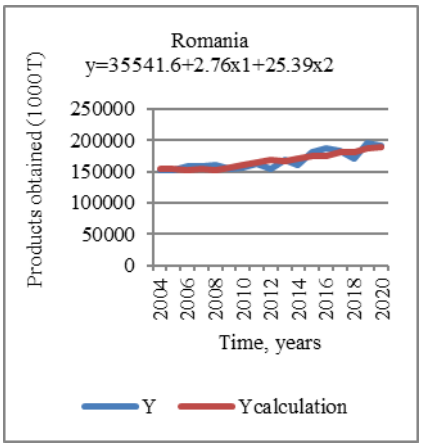

Malta
y=24491.8+302.87x1+3.61x2
Products obtained (1000T)
250000
200000
150000
100000
50000
0
2004 2006 2008 2010 2012 2014 2016 2018 2020
Time, years
Y
Ycalculation

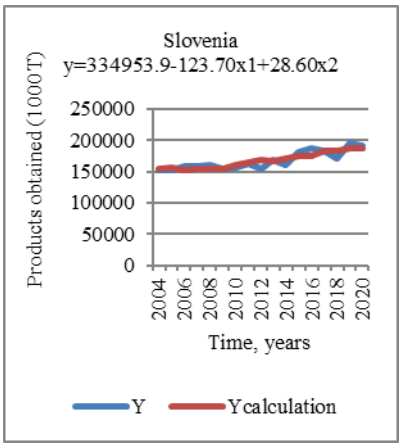

Netherlands
y=-700174.9+54.12x1-13.32x2
Products obtained (1000T)
250000
200000
150000
100000
50000
0
2004 2006 2008 2010 2012 2014 2016 2018 2020
Time, years
Y
Ycalculation

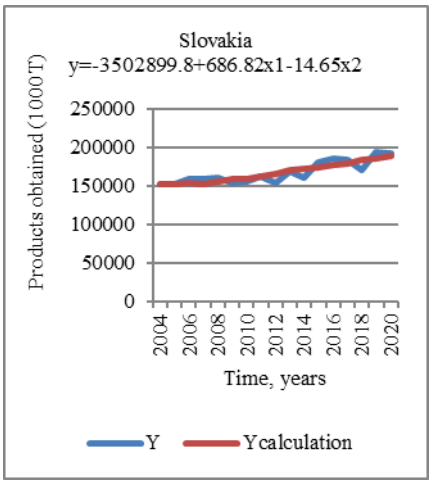

Austria
y=-491188.1+81.98x1-12.91x2
Products obtained (1000T)
250000
200000
150000
100000
50000
0
2004 2006 2008 2010 2012 2014 2016 2018 2020
Time, years
Y
Ycalculation

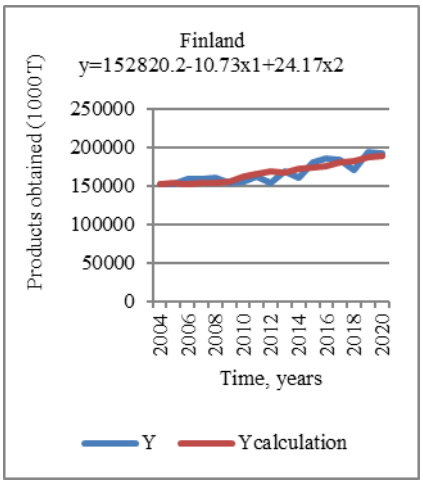

Poland
y=2830554.5-70.93x1+12.00x2
Products obtained (1000T)
250000
200000
150000
100000
50000
0
2004 2006 2008 2010 2012 2014 2016 2018 2020
Time, years
Y
Ycalculation

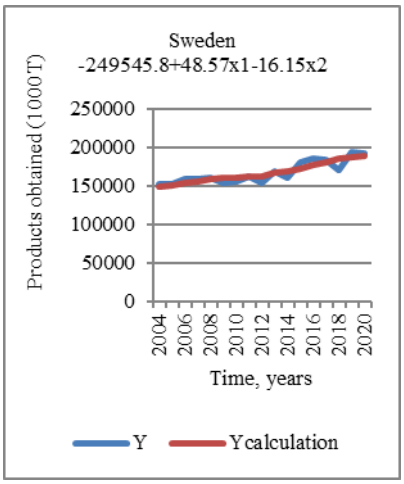


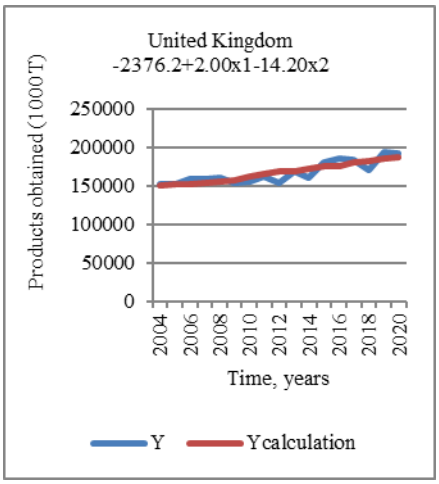












Soures: authors' calculations based on Eurostat.

Konwergencja czynników wpływających na rynek produktów mleczarskich: analiza porównawcza krajów Unii Europejskiej

Unia Europejska jest dużym producentem mleka i przetworów mlecznych, a jednocześnie znaczącym rynkiem konsumpcyjnym, który charakteryzuje się efektywnym popytem i znacząco wpływa na rynki innych produktów spożywczych. Głównymi producentami mleka w UE są Niemcy, Francja, Polska, Holandia, Włochy i Hiszpania. Intensywne procesy migracyjne przyczyniają się do dodatkowego popytu na produkty spożywcze, w szczególności produkty mleczne. Dało to podstawę do budowy i kalkulacji modelu dynamicznego produkcji mleczarskiej, eksportu produktów mleczarskich oraz współistnienia z populacją jako głównym konsumentem w krajach UE–27 i Wielkiej Brytanii w latach 2004–2020.
Uzyskane zależności umożliwiły analizę wpływu czynnika wzrostu populacji na wzrost wielkości produkcji. Jednocześnie zbadano zależność i wpływ eksportu produktów mleczarskich na wzrost wielkości produkcji produktów mleczarskich w krajach UE–27 i Wielkiej Brytanii.
Wyniki przeprowadzonego modelowania matematycznego wskazują na unikalne możliwości rozwoju sektora mleczarskiego poszczególnych krajów UE–27: Czech, Holandii, Polski. Kraje te mają racjonalny stosunek wpływu czynnika wzrostu liczby ludności na wzrost wolumenu produkcji mleczarskiej oraz optymalny wpływ eksportu produktów mleczarskich na wzrost wolumenu produkcji mleczarskiej.

Słowa kluczowe: mleko, produkty mleczarskie, Unia Europejska, producenci mleka, ludność, popyt, podaż

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The Day-of-the-Week Anomaly in Light of the COVID–19 Pandemic on an Example of Selected OMX Indices

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Abstract

This paper analyzes market efficiency (EMH) with the day-of-the-week effect and the changes that might appear after the outbreak of the COVID–19 pandemic, based on the example of the OMX Exchange and its indices. Before the pandemic, only the OMX Baltic All-share index was efficient; during the COVID–19 pandemic, the OMXCPI Index, which represents the Copenhagen stock market, was not affected by the day-of-the-week anomaly. The change in market efficiency was observed in relation to the periods before and during the pandemic, and additionally between specific days of the week. The value added of this paper is related to the evidence that COVID–19 influenced market efficiency but not the quality of trading.

Keywords: COVID–19, market efficiency, day-of-the-week anomaly

JEL: G10, G12, G14

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Introduction

The COVID–19 outbreak was a shock for markets, and this may have changed the way investors made their decisions in the area of market efficiency described by the Efficient Market Hypothesis (Fama 1960). Evidence of market changes regarding the reaction of prices and investors' decisions has been presented in many studies. To the existing literature, this paper adds an analysis of OMX (Open Mobile Exchange) market efficiency and the possible change in this efficiency during the COVID–19 pandemic regarding the day-of-the-week anomaly.

The objective of this study is to test the market efficiency before and during COVID–19. The authors hypothesize that the markets were efficient and that the COVID–19 pandemic affected their efficiency. The value added of this paper is that it enriches the relevant literature on market efficiency in relation to a pandemic, which is a health crisis and in comparison to not a financial one. So, the results of this study will show evidence that COVID–19 influenced the market efficiency of the selected OMX markets. An additional uniqueness of our paper is the investigation of the OMX markets, which also enriches the literature for academics. The results will also be of interest to investors and practitioners since they can see how a health crisis affects their investment decisions, and they can take precautions in a future similar situation.

OLS panel data regression models with fixed effects were tested to detect the differences between two periods: pre-COVID–19 and the time of the pandemic. Due to technical limitations related to the fixed effects analysis, only some of the OMX markets were considered: the Estonian OMXTGI, the Latvian OMXRGI, and the Lithuanian OMXVGI. Additionally, the OMX BGI – the OMX Baltic All-share index – which comprises selected equity securities listed on each of the Nasdaq Baltic Exchanges (AB Nasdaq Vilnius, Nasdaq Riga, AS, Nasdaq Tallinn AS), are examined. The Scandinavian group comprises the indices from Denmark, Iceland, and Norway. The OMXCPI Index is the OMX Copenhagen stock market index for the Copenhagen Stock Exchange, the OMXIPI is the OMX Iceland All-Share Index, which includes all the shares listed on the OMX Nordic Exchange Iceland, and the OSEAX index is the Oslo Børs All Share Index, which comprises all shares listed on the Norwegian market.

The paper is composed of several sections. The next section is the literature review. The third section presents the data description, the testable hypotheses, and the methodology. The fourth section presents and analyzes the results, and the final section offers conclusions and future research directions.

Review of the literature

The investigation of many markets and their reaction to the COVID–19 pandemic around the world have been presented in a great number of papers. Ngwakwe (2020, pp. 255–269) analyzed the global stock markets and found that the indices he considered reacted differently, and there was a change in their behavior before and during the COVID–19 pandemic. Ashraf (2020b) found that overall, stock markets reacted negatively to the COVID–19 outbreak. However, this reaction was only significant for the growth in COVID–19 cases but not for the growth in deaths. Narayan, Devpura, and Wang (2020) analyzed the Japanese market, and they found significant differences in the market between the periods before and after the critical day that the COVID–19 pandemic was announced. Yilmazkuday (2020) found that the negative effects of COVID–19 cases in the U.S. on the S&P 500 Index were mostly observed during March 2020. The critical period after the outbreak of the pandemic was strongly affected by uncertainty and the worst scenarios that were taken into consideration by market participants.

The papers related to the COVID–19 issue cover topics such as government actions that influenced or not the market rates of return. For example, based on the analysis of 20 markets around the world, Chang, Feng, and Zheng (2021, pp. 1–18) found that the stock market did not react significantly to government interventions in the health system. The response to the market was also analyzed by Liu et al. (2020), who found that countries in Asia experienced more negative abnormal returns than other countries on other continents.

Bash (2020, pp. 34–38) analyzed the effect of the first registered case of COVID–19 on stock market returns using event study analysis for 30 countries. He found that stock market returns experienced a downward trend and that significant negative returns following the COVID–19 outbreak. Ashraf (2020a) analyzed stock market returns from 77 countries and found that social distancing measures imposed by governments had a direct negative effect on stock market returns due to their adverse effect on economic activity. They also found an indirect positive effect by reducing confirmed COVID–19 cases. Chundakkadan and Nedumparambil (2021) found that the Google Search Volume Index related to the volume of the pandemic was associated negatively with daily returns. They also found that the COVID–19 sentiment generated excess volatility in the market. Other studies reported that stock markets reacted to the COVID–19 pandemic with strong negative returns (Al-Awadhi et al. 2020; Ashraf 2020b; Baker et al. 2020, pp. 742–758).

Many findings related to market volatility suggest a change in behavioral patterns. Apergis and Apergis (2020, pp. 1–9) found a significant negative effect of the COVID–19 pandemic on Chinese stock returns. They also found that the daily increases in COVID–19 cases and deaths increased market volatility due to investors' fear and uncertainty. Zhang, Hu, and Ji (2020) analyzed the volatility of the top 10 mar-

kets around the world regarding the number of cases and found that the risk levels of all the countries increased substantially. Engelhardt et al. (2021) investigated if trust affected global stock market volatility during the COVID–19 pandemic based on a sample of 47 national stock markets. He found that stock market volatility was significantly lower in high-trust countries' reactions to COVID–19 case announcements. Other papers on stock returns and volatility for global markets regarding the COVID–19 crisis were presented by Ali, Alam, and Rizvi (2020), Gil-Alana and Claudio-Quiroga (2020, pp. 19–22), Haroon and Rizvi (2020), Prabheesh (2020), Salisu and Akanni (2020), Salisu and Sikiru (2020).

This paper compares developed and developing markets, including OMX. These markets became highly volatile and unpredictable during the COVID–19 pandemic. Li and Zhong (2020) explored the effect of global economic policy uncertainty shocks on China's financial conditions index. They found that the uncertainty shocks emanating from China itself were the major sources of China's financial market volatility. The US market reaction appeared to be the most significant exogenous cause of the fall in the financial conditions index in China.

Narayan, Devpura, and Wang (2020, pp. 191–198) found that COVID–19 had a heterogeneous effect on sectors of the Australian exchange, with health, information technology, and consumer staples sectors gaining. Yarovaya et al. (2020) investigated the contagion phenomenon in light of COVID–19, considering it a "black swan" event. Aslam, Mohti, and Ferreira (2020) stated that the COVID–19 outbreak became one of the biggest threats to the global economy and financial markets. Therefore, they analyzed the effects of COVID–19 on 56 global stock indices using a complex network method. The findings revealed a structural change in the topological characteristics of the network.

A contagion effect was also identified in the network structure of emerging markets, and the number of positive correlations in the global stock indices increased during the outbreak. Contessi and De Pace (2021) identified periods of mildly explosive dynamics and collapses in the stock markets of 18 major economies during the first wave of the COVID–19 pandemic in 2020. They also found statistical evidence of instability transmission from the Chinese stock market to all other markets. The recovery, on the other hand, was heterogeneous and generally non-explosive.

Ashraf (2020c) reported that stock markets around the world reacted to the COVID–19 pandemic with negative returns, but this reaction was not uniform across countries. Their explanation was the national level of uncertainty avoidance, which determines how sensitive the members of a nation are to uncertainty and moderates the stock markets' reaction to the pandemic.

Seven and Yilmaz (2021) found that following the spread of the COVID–19 pandemic, most global equity market indices experienced significant falls, and many governments

announced unprecedented economic rescue packages. However, the recovery performance varied significantly across countries. Cao et al. (2020, pp. 1–5) analyzed 14 indices affected by COVID–19. They found that markets would likely recover in respnse to improved survival of COVID–19 patients, the natural development of herd immunity, and the projected success in vaccine development in the next 18 months. Goodell (2020) suggested that the COVID–19 pandemic might have a significant impact on the functioning of the financial sector and is a promising research domain.

The COVID–19 impact on the OMX market was examined by Ashraf (2020a; 2020b; 2020c), Aslam et al. (2020), Bash (2020, pp. 34–38), Pardal et al. (2020, pp. 627–650), Chundakkadan and Nedumparambil (2021), Contessi and De Pace (2021), and Yang and Deng (2021), but not in terms of the day-of-the-week anomaly or market efficiency compared to the pre-COVID–19 period.

There are many findings of the day-of-the-week effect on the OMX markets before COVID–19. For instance, Zhang, Lai, and Lin (2017, pp. 47–62) investigated the day-of-the-week anomalies in stock returns of the main indices in 28 markets from 25 countries using the calendar effect performance ratio to measure the significance of the day-of-the-week anomalies. The stock markets of Estonia, Latvia, and Lithuania are small, younger, and developing, which implies that there will be inefficiencies compared to more mature and developed stock markets, such as the Scandinavian markets. The weak form efficiency for Latvia and Lithuania was examined by Kvedaras and Basderant (2002), Mihailov and Linowski (2002), and Milieska (2004), but only Milieska showed that these Baltic markets were weak form efficient. Furthermore, Kiete and Uloza (2005) tested for the semi-strong form efficiency in the Lithuanian and Latvian stock markets by examining their reaction to earnings announcements from 2001 to 2004. They found that both markets were inefficient regarding earnings announcements, implying that brokers and investors could find several investment opportunities.

Some other studies found no day-of-the-week effect, since the returns on each weekday were not statistically different or significant. Lyroudi, Patev, and Kanaryan (2003) examined the day-of-the-week effect anomaly for the markets of Romania, Hungary, Latvia, the Czech Republic, Russia, Slovakia, Slovenia and Poland for 1997 to 2002. It was not present for the Latvian market. Only the Slovak market had significant negative Wednesday returns, while the Russian market had significant negative Wednesday returns and positive Friday returns. The Slovenian markets had significant positive Thursday and Friday returns. No day-of-the-week anomaly was found by Chukwuogor-Ndu (2006, pp. 112–124) for the markets of Switzerland and Denmark; by Apolinario et al. (2006) for 1997 to 2004 for Austria, Belgium, the Czech Republic, Denmark, France, Germany, Holland, Italy, Portugal, Spain, Sweden, and Switzerland; by Lyroudi (2007) for 2004 to 2007 for the Baltic markets comprising the OMX Bal-

tic all share index; by Borges (2009) for 1994 to 2007 for Austria, Denmark, France, Hungary, Italy, Poland, Portugal, Spain, Switzerland, and the United Kingdom.

Another day-of-the-week phenomenon is when we observe positive Monday returns – "the reverse Monday effect". Brusa and Liu (2004, pp. 19–30) tried to explain the "reserve" Monday effect in the USA stock markets between 1988 and 1998. They found a positive link between the trading activities of institutional investors and positive Monday returns because the former provided excess liquidity to the market. For the period 2006 to January 2019 for the Swedish stock market, Sandahl (2019) found a reverse Monday effect (positive Monday returns) and positive Thursday returns for small-capitalization stocks. He also found positive Wednesday, Thursday, and Friday returns for mid-capitalization stocks, while for large-capitalization stocks, there was no day-of-the-week anomaly.

For the Eastern European countries of Croatia, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Russia, Slovakia and Slovenia between 1994 or 1999 to 2002, Ajayi, Mehdian, and Perry (2004, pp. 53–62) found significant negative Monday returns for the Estonian and Lithuanian markets. Additionally, there was a reverse Monday effect for the Russian market, negative Tuesday returns for the Lithuanian market, and positive Friday returns for the Slovenian market.

For Lithuania, Mexico, Estonia, Indonesia, Malaysia, Slovenia, Thailand, and Turkey, Yalcin and Yucel (2006, pp. 258–279) observed negative Monday returns. Lithuania, Mexico, India, and South Korea had the highest Wednesday positive returns, while Estonia, the Czech Republic and Hungary had the highest positive Thursday returns. Thus, the phenomenon varies across countries. Borges (2009) found positive Friday returns in Greece, Iceland, Ireland and Norway, positive Tuesday returns in Germany, and negative Monday returns in Iceland between 1994 and 2007.

For the former East European Post-Communist stock markets of Bosnia, Bulgaria, Croatia, Czech Republic, Estonia, Hungary, Kazakhstan, Latvia, Lithuania, Montenegro, Poland, Romania, Russia, Serbia, Slovakia, Slovenia, and Ukraine from January 2005 to March 2014, Oprea and Ţilica (2014, pp. 119–129) found that most had no significant day-of-the-week effect. Only Bosnia, Croatia and Latvia had significant negative Friday average returns, while Bulgaria, Serbia and Slovenia had significant negative Monday average returns. Slovenia was the only one that had significant positive Thursday returns.

For the period 1999 to 2013, Cinko et al. (2015, pp. 96–108) found a significant positive Thursday effect for Norway and significant positive returns on Fridays for Denmark, Finland, and Norway.

Data, methodology, and testable hypothese

To achieve the objective of this study, closing prices of the OMX Indices were used to calculate the daily returns. The data used in the present study were collected from the EIKON Thomson database for the period after the economic crisis of 2008, from January 1st, 2009, to February 15th 2021. The entire research period was divided into two sub-periods:

- 1st period – pre-COVID, from January 2009 to January 2020.
- 2nd period – during the COVID pandemic, from February 2020 to February 2021.

The Baltic markets examined are the Estonian stock exchange in Tallinn, represented by the OMXTGI, the Latvian stock exchange in Riga, represented by the OMXRGI, and the Lithuanian stock exchange in Vilnius, represented by the OMXVGI. There is also the OMX BGI index – the OMX Baltic All-share index – which comprises selections of equity securities listed on each of the Nasdaq Baltic Exchanges.

The Nordic group comprises the Scandinavian markets, Denmark, Iceland and Norway, represented by the equivalent indices.

To test the hypothesis for the presence of the day-of-the-week effect in each of the OMX stock markets, we used the following regression model:

$$R_t = \propto_1 Mon_t + \propto_2 Tues_t + \propto_3 Wed_t + \propto_4 Thu_t + \propto_5 Fri_t + \varepsilon_t, \quad (1)$$

where:
Rt – index return on day *t*;
Mont – dummy variable equal to 1 if *t* is a Monday and 0 otherwise;
Tuest – dummy variable equal to 1 if *t* is a Tuesday and 0 otherwise;
Wedt – dummy variable equal to 1 if *t* is a Wednesday and 0 otherwise;
Thut – dummy variable equal to 1 if *t* is a Thursday and 0 otherwise;
Frit – dummy variable equal to 1 if *t* is a Friday and 0 otherwise;
et – error term.

The coefficients of the above regression equation (a_1, a_2, a_3, a_4, a_5) are the average returns for Monday through Friday. The OLS heteroskedasticity corrected panel data method was run with dummy variables for each day of the week. Tests for the presence of fixed and random effects were also carried out (the Wald Test for redundant fixed effects, and the Breusch-Pagan Test for random effects).

Based on the research question of whether the COVID–19 pandemic had any impact on the day-of-the-week anomaly in the Baltic and Scandinavian markets, the following hypotheses were formulated:

H_1: The surveyed markets are efficient;

H2: The market efficiency of the surveyed indices was affected by the COVID–19 pandemic.

Results and analysis

First, information about the tested groups is provided. The statistics for the indices before and during the COVID–19 pandemic are presented in Table 1.

Table 1. Statistics of the samples

	pre-COVID–19 period			COVID–19 period		
	Number of observations	Mean returns	Standard deviation	Number of observations	Mean returns	Standard deviation
OMXTGI. OMX TALLINN – Estonia	2776	0.0006	0.009463	258	0.0004	0.012807
OMXRGI. OMX RIGA – Latvia	2776	0.0005	0.012448	258	0.0005	0.015723
OMXVGI. OMX VILNIUS – Lithuania	2776	0.0005	0.008687	258	0.0598	1.064850
OMX BGI BALTIC COUNTRIES	8328	0.0005	0.010326	776	0.0005	0.013152
OMXCPI – COPENHAGEN – Denmark	6023	0.0004	0.010654	260	0.0010	0.013617
OMXIPI – OMX all share REYKJAVIK – Iceland	6732	0.0003	0.012496	259	0.0015	0.014045
OSEAX – OSLO Bors all-share – Norway	9305	0.0005	0.012786	264	0.0004	0.017313

Source: own study.

Based on the data in Table 1, it can be concluded that positive average rates of return were observed for all indices, both before and during the COVID–19 pandemic. The indices related to the Scandinavian countries were characterized by higher average rates of return than those in the Baltic countries, both before and during the pandemic. The volatility of the analyzed rates of return, measured by the standard deviation, was also higher in the Scandinavian countries. There is one exception, however. The Lithuanian market, the OMXVGI Index, was characterized by the highest average rate of return during the pandemic but also the highest volatility among all analyzed indices. Before testing the regression models, the Wald test and the Breusch-Pa-

gan test were performed to find fixed and random effects. The results of both tests for the pre-COVID–19 and COVID–19 periods are presented in Tables 2 and 3.

Table 2. The results of tests for the occurrence of fixed and random effects in the pre-COVID-19 period

	The results of the tests for the occurrence of fixed effects with respect to time (Wald test)	Results of tests for the occurrence of random effects with respect to time (Breusch-Pagan test)
OMXTGI. OMX TALLINN – Estonia p-value	634.163 (0.000)	0.0901 (0.7639)
OMXRGI. OMX RIGA – Latvia p-value	14.1236 (0.0008)	0.8471 (0.3573)
OMXVGI. OMX VILNIUS – Lithuania p-value	128.298 (0.000)	0.0131 (0.9089)
BALTIC COUNTRIES p-value	0.7696 (0.0681)	0.5021 (0.5439)
OMXCPI – COPENHAGEN – Denmark p-value	1484.66 (0.000)	0.7804 (0.3770)
OMXIPI – OMX all share REYKJAVIK – Iceland p-value	228.887 (0.000)	1.0710 (0.3007)
OSEAX – OSLO Bors all share – Norway p-value	63.6024 (0.000)	0.0791 (0.7784)

For p-value < 0.05, the Wald test indicates the presence of fixed effects; for p-value < 0.05, the Breusch-Pagan test indicates the presence of random effects
Source: own study.

Table 3. The results of tests for the occurrence of fixed and random effects in the COVID-19 period

	The results of the tests for the occurrence of fixed effects with respect to time (Wald test)	Results of tests for the occurrence of random effects with respect to time (Breusch-Pagan test)
OMXTGI. OMX TALLINN – Estonia p-value	1408.24 (0.000)	7.9631 (0.477)
OMXRGI. OMX RIGA – Latvia p-value	1722.55 (0.000)	0.2351 (0.6277)
OMXVGI. OMX VILNIUS – Lithuania p-value	1551.56 (0.000)	10.4404 (0.1232)

	The results of the tests for the occurrence of fixed effects with respect to time (Wald test)	Results of tests for the occurrence of random effects with respect to time (Breusch-Pagan test)
BALTIC COUNTRIES p-value	3.2041 (0.3612)	1.4728 (0.2248)
OMXCPI – COPENHAGEN – Denmark p-value	0.9810 (0.000)	0.8431 (0.3584)
OMXIPI – OMX all share REYKJAVIK – Iceland p-value	20.8969 (0.000)	0.0779 (0.7801)
OSEAX – OSLO Bors all share – Norway p-value	314.666 (0.000)	0.2102 (0.6465)

For p-value < 0.05, the Wald test indicates the presence of fixed effects; for p-value < 0.05, the Breusch-Pagan test indicates the presence of random effects
Source: own study.

Based on the results in Tables 2 and 3, it can be concluded that the Wald test indicated the presence of fixed effects in the model for both periods. On the other hand, the results of the Breusch-Pagan test in almost all cases indicated that there were no random effects in the models for both periods. It can be concluded that the effects did not change their pattern in both periods. Moreover, they were not random but related to specific events and companies' behavior. Panel data analysis can confirm both fixed and random effects, but only the OLS regressions with fixed effects are tested in the next step. Before the pandemic, the Baltic Countries Index was characterized by fixed effects on a more liberal level of confidence. During the pandemic, it was difficult to determine which effects dominated. This influenced the regression results later in the analysis.

Therefore, to address hypothesis (H1), we test the parameters of Equation (1) for each market index to investigate if the markets were efficient. These regression results (coefficients, R-squared, t-statistics and F-statistic) are shown in Table 4 for the pre-COVID–19 period and in Table 5 for the COVID–19 period. The regular OLS model with fixed effect was tested. The model specification was also analyzed using the RESET test, which indicates the correctness of the model.

Table 4. OLS regression results with fixed effect – pre-COVID–19 period. Explained variable: Average daily returns

	Sample	Const.	Mon	Tues	Wed	Thu	Fri	R^2 %	F-stat.
OMXTGI. OMX TALLINN – Estonia	2778	–0.0003***	0.00086*	0.00013	0.00157	0.0014***	0.00071	0.3491	0.0931596
OMXRGI. OMX RIGA – Latvia	2778		–0.0101**	–0.0104**	–0.0107**	–0.0097**	–0.0108 *	0.158	0.057298
OMXVGI. OMX VILNIUS – Lithuania	2778	0.00062***	0.0005	0.0008	–0.0005	–0.0004	0.00052	0.2416	0.109013
BALTIC COUNTRIES	8334	0.00381	–0.0031	–0.0035	–0.0033	–0.003	–0.0033	0.0388	0.700184
OMXCPI – COPENHAGEN – Denmark	6023	–0.0017***	0.0016**	0.00191***	0.00251	0.00178**	0.00215	0.0702	0.0145087*
OMXIPI – OMX all share REYKJAVIK – Iceland	6737	0.00101***	–0.0017***	–0.0008**	–0.0003	– 5.45E–05	–0.0003	1.8375	3.13522
OSEAX – OSLO Bors all share – Norway	9305	0.01675***	–0.0168**	–0.0162***	–0.0158**	–0.0166**	–0.0158***	0.2876	0.10991**

Note: */**/*** The coefficients or F-statistic are significant at the 10% / 5% / 1% level.
Source: own study.

Based on Table 4 for Estonia (OMXTGI; OMX TALLINN Index), the estimates of the returns were statistically significant and positive on Mondays and Thursdays for the pre-COVID–19 period. Thus, there was a day-of-the-week effect for this index.

For Latvia (OMXRGI; OMX RIGA Index), the estimates of the returns were negative on all weekdays and statistically significant at the 5% level of a two-tailed t-test for the examined COVID–19 period. Thus, there was a day-of-the-week effect for this index.

For Lithuania (OMXVGI; OMX VILNIUS Index), the estimates of the returns were positive on Mondays and Fridays and negative on Tuesdays, Wednesdays and Thursdays; none of them was statistically significant. Therefore, the day-of-the-week effect anomaly was not present in the stock market of Lithuania for the pre-COVID–19 period.

For all Baltic Countries (OMX BGI Index), the estimates of the returns were negative on all weekdays, but none were statistically significant for the pre-COVID–19 period. Thus, there was no day-of-the-week effect for this index.

For Denmark, the OMXCPI Index was investigated. The estimates of the returns on the OMXCPI Index were positive on all the weekdays. However, only Mondays, Tuesdays and Thursdays were characterized by statistically significant results at the 5% level of a two-tailed t-test for the pre-COVID–19 period, indicating a reverse Monday effect.

For Iceland, the OMXIPI Index was analyzed. The estimates of the average returns were negative on all the weekdays. Only Mondays and Tuesdays were characterized by statistically significant results at the 5% level of a two-tailed t-test for the pre-COVID–19 period.

For Norway, the OSEAX Index was surveyed. The estimates of the returns on the OSEAX Index were negative on all the weekdays. They were statistically significant at the 5% level of a two-tailed t-test on Mondays, Wednesdays and Thursdays and at the 1% level of a two-tailed t-test on Tuesdays and Fridays for the pre-COVID–19 period. Therefore, it can be stated that the day-of-the-week effect anomaly was present in the Norwegian stock market for this index.

Based on the results in Table 4, it can be concluded that the only efficient market without the day-of-the-week effect was the Baltic Countries Index. For the other indices, the day-of-the-week effect was found.

In the next stage, the parameters of Equation 1 were tested to investigate the market efficiency for the COVID–19 period. In this case, the period of one year related to the pandemic from February 2020 to February 2021 was analyzed for all selected indices. Table 5 shows the regression results (coefficients, R-squared, t-statistic and F-statistic) for the analyzed markets during the COVID–19 period.

Table 5. OLS regression results with fixed effect – COVID–19 period. Explained variable: Average daily returns

	Sample	Const.	Mon	Tues	Wed	Thu	Fri	R^2 %	F-stat.
OMXTGI. OMX TALLINN – Estonia	259	–0.001***	0.00508**	0.00108	0.00016	0.00295	–0.0024	10.80	10.0844
OMXRGI. OMX RIGA – Latvia	259	–0.0047***	0.00812***	0.0044***	0.00602***	0.00683***	0.00088***	4.5668	<0.0001***
OMXVGI. OMX VILNIUS – Lithuania	259	0.01569***	–0.0147***	–0.016***	–0.0132***	–0.0143***	–0.0174***	9.6209	4.29171***
BALTIC COUNTRIES	777	–0.0089***	0.01185***	0.00873***	0.01001***	0.01091***	0.00592**	2.4847	10.5239***
OMXCPI – COPENHAGEN – Denmark	261	0.0037***	–0.002	–0.0015	–0.002	–0.0044	–0.0039	10.006	0.177901
OMXIPI – OMX all share REYKJAVIK – Iceland	260	0.01703***	–0.0182	–0.0111	–0.014*	–0.0181*	–0.017**	5.2082	0.315061
OSEAX – OSLO Bors all share – Norway	265	–0.0147***	0.01268**	0.02143***	0.01558***	0.0108***	0.01515***	6.1605	8.80584***

Note: */**/*** The coefficients or F-statistic are significant at the 10% / 5% / 1% level.
Source: own study.

Based on the results in Table 5, for Estonia (OMXTGI. OMX TALLINN Index), the estimates of the returns were statistically significant and positive on Mondays only for the examined COVID–19 period. Thus, there was a day-of-the-week effect for this index.

For Latvia (OMXRGI. OMX RIGA Index), the estimates of the returns were positive on all weekdays and statistically significant at the 1% level of a two-tailed t-test for the COVID–19 period. Thus, there was a day-of-the-week effect for this index.

For Lithuania (OMXVGI. OMX VILNIUS Index), the estimates of the returns were negative on all weekdays and statistically significant at the 1% level of a two-tailed t-test for the COVID–19 period. Thus, there was a day-of-the-week effect for this index.

For all Baltic Countries (OMX BGI Index), the estimates of the returns were positive on all weekdays and statistically significant at the 1% level of a two-tailed t-test for the COVID–19 period. Thus, there was a day-of-the-week effect for this index.

For Denmark, the OMXCPI Index was analyzed. The estimates of the returns were negative on all weekdays, but none of them was statistically significant. Therefore, the day-of-the-week effect anomaly was not found for the COVID–19 period.

For Iceland, the OMXIPI index was analyzed. The estimates of the returns were negative on all the weekdays. They were statistically significant at the 10% level of a two-tailed t-test on Wednesdays and Thursdays and at the 5% level of a two-tailed t-test on Fridays for the COVID–19 period.

For Norway, the OSEAX Index was analyzed. The estimates of the returns on the OSEAX Index were positive on all weekdays and statistically significant at the 1% level of a two-tailed t-test for the COVID–19 period. Thus, there was a day-of-the-week effect for this index during the pandemic.

Based on the results for the COVID–19 period in Table 5, it can be concluded that the Denmark market was efficient, and the day-of-the-week anomaly was not found there during the COVID–19 period.

In the next step, the regression results related to hypothesis (H2) before and during the COVID–19 pandemic periods were compared with the effects that appeared on different weekdays. The results are presented in Table 6.

Table 6. The difference between effects on surveyed markets

	Before COVID–19	COVID–19 period	Result after outbreak
OMXTGI. OMX TALLINN – Estonia			
Monday	+	+	No change
Tuesday	–	–	No change
Wednesday	–	–	No change
Thursday	–	–	No change
Friday	–	–	No change
OMXRGI. OMX RIGA – Latvia			
Monday	+	+	No change
Tuesday	+	+	No change
Wednesday	+	+	No change
Thursday	+	+	No change
Friday	+	+	No change
OMXVGI. OMX VILNIUS – Lithuania			
Monday	+	+	No change
Tuesday	–	+	Change
Wednesday	–	+	Change
Thursday	–	+	Change
Friday	–	+	Change
OMXBGI, BALTIC COUNTRIES			
Monday	–	+	Change
Tuesday	–	+	Change
Wednesday	–	+	Change
Thursday	–	+	Change
Friday	–	+	Change
OMXCPI – COPENHAGEN – Denmark			
Monday	+	–	Change
Tuesday	+	–	Change
Wednesday	–	–	No change
Thursday	+	–	Change
Friday	–	–	No change
OMXIPI – OMX all share REYKJAVIK – Iceland			
Monday	+	–	Change
Tuesday	+	–	Change

	Before COVID–19	COVID–19 period	Result after outbreak
Wednesday	–	+	Change
Thursday	–	+	Change
Friday	–	+	Change
OSEAX – OSLO Bors all shares – Norway			
Monday	+	+	No change
Tuesday	+	+	No change
Wednesday	+	+	No change
Thursday	+	+	No change
Friday	+	+	No change

Source: own study.

The results in Table 6 help us understand the changes related to the health crisis in the selected markets. The Latvian, Estonian and Norwegian markets registered no change at all in their efficiency. There was no change in the Lithuanian market regarding the Monday anomaly. In Denmark, there was a lack of anomalies on Wednesdays and Fridays before the COVID–19 pandemic. However, changes were found, and some anomalies appeared in the Lithuanian, Baltic Countries Index and Icelandic market on Wednesday, Thursday and Friday. The anomalies disappeared in Denmark, and this market became fully efficient after the pandemic, while the Baltic Index lost its efficiency. This could have happened due to the increased importance of random effects related to the outbreak of the COVID–19 pandemic.

Conclusions

This study examined the OMX stock exchanges in the Baltic and Scandinavian markets. It empirically investigated the existence of the day-of-the-week effect anomaly for the equivalent indices and the change caused by the outbreak of the COVID–19 pandemic. The objective of this study was to test the market efficiency before and during COVID–19. It was hypothesized that the markets were efficient, and the COVID–19 pandemic affected their efficiency.

The results showed that the Baltic Markets, as indicated by the OMXBGI index, were efficient before COVID–19 started spreading around the world, but the index lost its efficiency during the pandemic period. On the other hand, the Danish market was inefficient before the pandemic, but efficient during the COVID–19 period. The other OMX markets were not efficient during the whole period; only some changes were registered on the days the anomaly appeared.

It can be concluded that the COVID–19 disease influenced OMX market efficiency. Investors changed their behavior profile and exhibited irrational behavior based on different profiles before and during the outbreak of the pandemic. This also shows that even a health crisis in the market can affect the efficiency of exchanges and the rates of return. Future research could focus on the influence of market liquidity on changes in market efficiency in relation to market crises.

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Anomalia dni tygodnia w świetle pandemii COVID–19 na przykładzie wybranych indeksów OMX

Niniejszy artykuł miał na celu zbadanie efektywności rynku oraz zmian, jakie mogły pojawić się w tym obszarze po wybuchu pandemii COVID–19. Giełda OMX i jej indeksy zostały wzięte pod uwagę ze względu na to, że reprezentują różne rynki zintegrowane na tej samej platformie giełdowej, a poza tym badaniu ich efektowności podczas pandemii nie poświęcono uwagi. Analizowane były dwa okresy: przed wybuchem pandemii COVID–19 i po jej wybuchu, a hipoteza efektywnego rynku (EMH) była testowana poprzez wykorzystanie anomalii efektu dnia tygodnia. Wyniki pokazują, że przed wybuchem pandemii tylko Indeks Krajów Bałtyckich był efektywny, ale stracił tę cechę podczas pandemii, podczas gdy rynek duński ją zyskał. Zaobserwowano zatem efektywność niektórych rynków oraz zmiany wywołane przez COVID–19.

Słowa kluczowe: COVID–19, anomalie dni tygodnia, efektywność rynku

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Environmental Quality, Infant Morality, and Economic Growth in Selected Sub-Saharan African Countries

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Abstract

Beyond the usual macroeconomic stability, which is a necessity for economic growth, more focus should be placed on the effects that environmental quality has on infant mortality in sub-Saharan Africa. Africa has always had the highest rate of infant mortality and the poorest environmental quality in the world. High infant mortality shows that there are unmet human needs and unenforced policies to protect the environment. Therefore, this research examines the impact of environmental quality on infant mortality and how environmental quality and infant mortality also affect economic growth using 15 selected sub-Saharan African countries for a period of 10 years (2010–2019). The study employed fixed and random effects methods of estimation. The results showed that environmental quality has a significant negative (51.53%) impact on infant mortality and that economic growth also has a negative (45.58%) impact on infant mortality. The study recommends that governments should increase expenditure on health, with more focus on financing infant healthcare, because it also affects economic growth.

Keywords: Environmental quality, infant mortality, economic growth, sub-Saharan African

JEL: O44, I15, N17, Q53

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Introduction

At the earliest stage of infant life, everything must be close to perfect in temperature, food, and environment for proper growth and development. However, many factors are often ignored regarding children's well-being, including pollution, climate, and clean water, among other things (Salthammer et al. 2016). Pollution is one of the most common factors that have a negative effect on infant mortality and other health-threatening diseases. This assertion was proven by Singh et al. (2019), whose analysis showed that air pollution causes birthing complications such as stunted growth and underweight babies. This implies that as bad as these ailments may seem to be, threatening children's lives, there is a more significant problem from which they stem, and that is the issue of bad environmental quality (Osabohien et al. 2021; Alege, Adediran, and Ogundipe 2016).

The environment begins to affect a baby from the womb (Gilliland et al. 2002). This is because children are more susceptible to sicknesses and diseases, especially those that stem from their environment. Exposure to prolonged negative weather conditions and weather shocks (like drought) in infancy and early childhood affects infant mortality (Andriano and Monden 2017; Urhie et al. 2020).

From raging fires all over Europe to rising sea levels, floods, and heatwaves in most parts of Africa, the globe is becoming increasingly conscious of environmental quality and climate change, and the global economy is growing increasingly concerned about these issues. The air quality in Africa gets worse daily due to various air pollutants, such as exhaust fumes from vehicles and industrial gas. Bourzac (2019) estimates that about 780,000 deaths are caused by air pollution in African countries every year.

Africa is the second most populated continent in the world, after Asia (Statista 2020). It is also the continent with the highest infant mortality rate, with 76 deaths per 1000 live births (UNICEF 2020). In 2019, 5.2 million children under the age of 5 died worldwide, and over half of those deaths were recorded in Sub-Saharan Africa. The continent faces the problem of balancing energy demands in the global economy and examining climate change issues. In previous years, sub-Saharan Africa experienced worse cases of infant and child mortality related to malaria and malnutrition, although total infant mortality has been declining. This is attributed to the low coping capacities of countries to climate change issues (United Nations 2020).

Thus, Africa needs to examine ways to implement its policies effectively to prevent and reduce the effect of carbon emissions, which is the main reason behind climate change. Some consequences in the region could include rising sea levels, rising temperatures, irregular rainfalls, and extreme weather events. This could then result in general issues that are prejudicial to health, like respiratory conditions, skin cancer, high blood pressure, malnutrition, and malaria (World Health Organization 2015).

However, there is little to no literature on the effects of environmental quality on infant mortality in Sub-Saharan Africa. This research seeks to add to the body of knowledge in this area. From a review of previous articles, this study examines the effects of environmental quality and economic growth on infant mortality in Sub-Saharan Africa. It also investigates the effect of economic growth on infant mortality and environmental quality.

This paper is divided into five sections. Following the introductory section, section two reviews some relevant literature. The methodology for the study is discussed in section three, while section four discusses the result and findings. Section five provides the conclusion and recommendations.

Literature review

Children breathe in twice as much air as adults They also have weaker immune systems, so their lungs are much more vulnerable and susceptible to diseases. Urban children are at risk due to living close to industrial sites, but children in rural areas seem to be the most at risk. The number of children at risk is expected to increase if action is not taken.

According to Bannister and Zhang (2005), child mortality is affected to a large extent by economic growth. Their study investigates the determinants of China's mortality levels and trends since 1981, and they found that if economic growth rises, standards of living increase and child mortality declines. If per capita income increases, individuals can afford better health care, which leads to higher life expectancy. Good health care coupled with higher life expectancy will lead to progressive economic growth.

Lower and middle-income countries face a threat to women and children stemming from indoor air pollution from sources like solid fuels for cooking (Aigbokhaode and Isara 2021). In Myanmar, data were collected during the first demographic and health survey conducted in 2016 to investigate the extent to which indoor air pollution affects the mortality of newborns, infants, and children under five years of age. The data showed that the prevalence of Solid Fuel Use (SFU) was 79%, and the mortality ratio per 1000 live births was 26, 45, and 49 in newborns, infants, and children under five years, respectively. Compared to the odds of mortality in households that do not use solid fuels, households that use solid fuels had a relatively higher mortality rate in children.

Quy-Toan, Joshi, and Stolper (2016) provide a link between industrial pollution and infant mortality, with the case study narrowed to pollution in the River Ganges. The logic explains that a nursing mother who bathes with polluted water is most likely to transfer it to the baby. This showed a link between infant mortality and river pollution. Although environmental policies helped to reduce pollution in India, there is still a long

way to go. The reason for the lack of improvements in environmental quality is the high marginal cost associated with pollution control.

Alege and Ogundipe (2013) established a relationship between economic growth and environmental pollution, showing how an increase in income could lead to poor economic performance. Recent improvements in the standard of living have been at the expense of the environment. They have contributed to environmental pollution through the increase in noise due to development, smoke from cars and transport systems, deforestation, and the burning of bushes, among other things. All these challenges come with development, but they can be managed. Increased growth tends to improve productivity and technical capacity in the nation. The need to increase production capacity rises to allow larger production volumes at lower rates of environmental degradation. The advancement in technological capacity, as well as the need to employ more labor, will eventually create more opportunities and bring about huge investments in new and upcoming technologies; this can help solve the problem of waste.

Carbon, which is one of the major causes of environmental pollution, has been observed to be related to economic growth in certain emerging economies. Carbon emissions appear to be falling in high-income nations, although it seems not to be the case in some emerging economies like China, Brazil, or Egypt. According to one study, economic growth propels pollution, but if this growth is sustained for a longer period, there could be a decline in pollution. This is because, with time, technology would have improved in certain areas and would help curb the effect and causes of pollution in those areas. A way to tackle carbon driven environmental pollution is by creating policies that regulate the number of carbon-intensive products that are imported into the country and observe the activities of huge companies that could be contributing massively to this problem (Alege and Ogundipe 2013).

Patel et al. (2018) investigated the relationship between environmental quality and infant mortality in the United States and discovered that there are high infant mortality rates with large ethnic or racial disparities. By obtaining linked birth and infant death data from the U.S. Centers for Disease Control and Prevention, five ethnic/racial groups were identified to examine the differences by race/ethnicity. In that study, conducted between 2000 and 2005, 144,741 infants died out of a total of 22,702,529, which is 6.4 infant deaths per 1000 live births. The results showed that there was less likelihood of mortality among infants of non-Hispanic white mothers, while the likelihood increased in infants of Non-Hispanic black mothers. (Patel et al. 2018).

The highest child mortality rate is in Sub-Saharan Africa, with about 92 deaths per 1,000 live births in 2013. We combined individual-level data from 83 Demographic and Health Surveys from 33 countries in Sub-Saharan Africa, paying attention to local rainfall information and temperature change, to ascertain the determi-

nants of child mortality. Exposure to adverse weather conditions, such as drought, at the early stages of life affects child mortality because of vulnerability to malaria and malnutrition, as well as other harmful diseases. Sub-Saharan Africa is the region hardest hit by climate change, and it is most likely going to experience far more extreme weather conditions in the future. We combined individual-level data with data on rainfall and temperature variations to study the anomalies in these factors and determine if maternal education can mitigate the effects of environmental changes on infants. The results suggest that climate shocks increase the risk of child mortality, while maternal education can mitigate the effects (Andriano and Monden 2017).

Rahman, Alam, and Khanam (2022) examined the socio-economic factors affecting high infant and child mortality rate in selected African countries using panel corrected standard error, feasible generalized least square models and pair-wise granger causality test. The result of the study shows that public health expenditure, number of physicians, globalization, economic development, education and good governance negatively affect the infant and child mortality rates.

Adeleye et al. (2022) examined the nexus among mortality rate, carbon emission, renewable energy and per capita income in 47 selected sub-Saharan African countries between 2005 to 2019 using generalized method of moments. The result of the study shows that carbon emissions and renewable energy increase mortality rate while per capita income reduces infant mortality rate.

Methodology

Infant mortality is a very important variable to be studied in any economy. If infant mortality is very high, the chances of growth are very low. This study is based on the modernization theory, which claims that infant mortality will fall because of industrialization due to the positive things that come with economic development, such as improvements in the medical sector, environmental policies, and education systems, among other things (Frey and Cui 2017).

This research focused on 15 countries in Sub-Saharan Africa: the Central African Republic, Sierra Leone, Nigeria, Chad, Lesotho, the Democratic Republic of Congo, Guinea, Liberia, Mali, Benin, Cote D'Ivoire, Mozambique, Burkina Faso, Guinea-Bissau, and Cameroon. They have the highest infant mortality rates and are also among the International Development Association (IDA) countries. The study used secondary data covering a period of 10 years, from 2010 to 2019. This data was sourced from World Development Indicators (WDI). For the analysis, the panel unit root test was conducted, followed by panel fixed and random effect models, taking into consideration the Hausman effect.

This study adapts the works of Mutizwa and Makochekanwa (2015), who explained the impact of environmental factors on health outcomes by using the following model:

$$\ln INF_{it} = \beta_o + \beta_1 \ln CO_{it} + \beta_2 \ln AS_{it} + \beta_3 \ln AW_{it} + F_i + e_{it},$$

where infant mortality rate (INF) is dependent on variables such as carbon emission (CO), access to sanitary facilities (AS), and improved water sources (AW).

Infant mortality is also dependent on environmental factors: Carbon emissions, economic growth, population, environmental policy, and gross domestic product. Therefore, the general model for the study is expressed thus:

$$INF = f\left(CO_2, APM, EVP, PGA, GDP\right), \tag{1}$$

where: INF = Infant Mortality, CO_2 = Carbon Emissions, APM = Air pollution, EVP = Policy and Institutions for Environmental Sustainability Rating, PGA = Annual growth of population, GDP = Gross Domestic Product.

Equation (2) is an econometric model:

$$INF_{ct} = \beta_o + \beta_1 CO_{2ct} + \beta_2 LAPM_{ct} + \beta_3 EVP_{ct} + \beta_4 PGA_{ct} + \beta_5 LGDP_{ct} + \mu_{ct}, \tag{2}$$

where: β_0 = Constant, β_1, …, β_5 = Coefficient of independent variables, L = Natural log, μ = Error Term, c = countries, t = time.

This study further examines the impact of economic growth on infant mortality and environmental quality. This objective was achieved using the following equations:

$$INF_{ct} = \beta_{0ct} + \beta_{1ct} LGDP_{ct} + \beta_{2ct} PGA_{ct} + \beta_{3ct} GEH_{ct}, \tag{3}$$

$$CO_{2ct} = \beta_{0ct} + \beta_{1ct} LGDP_{ct} + \beta_{2ct} PGA_{ct} + \beta_{3ct} PAE_{ct}, \tag{4}$$

where: INF = Infant Mortality, CO_2 = Carbon Emissions, PGA = Annual growth of population, GDP = Natural log of Gross Domestic Product, GEH = Government expenditure on health, PAE = Population with access to electricity.

Table 1. Definition and sources of data

Variable	Definition	Source
Infant Mortality (INF)	Infant mortality is the number of children that die between the ages of 0 and 1, as expressed per 1000 live births.	World Development Indicators (WDI), World Bank, 2020
Carbon Emission (CO_2)	Carbon emission is the release of excess amounts of the harmful gas carbon dioxide into the atmosphere, especially through deliberate human actions.	World Development Indicators (WDI), World Bank, 2020
Gross Domestic Product (GDP)	This is the total cost of all finished goods and services produced in a country over a given period, usually a year.	World Development Indicators (WDI), World Bank, 2019
Annual Growth of Population (%) (AGP)	Annual growth of population refers to the rate of change in population size for a given country or geographical area during a specific period which, in this case, is a year.	World Development Indicators (WDI), World Bank, 2019
Air Pollution (Micrograms per Cubic Meter) (APM)	This is the average level of exposure of a country's population to suspended particle concentrations less than 2.5 microns in aerodynamic dimension.	World Development Indicators (WDI), World Bank, 2020
Government Expenditure on Health (% of GDP) (GEH)	Government expenditure on healthcare is the amount of money allocated to the healthcare sector of the country per year.	World Development Indicators (WDI), World Bank, 2020
Policy And Institutions for Environmental Sustainability Rating (EVP)	The extent to which institutions for environmental sus tainability assess environmental policies that promote the protection and sustainable use of natural resources, as well as pollution control. This rating ranges from 1 to 6, with one being the lowest (bad) and 6 being the highest (good).	World Development Indicators (WDI), World Bank, 2020
Population with Access to Electricity (%) (PAE)	Population with access to electricity is the data that shows the percentage of the population who have access to electricity.	World Development Indicators (WDI), World Bank, 2020

Source: authors' compilation.

Result and discussion

The study employed panel random and fixed effects methods of analysis. Table 2 shows the result of the panel fixed and random effects for the effect of environmental quality and economic growth on infant mortality. Based on the results of the Hausman test, the results interpreted are the results of the fixed-effects model. The model has a goodness of fit represented by the R^2 of 90.6% and an adjusted R^2 of 89.2%, which accounts for the degree of freedom. The R^2 indicates that carbon dioxide emission, air pollution, environmental policy rating, annual population growth, and GDP account

for 90.6% of variations in infant mortality. The probability of the F-statistic is below 0.05, which indicates that the variables in the model are jointly significant.

Table 2. Effect of environmental quality and economic growth on infant mortality

Dependent variable: Infant mortality	Fixed effect		Random effect	
Variables	coefficient	p-value	coefficient	p-value
$C_0 2$	0.0005	0.0028	0.0002	0.0154
LAPM	– 51.5379	0.0000	– 39.1131	0.0000
EVP	1.8301	0.2466	– 3.5159	0.0123
PGA	– 1.3618	0.4404	0.0755	0.9622
LGDP	– 39.9826	0.0000	– 17.7260	0.0000
C	561.218	0.0000	323.5729	0.0000
R^2	0.9062		0.3291	
Adjusted R^2	0.8926		0.30580	
F-Statistics	66.1389	0.0000	14.12678	0.0000

Source: authors' compilation.

The coefficient of carbon dioxide emissions is statistically significant. There is a positive relationship between carbon dioxide emissions and infant mortality. This means that when carbon dioxide increases by one unit, infant mortality will increase by 0.0005 units. That is, when carbon dioxide increases by one kiloton, infant mortality will increase by 0.5 per 1000 live births. The coefficient of air pollution is statistically significant. There is a negative relationship between air pollution and infant mortality. This means that when air pollution increases by one unit, infant mortality will decrease by 51.54 units.

The coefficient of GDP is statistically significant. There is a negative relationship between GDP and infant mortality. This means that when GDP increases by one unit, infant mortality will decrease by 39.98 units. That is, when GDP increases by a dollar, infant mortality will decrease by approximately 40 per 1000 live births. Environmental policy ratings and the annual population growth are the variables that are not statistically significant in the model, as they all have p-values that are greater than 0.05.

To examine the effect of economic growth on infant mortality and environmental quality, Table 3 and 4 shows the result of the fixed and random effect analysis. Based on the results of the Hausman test, the results interpreted are the results of the fixed-effects model.

Table 3. Effect of economic growth on infant mortality

Dependent variable: infant mortality	Fixed effect		Random effect	
Variables	coefficient	p-value	coefficient	p-value
LGDP	– 45.58	0.0000	– 23.40444	0.0000
PGA	3.5547	0.0759	2.915941	0.0939
GEH	– 1.4170	0.0000	– 1.335828	0.0000
C	534.3866	0.0000	312.8701	0.0000
R^2	0.8910		0.2649	
Adjusted R^2	0.8770		0.2498	
F-Statistics	63.4903	0.0000	17.5379	0.0000

Source: authors' compilation.

The model has a goodness of fit represented by the R^2 of 89.1% and an adjusted R^2 of 87.7%, which accounts for the degree of freedom. The R^2 indicates that GDP, Annual population growth, and government expenditure on health account for 89.1% of variations in infant mortality. The probability of the F-statistic is below 0.05, which indicates that the variables in the model are jointly significant.

The coefficient of GDP is statistically significant. There is a negative relationship between GDP and infant mortality. This means that when GDP increases by one unit, infant mortality will decrease by 45.58 units. That is, when GDP increases by a dollar, infant mortality will decrease by 45.58 per 1000 live birth.

The coefficient of government health expenditure is statistically significant. There is a negative relationship between government health expenditure and infant mortality. This suggests that a one-unit increase in government health spending will result in a 1.42-unit reduction in infant mortality. That is, for every 1% increase in government health spending, infant mortality falls by 1.42 per thousand live births.

Table 4. Effect of economic growth on environmental quality

Dependent variable: Carbon emission	Fixed effect		Random effect	
Variables	coefficient	p-value	coefficient	p-value
LGDP	989.1684	0.0022	3278.79	0.1916
PGA	– 137.6650	0.8761	– 101.1947	0.9081
PAE	78.4002	0.0345	67.8252	0.0648
C	– 543.9630	0.9830	– 23310	0.3581

Dependent variable: Carbon emission	Fixed effect		Random effect	
Variables	coefficient	p-value	coefficient	p-value
R^2	0.9963		0.0618	
Adjusted R^2	0.9959		0.0425	
F-Statistics	2090.998	0.0000	3.2052	0.0251

Source: authors' compilation.

Based on the results of the Hausman test, the results interpreted are the results of the fixed-effects model. The model has a goodness of fit represented by the R^2 of 99.6% and an adjusted R^2 of 99.5%, which accounts for the degree of freedom. The R^2 indicates that GDP, annual population growth, and population with access to electricity account for 99.6% of variations in infant mortality. The probability of the F-statistic is below 0.05, which indicates that the variables in the model are jointly significant.

The coefficient of GDP is statistically significant. There is a positive relationship between GDP and carbon dioxide emissions. This means that when GDP increases by one unit, carbon dioxide emission will increase by 989.17 units. The coefficient of the population with access to electricity is statistically significant. There is a positive relationship between population with access to electricity and carbon emission. This means that when the population with access to electricity increases by one unit, carbon dioxide emission will increase by 78.40. That is, when the population with access to electricity increases by one percent, environmental quality represented by carbon emission will increase by 78.40.

Discussion and implication of findings

This study was carried out to determine if environmental quality affects infant mortality in selected sub-Saharan African countries. From the results, all variables met the *a priori* expectations. This means that for most countries in sub-Saharan Africa, carbon affects infant mortality. To reduce infant mortality, it will have to be measured to keep the environmental quality high. The results are supported by the findings of various previous studies. In different countries and regions, the findings still hold, e.g., Jayachandran (2009), Aguilera et al. (2013), Pullabhotla (2018), Anwar et al. (2019), and Singh et al. (2019) show that there is a positive relationship between infant mortality and environmental quality.

This study also showed that infant mortality has a negative effect on economic growth. This also aligns with previous studies. The study found that GDP is significant and negatively related to infant mortality. This explains that if infant mortali-

ty is effectively managed and kept at a minimum, there will be higher levels of economic growth. This study found that government expenditure on health negatively affects infant mortality. As the government increases expenditure in the healthcare sector, it allows for better medical care, reducing infant mortality.

This study found that carbon emissions are positively related to economic growth. As the economy and GDP grow, there will be more carbon dioxide emissions. This happens as economic growth brings about industrialization, which leads to carbon dioxide emissions. This was part of the implications of the environmental Kuznets curve.

This study shows that environmental quality significantly impacts infant mortality. Therefore, to reduce infant mortality, environmental quality should be addressed seriously. This study has also shown that environmental quality and infant mortality growth impact economic growth. Therefore, attempts should be made to keep these variables at a minimum. Actions could include greater investment in health and more environmental policies to promote environmental sustainability.

Conclusion

The study covered the relationship between environmental quality and infant mortality in selected sub-Saharan African countries from 2010 to 2019. It showed that the quality of the environment influences infant mortality. It is, therefore, necessary to improve the quality of the environment by reducing the level of air pollution and carbon emission in the atmosphere. Infant mortality is a problem that should be tackled because this study showed that infant mortality has a negative impact on economic growth. It leads to the loss of potential human capital.

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Jakość środowiska, śmiertelność niemowląt i wzrost gospodarczy w wybranych krajach Afryki Subsaharyjskiej

Obok zwykłej stabilności makroekonomicznej, która jest niezbędna dla wzrostu gospodarczego, elementem, na który należy zwrócić większą uwagę, jest wpływ jakości środowiska na śmiertelność niemowląt w Afryce Subsaharyjskiej. Afryka zawsze miała najwyższy wskaźnik śmiertelności niemowląt i najniższą jakość środowiska na świecie. Wysoka śmiertelność niemowląt pokazuje, że istnieją niezaspokojone potrzeby ludzkie i nieegzekwowana jest polityka ochrony środowiska. W związku z tym w niniejszym badaniu przeanalizowano wpływ jakości środowiska na śmiertelność niemowląt oraz wpływ jakości środowiska i śmiertelności niemowląt na wzrost gospodarczy na podstawie danych dla 15 wybranych krajów Afryki Subsaharyjskiej z okresu 10 lat (2010–2019). W badaniu zastosowano metody estymacji: efektów stałych i efektów losowych. Wyniki badania wykazały, że jakość środowiska ma znaczący negatywny wpływ (51,53%) na śmiertelność niemowląt. Wzrost gospodarczy ma również negatywny wpływ (45,58%) na śmiertelność niemowląt. Z opracowania wynika zalecenie, aby rządy zwiększyły wydatki na ochronę zdrowia, z większym naciskiem na finansowanie opieki zdrowotnej dla niemowląt, ponieważ wpływa to również na wzrost gospodarczy.

Słowa kluczowe: jakość środowiska, śmiertelność niemowląt, wzrost gospodarczy, Afryka Subsaharyjska

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Multi-criteria Analysis of the Competitiveness of Major Baltic Sea Container Terminals

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Abstract

The rapid growth in the volume of international container transport requires that the entire transport chain become more competitive, including maritime container terminals. The aim of the article is to identify the number and location of major Baltic container terminals and to perform a multi-criteria analysis of the competitiveness of maritime container terminals in the Baltic Sea Region (BSR). In our study, we perform the AHP multi-criteria analysis with subjective criteria weights, as well as the entropy method with objective criteria weights. Thus, we can evaluate the competitive advantages of each of the specified terminals in the region. We are among the first to study the competitiveness of individual maritime container terminals in the BSR. Thus, our research adds to the literature that has yielded results on the competitive advantage of the Baltic seaports.

Keywords: maritime container terminals, Baltic Sea, competitiveness, multi-criteria analysis, AHP, entropy

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Introduction

In 2020, 815.6 million twenty-foot containers (twenty-foot equivalent units – TEUs) were handled in ports worldwide, with the top 15 handling 76.8 million TEUs (2.8% less than in 2019). Although world container port throughput declined by 1.2% after the COVID–19 pandemic, this reduction is moderate compared to other shipping market segments and total seaborne trade (Notteboom 2021; UNCTAD 2021). Maritime container transportation will continue to grow because of economic growth and globalization, increased demand for this kind of transport, and the growing emphasis on efficient and environmentally friendly transport.

The intensive development of container transport increased the competitiveness of the entire transport chain, including maritime container terminals. Since the Baltic Sea is one of the most exploited water areas in terms of transport in the world (Klimek and Dąbrowski 2018, p. 1), it is worth comparing and evaluating the competitiveness of selected Baltic container terminals.

Competitiveness is a measure of past efficiency (Bernacki 2003, p. 56). Both Polish and foreign researchers are interested in the competitiveness of seaports, and some have contributed to the academic literature by conducting a thorough literature review on the subject. For example, Luo, Chen, and Zhang (2022) reviewed the relationships between port competition, cooperation, and competitiveness, while Baştuğ et al. (2022) undertook a 20-year-long literature search in peer-reviewed journals to identify the competitiveness criteria of both carriers and terminal operators. Ignasiak-Szulc, Juščius, and Bogatova (2018) developed an evaluation model of seaport performance to make it possible to assess the financial situation of the organization and determine its position in the market in relation to its competitors. On the other hand, Kaliszewski et al. (2021) aimed to understand forwarders' perceptions of competitiveness factors by surveying the global forwarder community using a unique snowball-like method.

Other authors have concentrated on a more empirical approach. Most recently, Li et al. (2021) empirically examined the relationship between dry port logistics supply chain integration, its operational performance, and dry port competitiveness in China. Zhao and Yu (2021) used principal component analysis to analyze 14 main coastal ports in China to clarify the position of Qingdao port in the whole country and to analyze its development potential. Meanwhile, Castelein, Geerlings, and Van Duin (2019) analyzed the Rotterdam container handling sector and described how pressures for competition and cooperation conflict, what problems this causes, and how they can be resolved. Using both linear regression and factor analysis, Haezendonck and Langenus (2019) analyzed the competitive advantages of the Antwerp port cluster for its integrated hinterland network area on data of fifty-nine port experts. Kusuma and Tseng (2019) investigated the impact of the "sea toll" program on seaport resilience and competitiveness through an online survey of key stakeholders of Indonesian sea-

ports, while Mustafa, Khan, and Farea (2019) employed Herfindahl-Hirschman Index (HHI) and Boston consulting group matrix (BCG) approach to analyze and compare different ports. Dang and Yeo (2017) also used the BCG matrix, but to investigate the competitive position of the largest ports in Southeast Asia. Issues such as the impact of using low-sulfur fuel in maritime transport (Vaferi, Ghaderi, and Jeevan 2017), the effectiveness of pro-ecological solutions used in the latest generation of seaports (di Vaio and Varriale 2018), and the impact of dry ports on the effectiveness of marine nodes (Jeevan, Chen, and Cahoon 2019) have also been included in the research on the competitiveness of seaports.

Some authors have used Data Envelopment Analysis (DEA) (Cruz and Ferreira 2016; Kuo, Lu, and Le 2020; Nguyen et al. 2021; Wang et al. 2021) and multi-criteria methods to study the competitiveness of marine reloading and storage bases (Bartosiewicz 2020a; 2020b; Elgazzar and Ismail 2021; Park 2021). At the same time, only a few authors have dealt with the issue of the competitiveness of seaports in the Baltic Sea Region (BSR) (Matczak 2016; Kotowska 2017; Bartosiewicz and Szterlik 2021).

Industry reports and research on the BSR usually consider the annual results achieved by individual ports, ignoring the effectiveness of the terminals that comprise them. Consequently, we decided to identify the Baltic maritime container terminals to determine their competitive position in relation to their biggest competitors in this region. To this end, we used the Analytic Hierarchy Process (AHP) multi-criteria analysis with subjective criteria weights and the entropy method with objective criteria weights. Thus, our research adds to the literature that has yielded results on the competitive advantage of the Baltic seaports.

Maritime container terminals in the Baltic Sea Region

Russia and eight European Union (EU) member states are part of the BSR. The region consists of Scandinavian countries (Denmark, Finland, and Sweden), Germany, Poland, the Baltic countries (Lithuania, Latvia, Estonia) and Russia. Due to shipping connections with the largest ocean ports and developed land transport corridors, the BSR maritime transport system, including the ports that operate in the region, is an important part of the European transport system. At the same time, Baltic ports are intermediaries in trade, not only between the BSR countries but also with the EU single market and the Far and Middle East (Grzybowski 2012).

At the end of 2021, there were more than fifty maritime container terminals in the BSR. Our study considers only those Baltic container terminals whose maximum annual transshipment capacity was over 150,000 TEUs (the *major terminals*).[1] The bounda-

1 The list of Baltic container terminals in 2021 was prepared based on the information provided by European Transport Maps (n.d.).

ry of this division is conventional. For comparison, Karwacka (2011, p. 697) distinguishes three types of terminals: peripheral with a transshipment of several hundred thousand TEUs, regional with a transshipment of over one million TEUs, and large (the continental hubs). Table 1 below lists eighteen major maritime container terminals ordered by country. Among the biggest container terminals, there are no German ones. There are four Russian, three Finnish, three Polish, and three Swedish terminals. At the same time, there are two Lithuanian, one Danish, one Estonian, and one Latvian maritime container terminals with a maximum annual transshipment capacity of over 150,000 TEUs.

Table 1. Eighteen major Baltic container terminals in 2021

Country	Place	Name of the terminal (code)
Denmark (D)	Aarhus	APM Terminals – Cargo Service (APM–T–CS)
Estonia (EE)	Tallin (Maardu)	Muuga Container Terminal (MCT)
Finland (FIN)	Kotka	Kotka (Mussalo CT)
	Helsinki	Vuosaari (Vuosaari) Vuosaari (Steveco)
	Rauma	Euroports Finland (Euroports Finland)
Latvia (LV)	Riga	Baltic Container Terminal Riga (BCT Riga)
Lithuania (LT)	Klaipeda	Klaipeda Container Terminal (KCT Klaipeda)
		Klaipedos Smelte (Smelte)
Poland (PL)	Gdańsk	Deepwater Container Terminal Gdańsk (DCT Gdańsk)
	Gdynia	Baltic Container Terminal Gdynia (BCT Gdynia)
		Gdynia Container Terminal (GCT Gdynia)
Russia (RUS)	St Petersburg	Bronka Container Terminal (Bronka CT)
		Container Terminal Saint–Petersburg (CTSP)
		First Container Terminal (FCT)
		Petrolesport (Petrolesport)
Sweden (S)	Gävle	Gävle Container Terminal (GCT Gävle)
	Gothenburg	APM Terminals Gothenburg (APMT)
	Helsingborg	Västhamnen Container Terminal (Västhamnen)

Source: authors based on European Transport Maps (n.d.).

The competitiveness of a maritime container terminal is influenced by factors such as its technical infrastructure, the work organization of the terminal, the use of advanced information technologies, and the provision of comprehensive logistic services (Urbanyi 2010, p. 1). In our study, we assumed that technical infrastructure is among the most im-

portant factors that determine a terminal's efficiency. Thus, in the multi-criteria analysis described below, we include factors such as the length of the quay (c_1), the maximum depth at the quay (c_5), the distance from the nearest motorways, expressways/national roads (c_6), and national railway stations (c_7). We also analyzed superstructural factors (i.e., the number of STS, Ship to Shore (c_3) and RTG, Rubber Tyred Gantry (c_2), cranes) as well as service factors (i.e., the number of short-sea shipping connections (c_4)).

For the first five factors, we obtained data from either the websites of individual terminals or various types of collective studies. We determined the distance from motorways and expressways/national roads, as well as national railway stations, based on our own calculations. To this end, we used navigation programs and digital maps. Table 2 summarizes the data used in the study.

Table 2. Data for eighteen major Baltic container terminals (2021)

Terminal	c_1	c_2	c_3	c_4	c_5	c_6	c_7
APM–T–CS (DK)	1,300	0	8	9	15	4,500	6,700
MCT (EE)	1,096	6	3	6	14.5	1,000	16,100
Mussalo CT (FIN)	1,850	0	9	4	15.3	4,800	6,700
Vuosaari (FIN)	2,500	0	8	14	13	600	16,500
Euroports Finland (FIN)	160	0	2	5	12	900	2,100
BCT Riga (LV)	450	4	5	4	12.5	8,500	5,600
KCT Klaipeda (LT)	820	13	4	5	13.4	4,800	9,800
Smelte (LT)	1,088	12	5	4	13.4	1,100	6,800
DCT Gdańsk (PL)	1,300	40	14	9	17	2,600	10,400
BCT Gdynia (PL)	800	18	6	6	12.7	4,100	3,100
GCT Gdynia (PL)	620	14	6	17	13.5	3,300	2,700
Bronka CT (RUS)	1,220	10	4	4	14.4	1,500	5,500
CTSP (RUS)	972	24	4	2	11.4	4,000	4,600
FCT (RUS)	780	12	7	15	11	2,600	3,000
Petrolesport (RUS)	2,071	26	7	12	11	3,700	4,000
GCT Gävle (S)	680	6	3	4	12.2	8,400	7,900
APMT (S)	1,800	0	10	9	16	1,900	10,300
Västhamnen (S)	770	0	3	11	13	1,600	3,900

Source: authors' elaboration based on European Transport Maps (n.d.) and the websites of individual terminals.

AHP multi-criteria analysis

Methods based on the utility function and on the outranking are among the most important multi-criteria analysis methods of decision-making (Kobryń 2014). The first group of methods applies a "top-down" approach where individual decision variants (alternatives) from each criterion point of view are considered separately and then aggregated into one synthetic indicator (or function). The second group of methods implements a "bottom-up" approach, where first, partial outranking between alternatives are constructed for each criterion separately, and then, overall outrankings are created. AHP belongs to the first group described above, while the family of Preference Ranking Organization Methods for Enrichment Evaluations (PROMETHEE) is an example of the method based on the outranking. The AHP method is presented in more detail later in this section.

Given a set of alternatives (variants, objects) and a set of assessment criteria (and their weights), the AHP method can be performed in five steps: (1) model the problem as a hierarchy, (2) pairwise compare alternatives and criteria, (3) determine local and global preference indexes, (4) test the compatibility of the pairwise comparison matrix, and (5) build the final multi-criteria ranking.

First, we must create the structure of the decision problem. We put the main decision-making goal at the top of the hierarchy. At the second level, there is a set of decision criteria by which the alternatives are compared. All alternatives of the problem are placed at the bottom of the structure.

Next, we must create a pairwise comparison matrix **P** between all alternatives for each criterion separately. We also construct such a matrix separately for all criteria. In the first case, we make comparisons based on the criteria values for each variant, while we compare pairs of criteria by their weights. Elements of matrix **P** are coherent [pi,i] – each element is equivalent to itself ($pi,i = 1$) while the evaluation value of element j respect to element i is the reciprocal of the evaluation value of element i respect to element j ($pj,i = 1/pi,j$). The general form of matrix **P** is shown below:

$$\boldsymbol{P} = \begin{bmatrix} 1 & p_{1,2} & \cdots & p_{1,n} \\ \dfrac{1}{p_{1,2}} & 1 & \cdots & p_{2,n} \\ \cdots & \cdots & \cdots & \cdots \\ \dfrac{1}{p_{1,n}} & \dfrac{1}{p_{2,n}} & \cdots & 1 \end{bmatrix}. \tag{1}$$

When creating matrix **P**, we use a relative grading scale defined by Saaty (2004). We may compare the variants descriptively by assigning an integer value from 1 to 9. The value of *pij* expresses the rank of the relationship between the compared variants, where *pij* = 1 means that variant *i* is equivalent to variant *j*, *pij* = 5 means that variant *j* is strongly preferred to variant *i*, and *pij* = 9 means that variant *j* is absolutely preferred to variant *i*. If quantitative data are available for a given criterion (where the decision vector $\mathbf{q}^{(c)}$ for the criterion *c* is given), the elements of matrix **P** for stimulants are determined according to the formula:

$$p_{ij} = \frac{q_i^{(c)} - q_j^{(c)}}{q_{max}^{(c)} - q_{min}^{(c)}} \cdot 8 + 1 \text{ for } q_i^{(c)} \geq q_j^{(c)} \tag{2}$$

and for destimulants according to the formula:

$$p_{ij} = \frac{q_j^{(c)} - q_i^{(c)}}{q_{max}^{(c)} - q_{min}^{(c)}} \cdot 8 + 1 \text{ for } q_i^{(c)} \leq q_j^{(c)}, \tag{3}$$

where $qi^{(c)}$ and $qj^{(c)}$ are the variants' evaluations for criterion *c*. It means that the elements *pij* take any value from the interval ⟨0, 1⟩.

In the third step of the AHP algorithm, we determine the indexes of local $\omega V^{(c)}$ and global preference ωC. The former correspond to individual rankings of variants for each criterion separately. The global preference index, in turn, sets the final weights for all criteria. We determine the global and local indexes through the normalized matrix $\hat{\mathbf{P}}$, with elements $\hat{p}\ ij$:

$$\hat{p}_{ij} = \frac{p_{ij}}{\sum_{i=1}^{n} p_{ij}}. \tag{4}$$

The local indexes ($\omega V^{(c)}$) for each criterion *c* are calculated according to the formula:

$$\omega_v = \frac{\hat{p}_{ij}}{\sum_{i=1}^{n}\sum_{j=1}^{n} \hat{p}_{ij}}. \tag{5}$$

The indexes of global preference ωC (final weights) are determined respectively according to formulas (4) and (5).

Next, we verify the compliance of the ratings that result from the pairwise comparisons. The consistency of the ratings should be maintained, which means that the relation

of transitivity (i.e., if a > b and b > c then a > c) must be fulfilled. To this end, we calculate index *CR* (6). The condition is satisfied when the *CR* value does not exceed 0.1. When we use quantitative data, the condition of consistency is always satisfied.

$$CR = \frac{CI}{RI} = \frac{\lambda_{\max} - n}{RI\left(n-1\right)}, \tag{6}$$

where $\lambda_{\max}$ is the maximal eigenvalue of matrix P, and *RI* is the average of *CI* values calculated for a big number of randomly generated matrixes P. The *RI* value can be taken from the Saaty table.

Finally, we must determine a final ranking of variants by calculating the value of the utility function for each variant separately, which is the sum of products of the local index for criterion *c* and its final weight (7):

$$U_v = \sum_j \omega_v^{(c)} \omega_c. \tag{7}$$

Multi-criteria analysis of maritime container terminals

We used the data from Table 2 in the AHP multi-criteria analysis of Baltic container terminals' competitiveness. The goal of the proposed multi-criteria scheme was to indicate the best terminal among $N = 18$ alternatives (CT*i*, where $i = 1, 2, ..., 18$) based on $C = 7$ criteria (*cj*, where $j = 1, 2, ..., 7$). Five of the seven criteria were maximized (stimulants), while two were minimized (destimulants). First, we determined our own weights for each criterion. Table 3 below presents all criteria along with their weights and desired direction.

The biggest weight (8) was assigned to criteria c_1 and c_4 since these parameters significantly affect the efficiency and accessibility of maritime container bases. A slightly lower weight (7) was assigned to the maximum water depth at the quay (c_5), as it is a parameter that determines the size of ships that can call at a given port, consequently affecting the ability to maintain oceanic connections. The c_3 (weight 5) and c_2 (weight 4) criteria were considered the least important as some container terminals use other types of equipment for handling multimodal units at the quay and in the storage yard. The technical equipment of container terminals may include gantry cranes, side lift trucks, front lift trucks, or reach stackers. However, both criteria were included in the analysis because the use of specialized equipment significantly improves the efficiency of container bases. In the last two criteria (the distance from motorways and expressways/national roads, as well as national railway stations), the parameters go to the minimum, and their weight is 6.

Table 3. Criteria selected for the competitiveness analysis along with their weights and desired direction

Criterion	c_1	c_2	c_3	c_4	c_5	c_6	c_7
Direction	max	max	max	max	max	min	min
Weight (w_j[s])	8	4	5	8	7	6	6

Source: authors.

Table 4 presents the AHP ranking for subjective criteria weights. The objects (container terminals) are listed, starting with those with the biggest annual transshipment capacity in TEUs. The table also shows the utility function values for each container terminal.

Table 4. The AHP multi-criteria rankings with utility function values (N = 18 CT) for subjective criteria weights

Terminal	CT_n	*Rank*	U_{CT}
DCT Gdańsk (PL)	CT_1	4	0.0867
Mussalo CT (FIN)	CT_2	7	0.0653
FCT (RUS)	CT_3	6	0.0709
Vuosaari (FIN)	CT_4	1	0.1231
BCT Gdynia (PL)	CT_5	13	0.0343
Bronka CT (RUS)	CT_6	10	0.0444
Petrolesport (RUS)	CT_7	3	0.0880
APMT (S)	CT_8	5	0.0837
CTSP (RUS)	CT_9	15	0.0270
APM–T–CS (DK)	CT_{10}	8	0.0571
MCT (EE)	CT_{11}	11	0.0435
GCT Gdynia (PL)	CT_{12}	2	0.0891
Smelte (LT)	CT_{13}	12	0.0377
KCT Klaipeda (LT)	CT_{14}	16	0.0268
BCT Riga (LV)	CT_{15}	17	0.0201
Euroports Finland (FIN)	CT_{16}	14	0.0327
GCT Gävle (S)	CT_{17}	18	0.0191
Västhamnen (S)	CT_{18}	9	0.0503

Source: authors.

The highest position in the ranking goes to the Vuosaari terminal in Helsinki, with a $U_{CT[4]}$ = 0.1231. The next four places are taken by two Polish terminals, one Swed-

ish and one Russian, with U_{CT} values ranging from 0.0837 to 0.0891. If we consider the values of the utility function, the Finnish terminal has a clear advantage over the next four terminals. Two terminals – BCT in Riga in Latvia and GCT Gävle in Sweden – achieved the worst results.

As mentioned earlier, first, we assigned the criteria weights subjectively, given that the decision-maker can provide scaled preferences of pairs of the decision criteria and alternatives with acceptable inconsistency. Thus, later in our study, we assessed criteria weights another way using the entropy method (Shannon 1948). In this approach, the evaluations of the decision alternatives at a certain criterion determine its relative importance without the direct involvement of the decision-maker. The main idea of this method is that the estimation of a criterion's weight is based on dispersion in the evaluations of the variants at the criterion (Al-Aomar 2010).

Given decision matrix $\mathbf{Q}_{[N\times K]}$, whose elements correspond to the values presented in Table 2, we must create matrix $\mathbf{M}_{[N\times K]}$, where $mij = qij$ for stimulants and $mij = 1/qij$ for destimulants. Next, matrix $\mathbf{M}$ must be normalized according to formula (4) to obtain matrix $\hat{\mathbf{M}}$. Based on matrix $\hat{\mathbf{M}}$, the degree of the internal divergence of evaluations dj is calculated for each criterion separately (8):

$$d_j = 1 + \frac{1}{\ln N}\sum_{i=1}^{N} \hat{m}_{ij} \ln \hat{m}_{ij}. \tag{8}$$

Finally, we use values dj to determine weights wj for the individual criteria (9):

$$w_j = \frac{d_j}{\sum_{j=1}^{K} d_j}. \tag{9}$$

Importantly, we can correct subjective weights $wj^{[s]}$ by using the weights obtained in the entropy method (10):

$$\overline{w}_j = \frac{w_j w_j^{[s]}}{\sum_{j=1}^{K} w_j w_j^{[s]}}. \tag{10}$$

Considering the formulas presented above, we determined two other sets of criterion weights. Table 5 shows all three sets of weights, where the subjective weights shown in Table 3 were normalized.

Table 5. Three sets of criteria weights

Criterion	c_1	c_2	c_3	c_4	c_5	c_6	c_7
Direction	max	max	max	max	max	min	min
subjective	0.182	0.091	0.114	0.182	0.159	0.136	0.136
entropy	0.094	0.417	0.080	0.104	0.005	0.192	0.107
corrected	0.138	0.304	0.073	0.152	0.007	0.210	0.117

Source: authors.

The values of two weights increased: the number of RTGs and the distance from the main roads. Note the significant increase in the second criterion, where the weight value increased four times and three times to the entropy method and the correction of the initial weights by the entropy method, respectively. On the other hand, the values of the remaining five weights decreased. Among them, there is a significant decrease in the significance of the c_5 criterion (maximum depth at the quay) from 0.159 to 0.005 and 0.007, respectively. Table 6 presents AHP rankings for all sets of weights.

Table 6. The AHP multi-criteria rankings (N = 18 CT) for subjective criteria weights, entropy, and corrected subjective weights

Terminal	CT_n	*Subjective weights*	*Entropy weights*	*Corrected entropy weights*
DCT Gdańsk (PL)	CT_1	4	1	1
Mussalo CT (FIN)	CT_2	7	15	15
FCT (RUS)	CT_3	6	7	6
Vuosaari (FIN)	CT_4	1	5	3
BCT Gdynia (PL)	CT_5	13	6	7
Bronka CT (RUS)	CT_6	10	9	9
Petrolesport (RUS)	CT_7	3	2	2
APMT (S)	CT_8	5	10	10
CTSP (RUS)	CT_9	15	3	5
APM–T–CS (DK)	CT_{10}	8	16	16
MCT (EE)	CT_{11}	11	11	11
GCT Gdynia (PL)	CT_{12}	2	4	4
Smelte (LT)	CT_{13}	12	8	8
KCT Klaipeda (LT)	CT_{14}	16	13	14
BCT Riga (LV)	CT_{15}	17	18	18
Euroports Finland (FIN)	CT_{16}	14	12	12

Terminal	CT_n	*Subjective weights*	*Entropy weights*	*Corrected entropy weights*
GCT Gävle (S)	CT_{17}	18	17	17
Västhamnen (S)	CT_{18}	9	14	13

Source: authors.

There are changes in the rankings if we use a different set of weights. As changes in relation to the first ranking (subjective weights) are clearly visible, the differences between two successive rankings are insignificant. If the entropy method is used, first place goes to Polish terminal DCT Gdańsk, which has a significant advantage over second place Petrolesport (Russia). In both rankings, the next five positions are occupied by two Polish (GCT Gdynia and BCT Gdynia), two Russian (FCT St Petersburg and CTSP St Petersburg) and one Finnish terminal (Vuosaari Helsinki – winner of the first ranking with subjective weights), where U_{CT} values range from 0.0621 to 0.0741.

Finally, we decided to measure the similarity of the three rankings. We used Spearman's rank correlation coefficient r_s (Zeliaś 2000, p. 91):

$$r_s = \frac{6\sum_{i=1}^{N} d_i}{N^3 - N}, \tag{11}$$

where *di* is the difference between the positions in the ranking of a given object and r_s take values from the interval ⟨–1, 1⟩. Values close to 1 indicate a high similarity of rankings. Once again, there is a high similarity when we compare both rankings that used weights obtained through the entropy method. The similarity between the ranking based on subjective weights and the other two rankings can be considered moderate.

Table 7. Values of r_s coefficients

	Entropy weights	*Corrected entropy weights*
Subjective weights	0.552	0.639
Entropy's weights	×	0.987

Source: authors.

Conclusion

This article identified eighteen major maritime container terminals located in the BSR, gathered the information for $C = 7$ criteria related to the technical infrastructure and location of the terminals, and presented the AHP multi-criteria analysis of the terminals' competitiveness. Thus, our research adds to the literature that has yielded results on the competitive advantage of Baltic seaports. More specifically, the goal of the multi-criteria scheme was to indicate the best terminal among $N = 18$ alternatives based on five stimulants and two destimulants. Since the adopted values of the weights of individual criteria are a critical factor in all multi-criteria analyses, the rankings were built based on both the subjective weights of the decision-maker and the objectified weights obtained using the entropy method.

The results allow us to conclude that out of all eighteen terminals, four should be rated the highest: two Polish terminals (DCT Gdańsk and BCT Gdynia), one Russian (Petrolesport), and one Finnish (Vuosaari). On the other hand, three terminals belong to the group of the lowest rated objects: GCT Gävle (Sweden), BCT Riga (Latvia), and KCT Klaipeda (Lithuania). Moreover, if we change the weights from subjective to objective (entropy method), the significant change in the position of four terminals deserves particular attention. Two terminals, CTSP (Russia) and BCT Gdynia (Poland), obtained better positions in the objective ranking, while the position of two other terminals, APM-T-CS (Denmark) and Mussalo CT (Finland), worsened.

Even though the rankings differ, we can identify groups of similarly assessed terminals. Moreover, the Spearman's rank coefficients allow us to conclude that these rankings are at least moderately similar. At the same time, we are aware that our analysis of the competitiveness of maritime container terminals in the BSR may be further developed. Hence, in further stages of the research, we plan, inter alia, to complete the analysis based on other discrete multi-criteria methods. We also plan to analyze the effectiveness of terminals and the use of their potential, and then incorporate the results into an extended multi-criteria analysis.

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Wielokryteriowa analiza konkurencyjności dużych terminali kontenerowych Morza Bałtyckiego

Szybki wzrost wolumenu międzynarodowych przewozów kontenerowych wymusza poprawę konkurencyjności całego łańcucha transportowego, w tym morskich terminali kontenerowych. Celem artykułu jest identyfikacja liczby i lokalizacji głównych bałtyckich terminali kontenerowych oraz przeprowadzenie wielokryteriowej analizy konkurencyjności morskich terminali kontenerowych w regionie Morza Bałtyckiego (RMB). W naszym badaniu zastosowaliśmy metodę AHP, aby uzyskać subiektywną ocenę wag kryteriów, a także metodę entropii, aby uzyskać obiektywne wagi kryteriów. Dzięki temu możemy ocenić przewagi konkurencyjne każdego z wyszczególnionych terminali w danym regionie. Jako jedni z pierwszych badamy konkurencyjność poszczególnych morskich terminali kontenerowych w RMB. Z tego powodu nasze badanie stanowi cenne uzupełnienie innych prac poświęconych identyfikacji przewag konkurencyjnych portów bałtyckich.

Słowa kluczowe: morskie terminale kontenerowe, Morze Bałtyckie, konkurencyjność, analiza wielokryteriowa, AHP, entropia