



VILNIUS GEDIMINAS TECHNICAL UNIVERSITY
FACULTY OF BUSINESS MANAGEMENT
DEPARTMENT OF ECONOMICS ENGINEERING

Gintarė Volskytė

**ŽIEDINĖS EKONOMIKOS KAIP VIENO IŠ DARNAUS
VYSTYMOSI MODELIŲ VERTINIMAS**

**ASSESSMENT OF CIRCULAR ECONOMY AS ONE OF THE
MODELS OF SUSTAINABLE DEVELOPMENT**

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Pavadinimas **Žiedinės ekonomikos kaip vieno iš darnaus vystymosi modelių vertinimas**
Autorius **Gintarė Volskytė**
Vadovas **Viktorija Skvarciany**

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Anotacija

Mokslinėje literatūroje vis dar diskutuojama apie žiedinę ekonomiką kaip vieną iš darnaus vystymosi modelių. Todėl šiuo straipsniu siekiama įvertinti žiedinę ekonomiką kaip vieną iš darnaus vystymosi modelių EBPO šalyse. Tyrimui buvo naudojami šie metodai: analitinės hierarchijos proceso metodas (AHP), pirmenybės eiliškumo pagal panašumą į idealų sprendimą (TOPSIS) technika, įvertinimas, pagrįstas atstumu nuo vidutinio sprendimo (EDAS) ir meta-regresinė analizė. Žiedinės ekonomikos rodiklių svoriams nustatyti buvo naudojamas AHP metodas su ekspertų pagalba. TOPSIS ir EDAS metodai buvo naudojami norint atskleisti, kurios EBPO šalys turi stipriausią žiedinę ekonomiką. Meta-regresijos analizės metodas buvo naudojamas siekiant nustatyti, ar žiedinė ekonomika daro įtaką tvariai plėtrai. Remiantis AHP, didžiausią poveikį žiedinei ekonomikai turi susidariusios komunalinės atliekos, su aplinka susijusių technologijų patentai, atsinaujinanti energija, CO2 emisija ir naudojamų lengvųjų automobilių skaičius. Rezultatai atskleidė, kad stipriausia žiedinė ekonomika turi Japoniją, o silpniausia - Australiją (pagal TOPSIS) ir Meksiką (pagal EDAS). Be to, remiantis meta-regresijos analize, nedarbo lygis, skurdo lygis, oro taršos poveikis ir CO2 emisija vienam gyventojui yra statistiškai reikšmingi rodikliai ir jie daro neigiamą poveikį tvariai plėtrai, o bendrosios vidaus išlaidos moksliniams tyrimams ir plėtrai, atsinaujinančiai energijai, naudojamų lengvųjų automobilių skaičius ir namų ūkiai, turintys prieigą prie interneto, yra statistiškai reikšmingi rodikliai, ir jie daro teigiamą poveikį darniai plėtrai.

Struktūra: įvadas, žiedinės ekonomikos teorija, kaip vienas iš darnaus vystymosi modelių, žiedinės ekonomikos, kaip vieno iš darnaus vystymosi modelių, vertinimo metodika, žiedinės ekonomikos, kaip vieno iš darnaus vystymosi modelių, vertinimo empiriniai rezultatai, išvados, rekomendacijos ir nuorodos.

Darbo apimtis: 79 p. be priedų, 22 iliustracijos, 18 lentelių, 105 literatūros šaltiniai.

Prasminiai žodžiai: Raktiniai žodžiai: žiedinė ekonomika; tvarus vystymasis; analitinės hierarchijos proceso metodas (AHP), technika, pagal kurią teikiama pirmenybė pagal panašų į idealų sprendimą (TOPSIS); vertinimas pagal atstumą nuo vidutinio sprendimo (EDAS); meta-regresinė analizė.

Gintarė Volskytė



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Annotation

There are still debates in the scientific literature about the circular economy as one of the models of sustainable development. Therefore, the current article aims at assessing of the circular economy as one of the models of sustainable development in the OECD countries. The following methods were employed for the research: analytic hierarchy process method (AHP), a technique for order of preference by similarity to ideal solution (TOPSIS), an evaluation based on distance from average solution (EDAS), and meta-regression analysis. AHP method with experts' assistance was used to determine the weights for the indicators of the circular economy. TOPSIS and EDAS methods were used to reveal which OECD countries have the strongest circular economy. The meta-regression analysis method was used to determine if the circular economy has an impact sustainable development. Based on the AHP, the municipal waste generated, patents in environment-related technologies, renewable energy, CO2 emission, and the number of passenger cars in use have the most significant impact on the circular economy. The results revealed that the strongest circular economy has Japan, and the weakest has Australia (according to TOPSIS) and Mexico (according to EDAS). Additionally, based on the meta-regression analysis, unemployment rate, poverty rate, air pollution exposure, and CO2 emission per capita are statistically significant indicators, and they do have a negative impact on sustainable development, while gross domestic expenditure on R&D, renewable energy, number of passenger cars in use, and households with Internet access are statistically significant indicators, and they do have a positive impact on sustainable development.

Structure: introduction, theoretical framework of circular economy as one of the models of sustainable development, methodology of the assessment of the circular economy as one of the models of sustainable development, and empirical results of the assessment of the circular economy as one of the models of sustainable development, conclusions, recommendations, and reference.

Thesis consists of: 79 p. without appendices, 22 figures, 18 tables, 105 references.

Keywords: Keywords: circular economy; sustainable development; analytic hierarchy process (AHP); technique for order of preference by similarity to ideal solution (TOPSIS); evaluation based on distance from average solution (EDAS); meta-regression analysis.

Gintarė Volskytė



CONTENT

CONTENT	7
INTRODUCTION	12
1. THEORETICAL FRAMEWORK OF CIRCULAR ECONOMY	14
1.1. Concept of circular economy	14
1.2. Circular economy as one of the models of sustainable development	21
1.3. Factors of circular economy	24
2. METHODOLOGY FOR ASSESSMENT OF CIRCULAR ECONOMY AS ON OF THE MODELS OF SUSTAINABLE DEVELOPMENT.....	29
3. EMPIRICAL RESULTS OF ASSESSMENT OF CIRCULAR ECONOMY AS ON OF THE MODELS OF SUSTAINABLE DEVELOPMENT.....	39
3.1. Circular economy criteria analysis.....	39
3.2. Determination of importance weights of circular economy indicators using Analytic Hierarchy Process (AHP) method.....	50
3.3. Circular economy assessment results using Technique for Order of Preference by Similarly to Ideal Solution (TOPSIS)	53
3.4. Circular economy assessment results using Evaluation based on Distance from Average Solution (EDAS)	57
3.5. Assessment of the circular economy as one of the models of sustainable development using fixed effect regression model	61
CONCLUSIONS.....	67
Recommendations	70
REFERENCES	71

LIST OF FIGURES

Fig. 1. Thesis structure	13
Fig. 2. Circular economy loops	15
Fig. 3. The Stages of application of MCDA.....	32
Fig. 4. Air pollution exposure (exposure PM2.5, ($\mu\text{g}/\text{m}^3$)), 2018-2019.....	40
Fig. 5. Electricity total production, TWh, 2018-2019	41
Fig. 6. Renewable energy, as % of primary energy supply, 2018-2019	41
Fig. 7. Patents in environment-related technologies, number, 2018-2019.....	42
Fig. 8. Gross domestic expenditures on R&D, as % of GDP, 2018-2019	43
Fig. 9. CO ₂ emission per capita, Tonnes/capita, 2018-2019	44
Fig. 10. Number of cars in use per 1000 capita, 2018-2019	44
Fig. 11. Gross domestic product, USD/capita, 2018-2019.....	45
Fig. 12. Unemployment rate as % of labour force, 2018-2019	46
Fig. 13. Poverty rate, %, 2018-2019.....	47
Fig. 14. Household disposable income Gross adjusted, USD per capita, 2018-2019	48
Fig. 15. Households with Internet access, %, 2018-2019	48
Fig. 16. Municipal waste generated, Tonnes per 1000 capita, 2018-2019.....	49
Fig. 17. Performance scores got by TOPSIS during 2018-2019.....	55
Fig. 18. Performance scores of OECD regions got by TOPSIS during 2018-2019...	56
Fig. 19. Circular economy analysis between the United States and Mexico, 2019 ...	57
Fig. 20. Appraisal scores get by EDAS, 2018-2019	59
Fig. 21. Appraisal scores of OECD regions got by EDAS during 2018-2019.....	60
Fig. 22. Circular economy analysis between Japan and Mexico, 2019.....	61

LIST OF TABLES

Table 1. Concept of the circular economy (CE).....	16
Table 2. Circular economy barriers	18
Table 3. Summary of the EU 2015 Action Plan for the Circular Economy and EU Strategy for Plastics in Circular economy	20
Table 4. Relationship between circular economy and sustainability	23
Table 5. Circular economy indicators	27
Table 6. Circular economy indicators	30
Table 7. Random average consistency indexes for various n	32
Table 8. Hierarchical model for the assessment of the circular economy	50
Table 9. Saaty's scale of evaluation	51
Table 10. List of experts.....	51
Table 11. Calculated weights of factors of the circular economy and consistency ratio (CR)	52
Table 12. Final weights of factors of the circular economy	52
Table 13. Performance scores get by TOPSIS method, 2018-2019. Note: PI – performance score.....	54
Table 14. Performance scores get by TOPSIS method according OECD regions, 2018-2019. Note: PI – performance score	55
Table 15. Appraisal scores get by EDAS method, 2018-2019. Note: AS – appraisal score.....	58
Table 16. Appraisal scores get by EDAS method, 2018-2019. Note: AS – appraisal score.....	59
Table 17. Comparative analysis between the results of EDAS and Sustainable Development Goals Index (SDGI), 2019	62
Table 18. Estimates of Fixed Effects regression	65

LIST OF APPENDICES

Appendix 1. Survey used in the research	81
Appendix 2. Pairwise comparison matrix of expert no. 1	84
Appendix 3. Pairwise comparison matrix of expert no. 2	85
Appendix 4. Pairwise comparison matrix of expert no. 3	86
Appendix 5. Pairwise comparison matrix of expert no. 4	87
Appendix 6. Pairwise comparison matrix of expert no. 5	88
Appendix 7. Pairwise comparison matrix of expert no. 6	89
Appendix 8. Standardized matrix of expert no. 1.....	90
Appendix 9. Standardized matrix of expert no. 2.....	91
Appendix 10. Standardized matrix of expert no. 3.....	92
Appendix 11. Standardized matrix of expert no. 4.....	93
Appendix 12. Standardized matrix of expert no. 5.....	94
Appendix 13. Standardized matrix of expert no. 6.....	95
Appendix 14. Random average consistency indexes for various n	95
Appendix 15. Result of calculation of normalized matrix in TOPSIS model, 2018 ..	96
Appendix 16. Results of calculation of normalized matrix in TOPSIS model, 2019	97
Appendix 17. Calculation of weighted normalized matrix by TOPSIS, 2018	98
Appendix 18. Calculation of weighted normalized matrix by TOPSIS, 2019	100
Appendix 19. Ideal and anti-ideal values by TOPSIS, 2018.....	101
Appendix 20. Ideal and anti-ideal values by TOPSIS, 2019.....	102
Appendix 21. TOPSIS calculation of the Euclidean distance from the ideal best (SI+) and anti ideal-best (SI-), calculation of the performance scores (PI), 2018-2019.....	102
Appendix 22. Results of calculation of normalized matrix in TOPSIS model, 2018	103
Appendix 23. Results of calculation of normalized matrix in TOPSIS model, 2019	104
Appendix 24. Calculation of weighted normalized matrix by TOPSIS, 2018	104
Appendix 25. Calculation of weighted normalized matrix by TOPSIS, 2019	105
Appendix 26. Ideal and anti-ideal values by TOPSIS, 2018.....	105
Appendix 27. Ideal and anti-ideal values by TOPSIS, 2019.....	105
Appendix 28. TOPSIS calculation of the Euclidean distance from the ideal best (SI+) and anti ideal-best (SI-), calculation of the performance scores (PI), 2018-2019.....	106
Appendix 29. Collected data and calculated average solution (Av), 2018	107
Appendix 30. Collected data and calculated average solution (Av), 2019	108

Appendix 31. Positive distance from Average (PDA), 2018	109
Appendix 32. Negative distance from Average (NDA), 2018	111
Appendix 33. Positive distance from Average (PDA), 2019	112
Appendix 34. Negative distance from Average (NDA), 2019	113
Appendix 35. Weighted sum of PDA, 2018.....	115
Appendix 36. Weighted sum of NDA, 2018	116
Appendix 37. Weighted sum of PDA, 2019.....	117
Appendix 38. Weighted sum of NDA, 2019	119
Appendix 39. Normalized values of SP_i and SN_i and final results (AS_i), 2018.....	121
Appendix 40. Normalized values of SP_i and SN_i and results (AS_i), 2019	122
Appendix 41. Collected data and calculated average solution (Av), 2018	123
Appendix 42. Collected data and calculated average solution (Av), 2019	123
Appendix 43. Positive distance from Average (PDA), 2018	124
Appendix 44. Positive distance from Average (PDA), 2019	124
Appendix 45. Negative distance from Average (NDA), 2018	125
Appendix 46. Negative distance from Average (NDA), 2019	125
Appendix 47. Weighted sum of PDA, 2018.....	126
Appendix 48. Weighted sum of PDA, 2019.....	126
Appendix 49. Weighted sum of NDA, 2018	127
Appendix 50. Weighted sum of NDA, 2019	127
Appendix 51. Normalized values of SP_i and SN_i and final results (AS_i), 2018.....	128
Appendix 52. Normalized values of SP_i and SN_i and final results (AS_i), 2019.....	128
Appendix 53. Test of normality	129
Appendix 54. Spearmans's corelation.....	130
Appendix 55. Estimates of Fixed Effects regression	132
Appendix 56. Assessment of Sustainable Socioeconomic Development in European Union Countries.....	131

INTRODUCTION

The relevance of the topic. The circular economy concept is received increasing attention at international and national policy levels and increasingly discussed among researchers, scientists, and policymakers all over the world. Due to the constantly increasing environmental issues, countries, companies, and policymakers starting to consider new models for environmental protection. One of the models is the circular economy, which tries to replace the current linear economy model, which is highly harmful to the environment with the modern economy model with the main principles of reducing, reusing, recycling, and recovering. The circular economy promotes the adaptation of close the loop process aiming to increase the efficiency of the resources through long-term value creation, waste minimisation, tries to keep products, components, and materials at their highest utility and value. The main reason behind the accelerating the process of the circular economy implementation rises from the pressure to reduce the negative environmental impacts, that cover resource scarcity, possibilities to prevent environmental impact from current actions. The measurement of the circular economy is at the center of many questions recently raised by scientists, researchers, and policymakers. These questions are: what is the concept of the circular economy? What are the factors that could be used to assess the circular economy? What are the appropriate methods to assess the circular economy? What are the appropriate methods to identify the importance weights of the circular economy criteria? How to measure the progress of the transition toward the circular economy? How is circularity measured in business and economies? Therefore, this research tries to contribute to a better understanding of the circular economy concept and implementation process.

The problem of the research – does circular economy is one of the models of sustainable development.

The objective of the research – the circular economy as one of the models of sustainable development.

The purpose of this research – to investigate whether the circular economy could be treated as one of the models of sustainable development.

Tasks:

2. To systemise scientific literature aimed at assessing the concept of the circular economy.
2. Based on the analysis of scientific literature and theoretical aspects provide the methodology for investigating whether the circular economy could be treated as one of the models of sustainable development.

3. To assess the circular economy as one of the models of sustainable development in OECD countries, for the 2018-2019 period.

Methods of research. analysis and systematisation of scientific theories, descriptive statistics, Analytic Hierarchy Process (AHP), Multi-Criteria Decision Method (MCDA), Technique for Order of Preference by Similarly to Ideal Solution (TOPSIS), Evaluation based on Distance from Average Solution (EDAS), meta-regression analysis.

Research structure. The research will consist of three interrelated parts. In the first part of the research will be analysed and assessed the theoretical aspects of the circular economy. In the second part methodologies for the assessment of the circular economy as one models of sustainable development in OECD countries in the 2018-2019 period will be described. In the last part will be presented empirical findings of the assessment of the circular economy as one of the models of sustainable development and clarify the outcomes of the calculations.

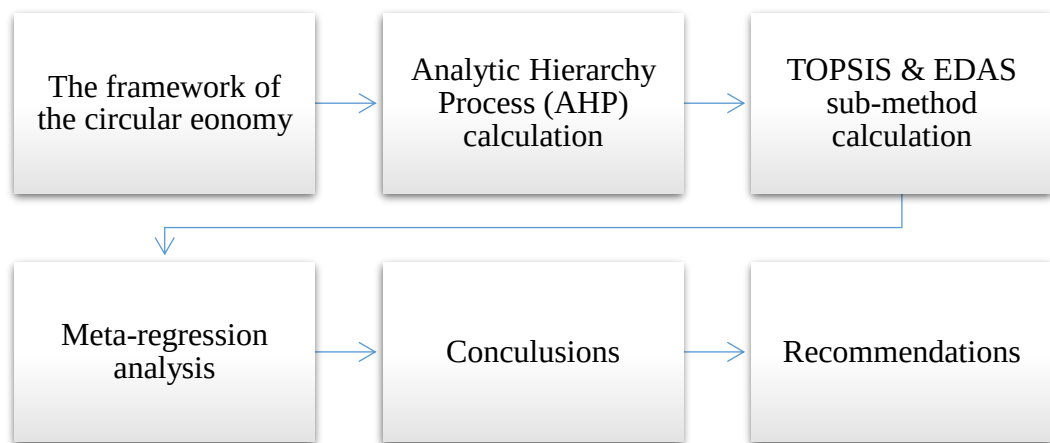


Fig. 1. Thesis structure

Source: created by author.

Limitations of the research. In the research only OECD countries will be analysed. Due to the lack of data, Colombia, Iceland, Israel, Switzerland, and New Zealand will be not included in the research. Additionally, due to the lack of information, the newest data will cover the 2018-2019 data.

1. THEORETICAL FRAMEWORK OF CIRCULAR ECONOMY

In this part will be provided a broader understanding of the research problem and will be discovered important variables related to the topic. The literature review will focus on the scientific research and studies related to the concept of the circular economy, the circular economy components, and factors used to assess the circular economy. In this part will be provided the answer to the first task, which is to systemize scientific literature aimed at assessing the concept of the circular economy.

1.1. Concept of circular economy

The circular economy could be explained as a systematic approach to economic development created for the benefit of business, society, and the environment. The concept of the circular economy can be explained as an economic model with the main aim of resource efficiency through long-term value creation, waste minimisation, reduction of closed loops products considering the environmental protection (Morseletto, 2020). The circular economy could be explained in various ways (see in Table 1). Many scientists the circular economy describe as the regenerative system, which replaces the outdated model of take, make, and dispose (Hobson, 2015). Moreau, Sahakian, Griethuysen, and Vuille (2017) claim that circular economy preserves and enhances natural capital, optimises resource yields, and minimises system. Additionally, the circular economy could be explained as an economic model in which planning, resource allocation, purchasing, production and processing are designed and managed as a process to maximise ecosystem functioning and human well-being (Murray, Skene, & Haynes, 2017). Moreover, Kirchherr, Reike, and Hekkert (2017) define the circular economy as a system based on business models that encourage the reduction, reuse, and recycling of materials at different level intending to achieve sustainable development. Furthermore, the circular economy could be explained through the output and input rule, and operational principle. The output rule points out the importance of waste and the assimilation limit of the environment. The input rule points out the importance of renewable and non-renewable resource exploitation including technological development. The operational principle points out the significance of efficiency of improvements (Simon, 2019). Additionally, the circular economy recognises the importance of the need of efficiency work in businesses, organizations, individuals, globally and locally. The main goal of the circular economy is to replace the outdated take, make and dispose of process and model, which is highly wasteful, with a closed system of make, use, reuse, remake, and recycle that a more responsible all-encompassing and abundant resource management process. The circular economy proposes a completely different

approach comparing to the outdated processes of take, make, and dispose model. The circular economy concept provides more comprehensive importance to the closed-loop economy and process. Normally, the circular economy could be presented by the five significant loops, determining the principles of the circular economy. The circular economy loops consist of raw materials extractions, product design, production and remanufacturing, consumption, and waste management (see in Fig. 2).

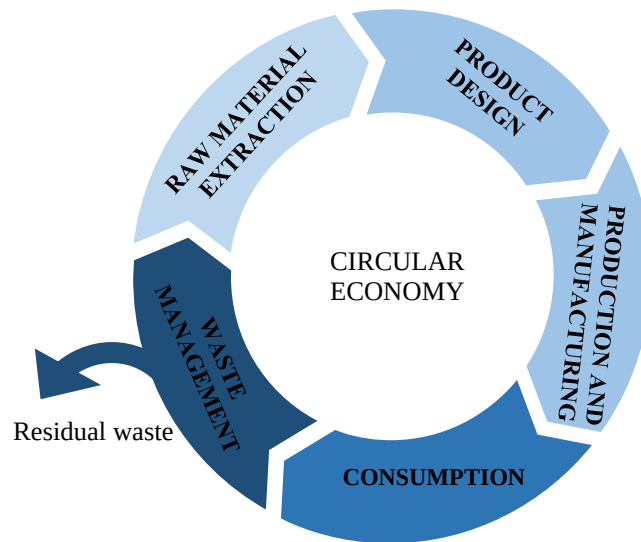


Fig. 2. Circular economy loops

Source: prepared by author according Ecologic Institute, 2020.

The raw material extraction loop points out the significance of environmental preservation – natural resources should be used in the most efficient way and without depleting the planet’s resources. Additionally, it points out that recycled raw materials could be injected back into the economy as secondary raw materials. Besides, to improve the quantity and quality of secondary raw materials, waste management needs to be improved (European Commission, 2020c). Product design loop is understood as a keyway to build the circular economy by creating long-lasting products that are easy to reuse and recycle. It is necessary to consider circularity aspects when designing and developing products. Products must be easily disassembled and separated into different components and materials, to facilitate the replacement of defective components, and to extend the service life of products in various ways (Shahbazi & Jönbrink, 2020). The production and remanufacturing loop aims to turn used, worn, damaged, or obsolete products into functional products with originality (Tjahjono & Ripanti, 2019). In the consumption loop, the significance is emphasised on customers' behaviour. The consumption loop emphasises the importance that customers have to take into

Table 1. Concept of the circular economy (CE)

Definition of the concept of the circular economy (CE)	Authors
The circular economy is restorative and regenerative system with the main aims to keep products, components, and materials at their highest utility and value, ensuring the resource efficiency through long-term value creation, waste minimization, reduction of closed loops products considering the environmental protection.	Cullen (2017), Morseletto (2020), Moreau, Sahakian, Griethuysen, & Vuille (2017)
The Circular economy could be explained by three main factors, called 3R's principles: reduction, reuse, and recycle.	Ghisellini, Cialani, & Ulgiati (2016)
The circular economy replaces old end-of-life concept shifting towards renewable resource use, restoration, eliminating waste by creating better quality materials, effective systems, and business models. Also, circular economy is based on business models that encourage the reduction, reuse, recycling, and recycling of materials operating at different levels to achieve sustainable development. The circular economy could be explained as a development protecting and increasing natural capital, optimizing the return on resources, and reducing systemic risk by managing finite stocks and renewable flows.	Hobson (2015), Moreau, Sahakian, Griethuysen, & Vuille (2017), Kirchherr et al. (2017)
The circular economy is an economic model in which planning, resource allocation, purchasing, production and processing are designed and managed as a process and output to maximize ecosystem functioning and human well-being.	Murray, Skene, & Haynes (2017)
The circular economy aims to extend the useful life of materials and to promote recycling to maximize the service of materials per resource, while minimizing environmental impact and resource use.	Tisserant et al. (2017)
The circular economy could be explained as the system where products are designed to be easier to recycle, reuse, and remanufacture. It should replace the traditional, linear pattern of collection, production, and disposal that has hitherto dominated the economy.	Wijkman & Skånberg (2016)
The circular economy could be explained through the output and input rule, and operational principle. The output rule points out the importance of waste and the assimilation limit of the environment. The input rule points out the importance of renewable and non-renewable resource exploitation including technological development. The operational principle points out the importance of efficiency improvements	Simon (2019)

Source: prepared by author based on Chulle (2017), Ghisellini, Cialani, & Ulgiati (2016), Moreau, Sahakian, Griethuysen, & Vuille (2017) and others.

consideration the environmental impact and to be more greener by choosing circular and sustainable products and services, that reduce environmental footprint and support a move towards a more circular economy (European Commission, 2020b). The waste management loop closes the loop in the circular economy. Notwithstanding, the main goal of the circular economy is to reach and maintain economic prosperity, with a high contribution to environmental quality, social equity, and future generation (Kirchherr et al., 2017).

The main reason behind the accelerating the process of the circular economy implementation rises from the pressure to reduce a negative environmental impacts, that cover resource scarcity, possibilities to prevent environmental impact from current actions (Linder & Williander, 2015, Lacy & Rutqvist, 2015). The core concept of the circular economy recognises the importance of economic efficiency at all scales of business, organizations, and individuals. This concept offers a more sustainable business through activities that preserve the value of materials and products already in circulation for longer (Ranta, Aarikka-Stenroos, & Väisänen, 2021). The circular economy concept provides a large business opportunity that can bring huge benefits to everyone – society, businesses, and the environment (Bressanelli, Adrodegari, Perona, & Saccani, 2018). However, to take advantage of this opportunity, companies need to adopt the circular economy in their business, moving from linear to more circular thinking in supply chains and from product-orientated to service-orientated propositions (Urbinati, Chiaroni, & Chiesa, 2017). The implementation of the concept of the circular economy is at an early stage, but there are various examples of how the circular economy has started to promote more sustainable production and consumption practices (Kalmykova, Sadagopan, & Rosado, 2018). The concept of the circular economy has largely shaped waste management and recycling practices, and the practice of reusing or reproducing materials (Reike, Vermeulen, & Witjes, 2018). Nevertheless, some companies are increasingly working to extend the life cycle of their products by offering maintenance and repair services (Lewandowski, 2018). Despite the many possibilities of the circular economy, some barriers exist regarding implementing the circular economy concept. (see in Table 2). According to the Salmenperä, Pitkänen, Kautto, Saikku (2021), and Tura et al. (2019), there are economic and market-related, technological and information-related, institutional and regulatory, and social-cultural barriers. Economic and market-related barriers are connected to the economic vulnerability, viability, market uncertainty, investment costs, financing, and pricing of virgin materials. The rapid changes in the market, increasing business competition, lack of financing from the government, lack of government and regional support, lack of resources in general, difficulties in finding investments aggravate the implementation process of the circular economy.

Table 2. Circular economy barriers

Barriers	Related variables	Explanation
Economic and market related barriers	Economic vulnerability and viability	High initial investment costs and lack of financial capability and support
		Lack of governmental and regional support
	Investment costs	Developing new business and planning investment takes time
	Market uncertainty	Rapid changes in market
		Business competition
	External financing	Lack of financing from the government
		Difficult to find investments
	Virgin material pricing	Virgin materials are cheap compared to recycled materials
Technological and information-related barriers	Technological solutions and skills	Increased technical difficulty in handling circular economic material flows
	Innovations	Product design should take circularity into account
	Information exchange	Lack of tools and data
		Lack of indicators for circular economic
	R&D	Lack of assessment of environmental impacts
		Small companies lack tools and knowledge
Institutional and regulatory barriers	Regulations	Complex and overlapping regulation
		Administrative burdens and lack of knowledge
		Lack of circular economic know-how of political decision-makers
	Taxation and subsidies	High future uncertainty due to the fluctuations in taxes and governmental subsidies
Social-cultural barriers	Customer preferences and behaviour	Difficult to forecast the customers behavioural
	Public awareness and acceptance	Misconceptions and a lack of understanding concerning circular economy

Source: prepared by author based on Salmenperä, Pitkänen, Kautto, & Saikku (2021), Tura et al. (2019).

Technological and information-related barriers are connected to the technological solutions and skills, innovations, information exchange, and R&D. Also, it is emphasised that there is a lack of assessment of the environmental impact, lack of tools for small business, and lack of data on the market, which negatively affect the implementation of the circular economy concept. Other aspects that negatively affect the implementation process of the circular economy are regulation, taxation, and subsidies. Researchers single out that different regulations, lack of knowledge, administration burden, lack of public support further complicate the circular economy process. Social-cultural barriers consist of customer preferences and behavioural, and public awareness and acceptance. Scientists emphasise that in society exist misconceptions and a lack of understanding concerning the circular economy, also it is difficult to forecast customer behaviour (Salmenperä et al., 2021). The circular economy concept is currently received increasing attention at international and national policy levels and increasingly discussed among researchers and policymakers. The transition towards the circular economy requires a systemic change, where governments and whole regions must play the main role. According to Vanhamäki, Virtanen, Luste, & Manskinen (2020), the changes toward the circular economy are based on regional characteristics depending on

economic, social, environmental, and geographical factors. In addition, the transition to the circular economy requires common changes across all value chains, from product design to new business and market models, from new ways of turning waste into resources, and from new ways of dealing with customers. This means an overall systematic change not only in innovation and technologies area, but in organizations, societies, and policies too (European Commission, 2014a).

There are lots of critiques of the concept of the circular economy due to the remaining issues that are not solved yet. There is no general agreement on the exact definition of the social dimension and how it might affect inequality, the role of rights of consumers and users, and the resource allocation and labour utilization. Moreover, it is not clear whether the circular economy can ensure sustainability in a world where people's needs are very high (Schröder et al., 2019). Furthermore, it is necessary to overcome the financial, economic, and knowledge based barriers in order the circular economy would be profitable and environmental sustainable (Millette, Eiríkur Hull, & Williams, 2020). The circular economy barriers considered to be individuals' behaviours that are rooted in the beliefs, attitudes, cultural and social norms, lack of scientific and technological knowledge, and lack of governments' and community' awareness about environmental (Govindan & Hasanagic, 2017). Additionally, it is difficult to measure the financial benefits and profitability derived from the adaptation of the circular economy (Chiappetta Jabbour et al., 2020). On the other hand, the circular economy offers an opportunity to reinvent economy, encourages innovation, increases growth, and creates more robust employment (Ellen MacArthur Foundation ANBI, 2017). This brings benefits for businesses, industries, and citizens. Additionally, the circular economy ensures and promotes more innovative and efficient production and consumption patterns, protection of businesses from resource scarcity, opportunities for local jobs and social inclusion, optimisation of waste management, growth promotion and job creation (OECD, 2016).

One of the first countries that adopted the circular economy ideas is China, which in national development strategy in 2002 emphasises the importance of the circular economy. In the strategy was determined the requirements for cleaner production, introduced the eco-industrial parks, and introduced the plans to turn the urban areas into eco-cities (Winans, Kendall, & Deng, 2017, Ghisellini, Cialani, & Ulgiati, 2016, Ghisellini et al., 2016). On the contrary, the European Union took over the idea of the circular economy much later, but is still considered a front runner, as it has been particularly active in promoting the circular economy internationally (Winans et al., 2017). The idea of the transition of the circular economy was published in EU action plan for the Circular Economy (European Commission, 2015a). The action plan highly contributes to the transition toward the circular economy, with the main aim

to keep the products, material, and resources in the economy for as long as possible and minimised the waste for as much as possible. The key elements of action plan are production, consumption, waste management, market boosting for secondary raw materials and water reuse, priority areas, and monitoring progress toward the circular economy concept (European Commission, 2015b). In 2018, the European Commission adopted strategy for plastic in the Circular economy (European Commission, 2018). According to this strategy, by 2030 all plastics packaging should be recyclable (see in Table 3). Thus, the European Union is considered a key player in international environmental policy (Kern, Sharp, & Hachmann, 2020).

Table 3. Summary of the EU 2015 Action Plan for the Circular Economy and EU Strategy for Plastics in Circular economy

Area	Examples of European Commission carried out policies
Production	The European Commission will adapt the eco-design work plan to increase reparability, upgradability, durability, and recyclability of products.
Consumption	Include recommendations and proposes new rules regarding resource efficiency, re-use activities, and waste management.
Waste management	Long-term recycling targets for municipal, packaging waste; reduce landfill; promote greater use of economic instruments; general requirements for extended producer responsibility schemes.
Boosting the market for secondary raw materials and water reuse	Simplification of definitions and calculation methods; develop quality standards for secondary raw materials where they are needed; take a series of actions to facilitate water reuse; revised EU regulation on fertilisers and chemicals.
Priority areas	Emphasised the attention on plastics, food waste, critical raw materials, construction/demolition waste, and biomass and bioproducts.
Monitoring progress towards CE	Develop a monitoring framework for the circular economy.
Plastics	By 2030 all plastics packaging should be recyclable by increasing investments and innovation; improve the economics and quality of plastic recycling

Source: prepared by author based European Commission.

Economic actors as businesses and customers are the main driving force for the circular economy. Therefore, the long-term involvement is obligatory at all levels from countries, regions, and cities, to move as soon as possible toward the circular economy. According to the European Commission, the action plan and strategy for the circular economy will ensure the business against resource scarcity, promote the competitiveness, and create the new jobs. On the other hand, it will highly contribute to the reduction of the negative consequences of industrial actions (European Commission, 2015a).

To conclude, there are many explanations of the circular economy, however, the most common definition of the circular economy could be explained as a new economic system that replaces the end-of-life concept with the main principles of reducing, reusing, recycling, and recovering. The circular economy aims for the efficiency of resources through long-term value

creation, waste minimisation, reduction of closed loops products considering environmental protection. Additionally, the circular economy tries to maintain economic prosperity with a high contribution to environmental quality, social equity, and future generation. The circular economy concept is currently received increasing attention at international and national policy levels and increasingly discussed among researchers and policymakers across all over the world. There are clear arguments that circular economy has a significant impact on industry, economy, environment, and society by offering an opportunity to reinvent the economy, making it more sustainable and competitive, ensuring and promoting more innovative and efficient ways of producing and consuming, protecting business against scarcity of resources, boosting economic growth, and creating jobs.

1.2. Circular economy as one of the models of sustainable development

The concept of the circular economy could be explained as a new business model, which could lead the sustainable development by decoupling economic growth from the negative effects of resource depletion and environmental degradation (Korhonen, Nuur, Feldmann, & Birkie, 2018). Moving toward the circular economy it is necessary that transition process would be managed in a sustainable way (Philp & Winickoff, 2018). The circular economy highly contributes to the sustainable development by promoting more appropriate use of resources aimed at the implementation of the circular economy (Ellen Macarthur Foundation, 2013). Sustainability is a three-dimensional concept that encompasses economic, environmental, and social aspects. Sustainability might be achieved in the conditions of the environmental protection, equity promotion, and preservation of economic growth and development (Skvarciany, Jureviciene, & Volskyte, 2020). In order to achieve the sustainability one pillar cannot be accomplished by sacrificing another pillar (Portney, 2015). Environmental sustainability can be explained as the ability to live with the means of nature and natural resources, social sustainability – as the ability to fulfil human needs without damaging nature, while economic sustainability – as the ability of the economy to support and maintain the economic growth but at the same time requires that natural resources would be used efficiently (Goniadis, 2015). The main aim of sustainability and sustainable development is to seek the long-term stability between economy and environment. This goal can be achieved under the condition of integration of economic, environmental and social concern, also in the conditions of the environmental protection, equity promotion, and preservation of economic growth and development (Emas, 2015). The concepts of the sustainable development and sustainability are highly related to the long-term growth strategies, especially in developed countries. The realization process of sustainability and sustainable development should be based on growth,

as well as improvements in social inclusion and labour market. If the process remains effective in the long-term perspective, it can have a significant impact on reducing the negative externalities of globalization and in this way increasing the sustainability (Chochół, 2016).

There are many ways and indices to measure the sustainability and sustainable development, such as environmental performance index (EPI), human development index (HDI), human sustainable development index (HSDI), human green development index (HGDI), national sustainable development index (NSDI), and sustainable development index (SDI). Some of these indices are quite new and were created to solve the gaps of existing indices to help governments to make better national development decisions. These indexes are criticized for incompleteness to measure the sustainability and sustainable development. Jin, Qian, Chin, & Zhang (2020) state that these indexes do not well integrate the environmental and ecological aspects. However, the sustainable development goal index (SDGI) has received increasing attention due to an effective roadmap to measure and improve the sustainability (Weitz, Persson, Nilsson, & Tenggren, 2015). The sustainable development goal index is calculated according to the released United Nations 17 sustainable goals, which includes no poverty, zero hunger, good health and well-being, quality education, gender equity, clean water and sanitation, affordable and clean energy, decent work and economic growth, industry, innovation and infrastructure, reduced inequalities, sustainable cities and communities, responsible consumption and production, climate action, life below water, life on land, peace, justice and strong institutions, and partnerships for the goals (United Nations, 2020). The released sustainable development goals present the solution to the sustainability problems dealing with nations' economies, environment, and societies. According to the Asadikia, Rajabifard, and Kalantari (2020) research results, all sustainable development goals have significant impact on sustainability and sustainable development, however the biggest impact have good health and well-being, quality education, and affordable and clean energy. In the research sustainable development will be measured and evaluated according to the sustainable development goals index.

According to the (Geissdoerfer, Savaget, Bocken, and Hultink (2017), some similarities between the circular economy and sustainability have been revealed. Both concepts emphasise the importance of the commitments motivated by environmental hazards; highlight the necessity of system change and innovation at the core. Also, the main key for industry transformation considered to be business model innovations and technological solutions. Moreover, both concepts recognise the importance of regulation and incentives as core implementation tools. The literature review also reveals a various range of differences between the circular economy and sustainability concept. These two concepts differ by goals,

motivations, beneficiaries, and perception of responsibilities. The main goal of the circular economy is to close the loop by keeping products as long as possible into the economy and eliminating waste, while sustainability has a multitude of goals, which shift depending on the agents' interests. The main motivation behind the circular economy is the better use of resources, waste reduction, while the motivation for sustainability is past trajectories. Moreover, in the concept of the circular economy, the main beneficiaries are economic actors that implementing the system, while in the sustainability concept – environment, economy, and society at large. Furthermore, in the circular economy private business and policymakers are responsible for changes, while in sustainability concept responsibilities are shared but not clearly defined (Geissdoerfer et al., 2017).

According to the Rashid, Asif, Krajnik, and Nicolescu (2013), the relationship between concepts of sustainability and the circular economy could be explained in various ways (see in Table 4).

Table 4. Relationship between circular economy and sustainability

Relationship	Explanation	Authors
Positive	1. The circular economy is seen as the precondition to the sustainability. 2. The circular economy is considered as beneficial tool for different sustainability dimensions – economy, environment, society – such as economy growth, job creation, and recourse productivity. 3. The circular economy seen as one of the sustainability business models, which highly contributes to the core sustainability process.	Rashid, Asif, Krajnik, & Nicolescu (2013), European Commission (2014), Bocken, Short, Rana, & Evans (2014)
Negative	1. The circular economy implementation costs, the technical impossibility of a closed the loop. 2. The circular economy integrating environment and economy dimensions, but do not well integrate social dimension	Allwood, 2014, Murray, A., Skene, K., & Haynes, K. (2017)

Source: prepared by author based on Rashid, Asif, Krajnik, & Nicolescu (2013), European Commission (2014), Bocken, Short, Rana, & Evans (2014), and others.

First, the circular economy could be explained as a precondition for sustainability, with highly contributions to economic and environment. Second, the circular economy is considered as beneficial tool for different sustainability dimensions – economy, environment, society. The circular economy highly contributes to the improving resource productivity and decreasing import dependency, reducing environmental impact, economic growth and innovation opportunities, and sustainable consumer behaviour and job opportunities (European Commission, 2014, EEA, 2016). Moreover, the circular economy seen as one of the sustainability business models, which greatly contributes to the core sustainability concepts (Bocken, Short, Rana, & Evans, 2014). However, negative relationship between the circular

economy and sustainability concepts are revealed. In the literature review Allwood (2014) determine potential costs, and technical impossibility as the main negative relationships. Additionally, the circular economy impacting environment and economy dimensions, but do not well integrate social dimension (Murray et al., 2017). The circular economy and sustainability concepts are highly related in between. The circular economy concept is seen as the precondition to sustainability by considering all sustainability dimensions of economy, environment, and society. The circular economy highly contributes to sustainability and sustainable development by promoting more appropriate use of resources aimed at the implementation of a circular economy.

According to the literature review, some hypotheses were raised. Based on the empirical results, hypotheses presented below will be accepted or rejected.

1. Hypothesis 1. The circular economy has a significant impact on sustainable development.
2. Hypothesis 2. The circular economy has not a significant impact on sustainable development.
3. Hypothesis 3. The circular economy only partially affects sustainable development.
4. Hypothesis 4. The most significant circular economic indicators have significant impact on sustainable development.

To conclude, the circular economy concept is seen as the precondition to sustainability by considering all sustainability dimensions of the economy, environment, and society. Additionally, the circular economy concept is seen as one of the sustainability business models, which significantly contributes to the core sustainability process. Due to that reason, the circular economy and sustainability are highly related and currently received increasing attention at international and national policy levels.

1.3. Factors of circular economy

The importance to measure the progress toward the circular economy has increasingly gained attention from various countries in the world. The evaluation of the effectiveness of the transition to the circular economy is crucial to reach the greatest results. However, there are a limited number of studies measuring the circular economy in different countries, regions, cities, or companies. In the research, the factor is interpreted as the driving force that affects or impacts the result of the circular economy. In this section will be analysed the scientific research and the factors which are used to assess a circular economy.

Marino and Pariso (2020) in the research compare the EU performance regarding the circular economy. Scientists in the research include various indicators as municipal waste, food waste, recycling rate, domestic consumption, reuse rate, and recyclable raw materials. McDowall et al. (2017) measuring the circular economy in China use three levels of indicators: micro (firm-level), meso (eco-industrial park), and macro (city or province). Indicators consist of waste and emission intensity, waste and pollution treatment, resource intensity of GDP, and waste recycle. These indicators work across geographical scale, reflecting circular economy implementation from a multilevel view. Avdiushchenko and Zaj (2019) identify the main areas of the circular economy such as prosperity of the economy considering financial aspects of environmental actions, zero-waste economy, innovative economy, energy-efficient and renewable energy-based economy, low carbon economy, smart economy, spatially effective economy, bioeconomy, service/performance economy, sharing economy, resource and material efficient economy, and socially oriented economy. All these distinguished areas of the circular economy could be measured by different indicators such as increase in household income, poverty risk indicator, municipal waste generated per inhabitant in a region, eco-innovations, patents related to recycling sectors, expenditure on research and development in relation to GDP, final energy intensity of GDP, electricity consumption, carbon dioxide emissions, expenditures on research and development (R&D) in the field of biotechnology, households with Internet access, productivity of resources (GDP per unit of resources used by the regional economy), forest cover indicator and many others. Saidani, Yannou, Leroy, Cluzel, and Kendall (2019) in the research state that various indicators could be used in the circular economy assessment such as zero waste index, sustainable circular index, resource productivity, recycling rates, input-output balance sheet, indicators for consumption, environmental protection indicators, circular economy index, and many others. Moraga et al. (2019) in the assessment of the circular economy single out different indicators. Scientists state, that circular economy assessment indicators could be generation of municipal waste per capita, recycling rate of municipal rate, recycling rate of all waste, recycling of biowaste, imports from non-EU countries, exports to non-EU countries, number of persons employed, patents of recycling and secondary materials and others. European Commission provides a huge variety of indicators, according to them could be measured by the circular economy. The circular economy indicators are divided into four sections of production and consumption, waste management, secondary raw materials, and competitiveness and innovation. European Commission provides a recommendation on what indicators to use to assess the circular economy. The indicators consist of generation of municipal waste per capita, food waste, recycling rate of municipal waste, recycling rate of all waste excluding major mineral waste, recycling rate of overall

packaging, recycling rate of plastic packaging, recovery rate of construction and demolition waste, circular material use rate, imports from non-EU countries , exports to non-EU countries, intra EU trade , gross investment in tangible goods, persons employed, value added at factor cost, number of patents related to recycling and secondary raw materials and others (European Commission, 2020a). Yadav, Mangla, Bhattacharya, and Luthra (2020) in the research state that indicators as an effective facility layout decision making, effective information management system, and adoption of innovative quality improvement practices are considered as key players in the circular economy implementation process. Additionally, Saavedra, Iritani, Pavan, and Ometto (2018) emphasise the importance on the penetration of the social media and big data analytics within an organization, which helps to circulate the information within a correct loop. Furthermore, Urbinati et al. (2017) single out that access of advance technological setup will make it easier for practitioners to carry out their production activities and at the same time help to deliver high quality products to end users.

Circular economy focusing not only on the efficiency of primary and secondary raw materials and resources, but also on a wide range of questions and issues, that are raised and actively discussed among scientists, policymakers, and researchers. Avdiushchenko and Zaj (2019) state that the circular economy monitoring framework released by the European Commission is not detailed enough for monitoring the effects of important circular economy areas such as social innovations, eco-innovations, sharing economy initiatives, the level of the greening of the main economic sectors, new business models' implementation, and eco-design. Due to that reason, concluded data were grouped according to the specific areas of the circular economy (see in Table 5). The specific areas of the circular economy consist of economic prosperity, zero-waste economy, innovative economy, energy-efficient and renewable energy-based economy, low carbon economy, smart economy, spatially effective economy, bioeconomy, resources and material efficient economy, and socially orientated economy. All the specific areas, presented in the table above, represent the five loops of the circular economy. Bioeconomy, resource and material-efficient economy, and spatially effective economy represent the raw materials extractions loop, innovative economy represents the product design loop, low carbon economy, energy-efficient and renewable energy-based economy represent the production and remanufacturing loop, smart economy, socially oriented economy, and economic prosperity represent the consumption loop, while zero-waste economy represents the waste management loop.

Table 5. Circular economy indicators

Loop of CE	CE specific area	Indicators
Raw materials extractions	Spatially effective economy	Forest cover indicator, urbanization rate.
	Bioeconomy	Biofuels, biomass, bio-based products.
	Energy-efficient and renewable energy-based economy	Share of renewable energy sources in total production of electricity, electricity consumption, final energy intensity of GDP, resource intensity of GDP, domestic material consumption.
	Resource and material efficient economy	Productivity of resource, domestic material consumption, production material reuse rate.
Product design	Innovative economy	Eco-innovations, patents related to recycling sectors, expenditure on research and development in relation to GDP, patents of recycling and secondary materials and others, expenditures on research and development (R&D) in the field of biotechnology, patent applications for 1 million inhabitants.
Production and remanufacturing	Low carbon economy	Emission of particulates, CO ₂ emission intensity, pollution treatment.
Consumption	Economic prosperity	GDP, increase in household income, poverty risk indicator, number of persons employed, economic growth.
	Smart economy	Households with Internet access.
	Socially oriented economy	Innovative social enterprises.
Waste management	Zero-waste economy	Municipal waste, food waste, municipal waste recycling rate, market rate of recyclable raw materials, zero waste index.

Source: prepared by author based on Marino & Pariso (2020), Saidani, Yannou, Leroy, Cluzel, & Kendall (2019), and others.

To conclude, the circular economy concepts could be explained as a new economic system that replaces the end-of-life concept with the main principles of reducing, reusing, recycling, and recovering. The circular economy aims for the efficiency of resources through long-term value creation, waste minimization, reduction of closed loops products considering the environmental protection. Also, the circular economy tries to reach and maintain economic prosperity with a high contribution to environmental quality, social equity, and future generation. The circular economy has a significant impact on industry, economy, environment, and society by offering an opportunity to reinvent the economy and industry, making it more sustainable and competitive. The circular economy concept is seen as the precondition to sustainability and considered a beneficial tool for different sustainability dimensions of the economy, environment, and society. Moreover, the circular economy is seen as one of the sustainability business models, which greatly contributes to the core sustainability concepts. Thus, due to that reason, the circular economy and sustainability are highly related. Both the circular economy and sustainability concepts are currently received increasing attention at international and national policy levels. According to the literature, there are many indices that could be used to evaluate the circular economy. All these indices could be divided into various groups such as micro, meso, and macro groups, production and consumption, waste management, secondary raw materials, and competitiveness and innovation groups or economic prosperity, zero-waste economy, innovative economy, energy-efficient and renewable energy-

based economy, low carbon economy, smart economy, spatially effective economy, bioeconomy, resource and material-efficient economy, and socially oriented economy groups.

2. METHODOLOGY FOR ASSESSMENT OF CIRCULAR ECONOMY AS ONE OF THE MODELS OF SUSTAINABLE DEVELOPMENT

In this section will be answered the second question, which is based on the analysis of the research and theoretical aspects provide the methodology for assessing the circular economy and assessing the circular economy as one of the models of sustainable development in the OECD countries for 2018-2019 period.

In the research, the circular economy will be assessed in OECD countries, that include five different regions such as Asia (Japan, South Korea, Turkey), North America (Canada, Mexico, United States), South America (Chile), Europe (Austria, Belgium, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Netherlands, Norway, Poland, Portugal, Slovak Republic, Slovenia, Spain, Sweden, United Kingdom), and Australia (Australia). Due to the research limitations, Colombia, Iceland, Israel, Switzerland, and New Zealand will be not included in the research. Additionally, the study will cover the latest data of 2018-2019. Furthermore, due to the lack of information some data will be forecasted. The dataset used in the study is obtained from different sources, including databases of the Eurostat, OECD, UNESCO, IEA, and OICA.

According to the analysed literature and theoretical background, various methods could be used to assess the circular economy. Marino and Pariso (2020) in the research use the comparison analysis and correlation analysis with quantitative indicators to measure the implementation of the transition to the circular economy. McDowall et al. (2017) carried out the policy documents' content analysis regarding to the transition to the circular economy. Furthermore, Avdiushchenko and Zaj (2019) were used the grey correlation degree method with principal component analysis, which helps to construct the circular economy index. Moreover, Salmenperä et al. (2021) were used qualitative semi-structured interviews method that are relevant for collating the perceptions of respondents in complex. However due to the conflicting aspects, different measurement units of indicators, it is not a suitable way to assess the circular economy according to the indicators. Due to that reason, in the research will be used the methodology that aggregates the overall circular economy in different regions of Asia, North America, South America, Europe, and Australia assuming that country with a strong circular economy should be near the best scores on each indicator and far from the worst one and oppositely country that has weak circular economy should be near the worst scores and far from the best scores. Therefore, in the research Multi-Criteria Decision Analysis (MCDA) and Analytic Hierarchy Process (AHP) methods will be used. Multi-Criteria Decision Analysis

(MCDA) method will help to assess the circular economy in different analysed regions and countries, while the Analytic Hierarchy Process (AHP) method will help to estimate the weights of indicators that are used in the research. Second, in the research will assess the circular economy as one of the models of sustainable development. In this stage will be analysed the circular economy indicators' impact on sustainable development. The meta-regression analysis method will be applied to assess the circular economy as one of the models of sustainable development.

According to the analysed literature and theoretical background, in the research will be used various circular economy indicators, which are group into the circular economy specific areas according by the loops of the circular economy. Due to the lack of information, only energy-efficient and renewable energy-based economy, innovative economy, low carbon economy, economic prosperity, smart economy, and zero-waste economy specific areas of the circular economy will be included in the research (see in Table 6).

Table 6. Circular economy indicators

Loop of CE	CE specific area	Indicators	Units
Raw materials extractions	Energy-efficient and renewable energy-based economy	Air pollution exposure	Exposure to PM2.5 ($\mu\text{g}/\text{m}^3$)
		Electricity total production	GWh
		Renewable energy	% of primary energy supply
Product design	Innovative economy	Patents in environment-related technologies	Number
		Gross domestic expenditure on R&D	% of GDP
Production and remanufacturing	Low carbon economy	CO ₂ emission intensity	Tonnes/capita
		Number of passenger cars in use	Cars/1000 population
Consumption	Economic prosperity	Gross Domestic Product	USD/capita
		Unemployment rate	Total, % of labour force
		Poverty rate	%
		Household disposable income Gross adjusted	USD/capita
	Smart economy	Households with Internet access	%
Waste management	Zero-waste economy	Municipal waste generated	Tonnes/1000 capita

Source: composed by author based on based on Marino & Pariso (2020), Saidani, Yannou, Leroy, Cluzel, & Kendall (2019), and others.

Each specific areas of the circular economy will be measured be different indicators suggested by scientists. Specific area of energy-efficient and renewable energy-based economy will be measured by air pollution exposure (exposure to PM2.5 concentration ($\mu\text{g}/\text{m}^3$)), electricity total production (GWh), and renewable energy (% of primary energy supply), innovative economy specific area will be measured by number of patents in environment-related technologies and gross domestic expenditures on R&D (as % of GDP), low carbon economy specific area will be measured by CO₂ emission intensity (tonnes/capita) and number

of passenger cars in use (cars/1000 population), economic prosperity specific area will be measured by gross domestic product (USD/capita), unemployment rate (% of labour force), poverty rate (%), and household disposable income gross adjusted (USD/capita), smart economy specific area will be measured by households with Internet access (%), and zero-waste economy specific area according municipal waste generated (tonnes/1000 capita).

In the research, the weights of indicators will be assigned by Analytic Hierarchy Process (AHP) method. AHP method is one of the most popular methods in multi-criteria decision making and widely used in different problems of criteria weighting factors (Pamučar, Stević, & Sremac, 2018). AHP model allows to assessment of the consistency of experts' preferences in group decision-making and allows to manipulate qualitative and quantitative criteria (Starčević, Bojovic, Junevičius, & Skriskij, 2019). AHP method is a broadly applied in multi-criteria decision-making method to determine the weights of criteria and prioritise alternatives based on a pairwise comparison (Liu, Eckert, & Earl, 2020). The pairwise comparison matrix was developed based on the importance of one criterion for another in the pair to determine the weight of the parameters according to the AHP priority scale. An expert provides an overall view of the complex relationship between the selected elements and help to assess whether the elements are comparable in between. In AHP method elements are compared in pairwise according to the 9 point scale, so called “Saaty's Fundamental Scale” (Khashei-Siuki, keshavarz, & Sharifan, 2020). However, the pairwise comparison might introduces inaccuracies due to experts may not be able to assign accurate numerical values to their preferences due to limited information or capabilities (Cavallo & D'Apuzzo, 2020). The methodology of the AHP is provided below.

First, the pairwise matrix of the ratios of all weights is constructed:

$$A = [a_{ij}]_{n \times n} = \begin{bmatrix} w_1/w_1 & \cdots & w_1/w_n \\ \cdots & \cdots & \cdots \\ w_n/w_1 & \cdots & w_n/w_n \end{bmatrix}, \quad (1)$$

where:

$A = [a]_{ij}$ – pairwise matrix

$w_{1...n}$ – vector of current weights of the alternative

n – number of factors in the judgement

Second, the consistency index (CI) is calculated:

$$CI = \frac{\lambda_{max} - n}{n - 1}, \quad (2)$$

where:

λ_{max} – is the maximum eigenvalue

Third, the consistency ration (CR) is calculated:

$$CR \frac{CI}{RI}, \quad (3)$$

where:

RI – is the consistency index of a randomly generated reciprocal matrix from the 9-point scale, with forced reciprocals

CI – consistency index.

The random index is one of the most popular and most effectively used decision-making methods developed by Saaty (Shyamprasad & Kousalya, 2020). Random index values are assigned according to the Saaty's scale provided in the Table 7.

Table 7. Random average consistency indexes for various n

n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.84	1.56	1.57	1.59

Source: based on author according Shaoa et al. (2020).

Moreover, Multi-Criteria Decision Analysis (MCDA) method will be used. Multi-Criteria Decision Analysis refers to making the choice of the best alternative (Roszkowska, 2016). MCDA approach is characterized by the ability to handle large amounts of conflicting data, the ability to integrate values and perceptions, identify risks, and manage vast amounts of information (Balioti, Tzimopoulos, & Evangelides, 2018). This method assumes that country, which has a well-developed circular economy must be near the best scores on indicators and far from the worst scores, and vice versa. The Multi-Criteria Decision Analysis method is based on the distance between two reference points – one is desirable and the other undesirable (Bilbao-Terol, Arenas-Parra, Cañal-Fernández, & Antomil-Ibias, 2014). According to this method, the circular economy will be assessed in the analysed countries.

Multi-Criteria Decision Analysis method consists of three application stages: decision context and structuring, analysis, and decision (see in Fig. 3).

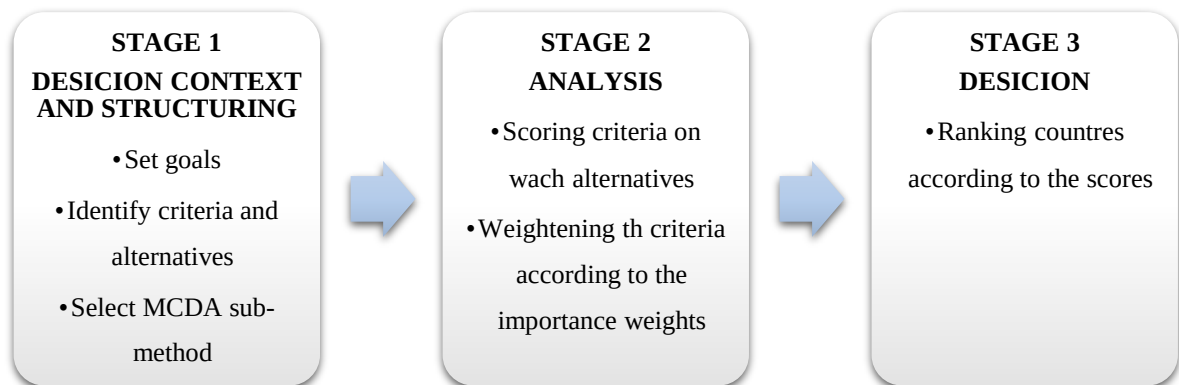


Fig. 3. The Stages of application of MCDA

Source: composed by the author.

In the decision context and structuring stage, it is important to determine the goals, identify the criteria and alternatives, and select the sub-method of the Multi-Criteria Decision Analysis method. In analysis stage will be scored each alternative on each criterion and weighting the criteria by importance weights, while in the decision stage, will be ranked the alternatives according to the scores (Esmail & Geneletti, 2018). The goals of the Multi-Criteria Decision Analysis method are to assess the circular economy in analysed countries and rank countries according to the get results. In the research 13 criteria from different circular economy specific areas will be used. The used criteria are presented in the Table 6. The alternatives in the Multi-Criteria Decision Analysis method will be analysed countries from different regions – Australia, Austria, Belgium, Canada, Chile, Check Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Italy, Japan, Latvia, Lithuania, Luxembourg, Mexico, Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, South Korea, Spain, Sweden, Turkey, United Kingdom, and United States. In the research the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) and Distance from Average Solution (EDAS) sub-methods will be used. Different Multi-Criteria Decision Analysis sub-methods may reach different results even if the same weights of criteria are applied. This fact has been confirmed in various research, in which rankings of decisions were examined with the use of different sub-methods of MCDA method. The problem of the different results might be occurring due to the use of an incorrect sub-method of MCDA (Wątróbski, Jankowski, Ziemia, Karczmarczyk, & Ziolo, 2019).

The Technique for Order of Preference by Similarly to Ideal Solution (TOPSIS) is one of the Multi-Criteria Decision Analysis sun-method that prioritize the alternatives by similarity to the ideal solution which has very low sensitivity to the weighting technique. By TOPSIS, the best alternative should have the shortest distance from the ideal point ant the farthest distance from the anti-ideal point. In the TOPSIS model $n \times m$ matrix is assessed where there are m alternatives and n criteria. It is assumed that each criterion in the MCDA model matrix has either increasing or decreasing desirability (Sangchini, Nalivan, & Nasser Tahmasebipour, 2017). This model requires that all criteria would be quantitative data or converted in quantitative if data are qualitative.

The TOPSIS model is described in seven steps below:

First, construct the decision matrix and determine the weight of criteria.

$$X = (x_{ij}), \quad (5)$$

$$W = [w_1, w_2, \dots, w_n], \quad (6)$$

where:

X – decision matrix

W – weight vector, $x_{ij} \in \mathcal{R}$ and $w_1 + w_2 + \dots + w_n = 1$

Criteria of the functions can be benefit functions (more is better) or cost functions (less is better).

Second, the normalized decision matrix calculation, which transforms criteria dimensions into non-dimensional criteria and allow comparisons across criteria. The normalized value n_{ij} is calculated as follows:

$$n_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^m x_{ij}^2}}, \quad (7)$$

Third, the weighted normalized decision matrix calculation. The weighted normalized value v_{ij} is calculated as follows:

$$v_{ij} = w_j n_{ij} \text{ for } i = 1, \dots, m; j = 1, \dots, n, \quad (8)$$

where:

w_j – the weight of the j^{th} criteria

Fourth, determine the positive ideal (V^+) and negative ideal (V^-) solutions. The ideal positive solution is the solution that maximizes the benefit criteria and minimizes the cost criteria whereas the negative ideal solution maximizes the cost criteria and minimizes the benefit criteria.

$$V^+ = (v_1^+, v_2^+, \dots, v_n^+) = \left(\left(\max_i v_{ij} \mid j \in I \right), \left(\min_i v_{ij} \mid j \in J \right) \right), \quad (9)$$

$$V^- = (v_1^-, v_2^-, \dots, v_n^-) = \left(\left(\min_i v_{ij} \mid j \in I \right), \left(\max_i v_{ij} \mid j \in J \right) \right), \quad (10)$$

where:

I is associated with benefit criteria and J with the cost criteria, $i = 1, \dots, m; j = 1, \dots, n$.

Fifth, the Euclidean distance from the ideal best (V^+) solution and the anti-ideal best (V^-) solution calculation. The separation measures of each alternative from the ideal best (V^+) solution and the anti-ideal (V^-) solution, respectively, are as follows:

$$S_i^+ = \sqrt{\sum_{j=1}^n (v_{ij} - v_i^+)^2}, \quad i = 1, 2, \dots, m, \quad (11)$$

$$S_i^- = \sqrt{\sum_{j=1}^n (v_{ij} - v_i^-)^2}, \quad i = 1, 2, \dots, m, \quad (12)$$

Sixth, the relative closeness to the positive ideal solution calculation. The relative closeness is defined as follows:

$$P_i = \frac{S_i^-}{S_i^- + S_i^+}, \quad (13)$$

where:

$$0 \leq P_i \leq 1, i = 1, 2, \dots, m.$$

Seventh, rank the preference order.

Based on the steps above the Technique for Order of Preference by Similarly to Ideal Solution (TOPSIS) will be calculated in the research.

Evaluation based on Distance from Average Solution (EDAS) is an innovative and useful sub-method to assess the Multi-Criteria Decision method (MCDM) problem especially in case of conflicting criteria. EDAS method relatively new compared with the other Multi-Criteria Decision making methods. This method includes the positive and negative distances from the average solutions, not the ideal and anti-ideal solutions (Fan, Cheng, & Wu, 2019). EDAS allows to generate more accurate solutions to real-life problems due to the calculation results are based on the average solutions that significantly limit the likelihood of deviating from the best decision (Tadić, Krstić, & Brnjac, 2019). The methodology of the EDAS is provided below.

First, the decision-making matrix is constructed:

$$X = [X_{ij}]_{m \times n} = \begin{bmatrix} X_{11} & \cdots & X_{1m} \\ \vdots & \ddots & \vdots \\ X_{n1} & \cdots & X_{nm} \end{bmatrix}, \quad (14)$$

where:

X_{ij} – value of i -th alternative on j -th criterion

n – number of alternatives

m – number of criteria

Second, the average solution is determined:

$$AV_j = \frac{\sum_{i=1}^n X_{ij}}{n}, \quad (15)$$

where: AV_j is the average solution.

Third, the positive distance from average (PDA) and the negative distance from average (NDA) matrixes according to the type of criteria (benefit and cost) are calculated:

if j -th criterion is beneficial:

$$PDA_{ij} = \frac{\max(0, (X_{ij} - AV_j))}{AV_j}, \quad (16)$$

$$NDA_{ij} = \frac{\max(0, (AV_j - X_{ij}))}{AV_j}, \quad (17)$$

if j -th criterion is cost:

$$PDA_{ij} = \frac{\max(0, (AV_j - X_{ij}))}{AV_j}, \quad (18)$$

$$NDA_{ij} = \frac{\max(0, (X_{ij} - AV_j))}{AV_j}, \quad (19)$$

where:

PDA_{ij} – positive distance from average

NDA_{ij} – negative distance from average.

Fourth, the weighted sums of PDA_{ij} and NDA_{ij} for all alternatives are determined:

$$SP_i = \sum_{j=1}^m w_j PDA_{ij}, \quad (20)$$

$$NP_i = \sum_{j=1}^m w_j NDA_{ij}, \quad (21)$$

where:

SP_i – weighted sum of PDA_{ij}

NP_i – weighted sum of NDA_{ij}

Fifth, the values of SP_i and NP_i for all alternative are normalised:

$$NSP_i = \frac{SP_i}{\max_i(SP_i)}, \quad (22)$$

$$NSN_i = 1 - \frac{SN_i}{\max_i(SN_i)}, \quad (23)$$

where:

NSP_i – normalized value of SP_i

NSN_i – normalized value of SN_i .

Sixth, the appraisal score (AS_i) for all alternatives is calculated:

$$AS_i = \frac{1}{2} (NSP_i + NSN_i), \quad (24)$$

where AS_i is the appraisal score (AS) for all alternatives, $0 \leq AS_i \leq 1$

Lastly, the alternatives are ranked according to the decreasing values of AS_i , i.e., the alternative with the highest AS is the best choice among the candidate alternatives.

Moreover, the other method is meta-regression analysis. Meta-regression refers to a fixed effects model or random effects model that includes one or more study features as covariates. The main difference between fixed and random effect is the interpretation of the variability of the results. The fixed-effect model assumes that all meta-analysis studies have a common true effect size, meaning that they have the same effect in all study size, while the random effect model assumes that study results were performed from populations that differ from each other in ways that may influence the effect of treatment (Fagerland, 2015, Borenstein, Hedges, & Rothstein, 2007). The random effects model involves the heterogeneity of the study, while the fixed effect does not. For this reason, the common strategy is to use the fixed effect regression model if the study results are similar, and alternatively if results are not similar use the random effect regression model (Borenstein et al., 2007). There are some scientists claiming that fixed effect method is more commonly used, due to its potential to improve causal interpretations. Additionally, Hausman test helps to identify which model is more appropriate

to use in the study. The null hypothesis of this test states that random effect model is more preferred, while alternative hypothesis states that fixed effect model is more preferred (Young & Johnson, 2015, Giesselmann & Windzio, 2014).

The fixed effect model is:

$$f_i(x) = \alpha_i + \beta_i x, \quad (25)$$

where:

$i=1,2,\dots,n$.

x – indicator of treatment.

α_i – control or unexpected effect.

β_i – fixed effect, $\beta = \beta_1 = \beta_2 = \dots = \beta_n$.

The random effects model rejects the idea of a single overall study effect. Instead, each study is considered to have its main effect. The random effects model is:

$$f_i(x) = \alpha_i + \beta x + z_i x, \quad (26)$$

where:

β – the average common effect.

$z_i \sim N(0; \sigma^2)$ – is a normal random variable with the mean of zero and SD σ .

To conclude, the area of the research will cover the five different regions of Asia (Japan, South Korea, Turkey), North America (Canada, Mexico, United States), South America (Chile), Europe (Austria, Belgium, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, United Kingdom), and Australia (Australia). The historical data cover 2018-2019. In the research 13 different indicators from specific area of the circular economy will be used. These indicators are air pollution exposure (exposure to PM2.5, ($\mu\text{g}/\text{m}^3$)), electricity total production (GWh), renewable energy (% of primary energy supply), number of patents in environment-related technologies, gross domestic expenditures on R&D (as % of GDP), CO₂ emission intensity (tonnes/capita), number of passenger cars in use (cars/1000 population), gross domestic product (USD/capita), unemployment rate (% of labour force), poverty rate (%), household disposable income gross adjusted (USD/capita), households with Internet access (%), and municipal waste generated (tonnes/1000 capita). In the research three different methods will be used. The first method is Analytic Hierarchy Process (AHP) method. AHP method is one of the most popular methods in multi-criteria decision making and widely used in different problems of criteria weighting factors. AHP method helps to identify the importance weights of the circular economy. The

second method is Multi-Criteria Decision Analysis (MCDA) method, which will be calculated according to the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) sub-method and Evaluation based on Distance from Average Solution (EDAS) sub-method. TOPSIS and EDAS sub-methods help to obtain the performance and appraisal scores and ranks countries and regions by performance of the circular economy. The third method is meta-regression. With this method will be assess the circular economy as one of the models of sustainable development.

3. EMPIRICAL RESULTS OF ASSESSMENT OF CIRCULAR ECONOMY AS ONE OF THE MODELS OF SUSTAINABLE DEVELOPMENT

In this section will be answered the third task, which is to assesses the circular economy as one of the models of sustainable development in OECD countries in 2018-2019. In this part the analysis of the circular economy factors and the empirical results of Analytic Hierarchy Process (AHP), Multi-Criteria Decision Analysis (MCDA), and meta-regression results will be provided.

3.1. Circular economy criteria analysis

Selection of indicators is one of the important steps in Multi-Criteria Decision Analysis method. Selected indicators in multi-criteria decision analysis method must encompass all specific areas of the circular economy and highlight differences between the alternatives. Thus, in the research 13 different indicators from a specific area of the circular economy were selected. Each specific area of the circular economy will be measured by different indicator, such as energy-efficient and renewable energy-based economy will be measured by air pollution exposure (exposure to PM_{2.5}, ($\mu\text{g}/\text{m}^3$)), electricity total production (MWh/1000 capita), renewable energy (% of primary energy supply), innovative economy – number of patents in environment-related technologies, gross domestic expenditures on R&D (as % of GDP), low carbon economy – CO₂ emission intensity (tonnes/capita), passenger cars (cars/1000 population), economic prosperity – gross domestic product (USD/capita), unemployment rate (% of labour force), poverty rate (%), household disposable income gross adjusted (USD/capita), smart economy – households with Internet access (%), and zero-waste economy – municipal waste generated (tonnes/1000 capita). Additionally, due to the research limitations the forecasting will be used to provide the newest empirical results for the assessment of the circular economy of 2018-2019. In the study, forecasts are made based on data from the last five year. Explanation of every criteria and the comparison between OECD countries are provided below.

The first indicator is air pollution exposure. The air pollution exposure is measured accordingly PM_{2.5} pollutant as PM_{2.5} refers to atmospheric particulate matter that have a diameter of less than 2.5 micrometres. The PM_{2.5} are formed because of burning fuel and chemical reactions that take place in the atmosphere. Additionally, natural process as forest fires also contributes to the PM_{2.5} in the air. Air pollution exposure quality is divided in six

stages of good (0-12 PM2.5 $\mu\text{g}/\text{m}^3$), moderate (12,1-35,4), unhealthy for sensitive groups (35,5-55,4 PM2.5 $\mu\text{g}/\text{m}^3$), unhealthy (55,5-150,4 PM2.5 $\mu\text{g}/\text{m}^3$), very unhealthy (150,5-250,4 PM2.5 $\mu\text{g}/\text{m}^3$), and hazardous (250,5 and more PM2.5 $\mu\text{g}/\text{m}^3$) (IQAir, 2020). In the research it is interpreted as a factor that negatively affects the circular economy. It is assumed that the lowest PM2.5 concentration in the air, the weakest circular economy in the country.

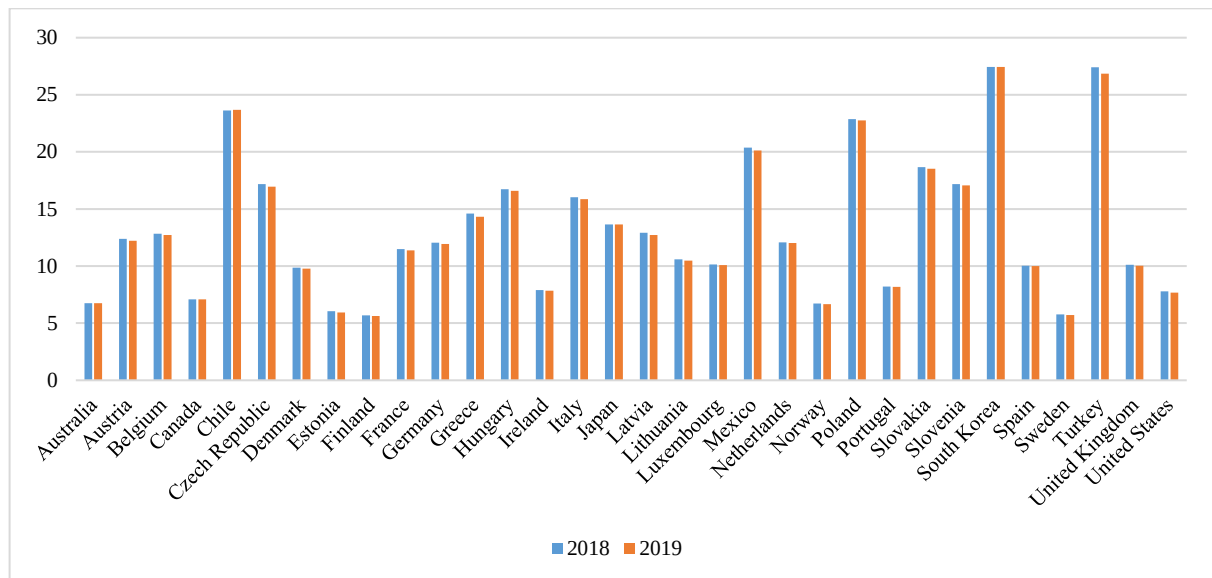


Fig. 4. Air pollution exposure (exposure PM2.5, ($\mu\text{g}/\text{m}^3$)), 2018-2019

Source: OECD (2020).

Figure 4 presents the air pollution exposure (exposure PM2.5, ($\mu\text{g}/\text{m}^3$)) across the OECD countries. From the figure can be seen that South Korea, Turkey, Poland, Mexico, and Chile suffer from the biggest amount of PM2.5 concentration, which is greater than 20 PM2.5 concentration in $\mu\text{g}/\text{m}^3$ in 2019, while Australia, Canada, Estonia, Finland, Norway, and Sweden have the lowest PM2.5 concentration level in 2019. This means that air quality in those countries is the best.

The other indicator is electricity total production (TWh). In the research this indicator is interpreted as factors that negatively affects the circular economy. It is assumed that the greatest amount of electricity total production, the weakest circular economy in the country. Figure 5 presents the electricity total production across OECD countries. From the figure can be seen that the United States produce the biggest amount of electricity, which is almost 1500 TWh, while Estonia, Latvia, Lithuania, and Luxembourg produce the lowest amount of electricity, which seeks less than 10 TWh per year. In electricity consumption analysis, it is necessary to take into consideration the country and population size. The greater the country and population size, the greater electricity production.

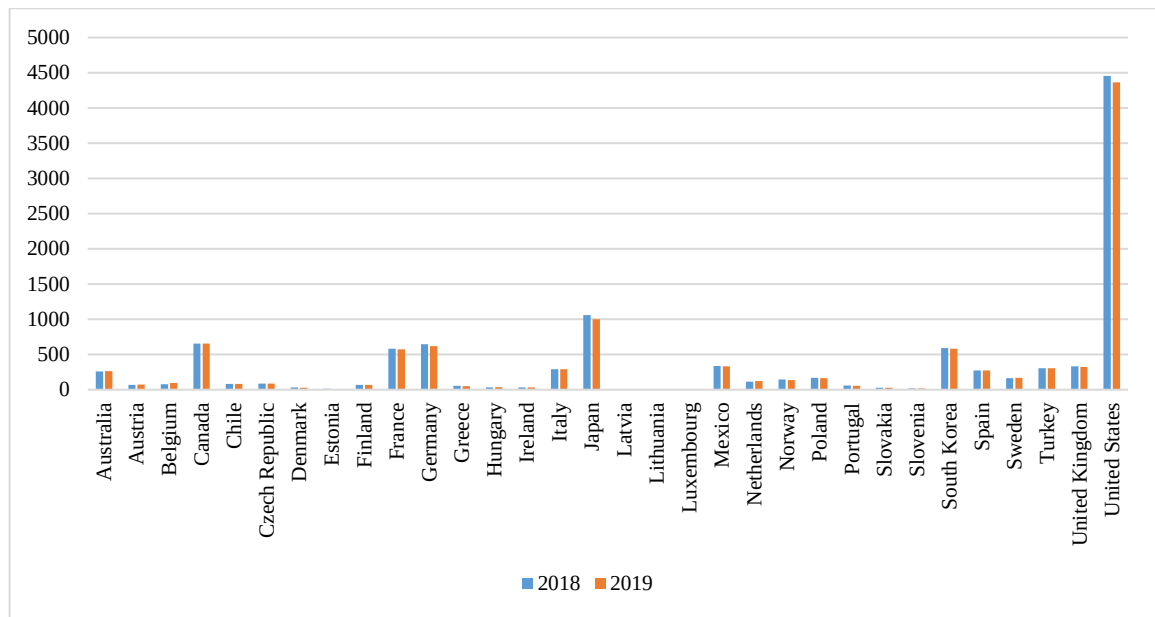


Fig. 5. Electricity total production, TWh, 2018-2019

Source: IEA (2020).

The other indicator is renewable energy (as % of primary energy supply), which includes the primary energy equivalent of hydro, geothermal, solar, wind, tide, and wave sources. Additionally, energy derived from solid biofuels, bio gasoline, biodiesels, biogases, and other liquid biofuels are included. In the research renewable energy indicator is interpreted as a factor that positively affects the circular economy. It is assumed that the higher % of renewable energy, the greater circular economy in the country.

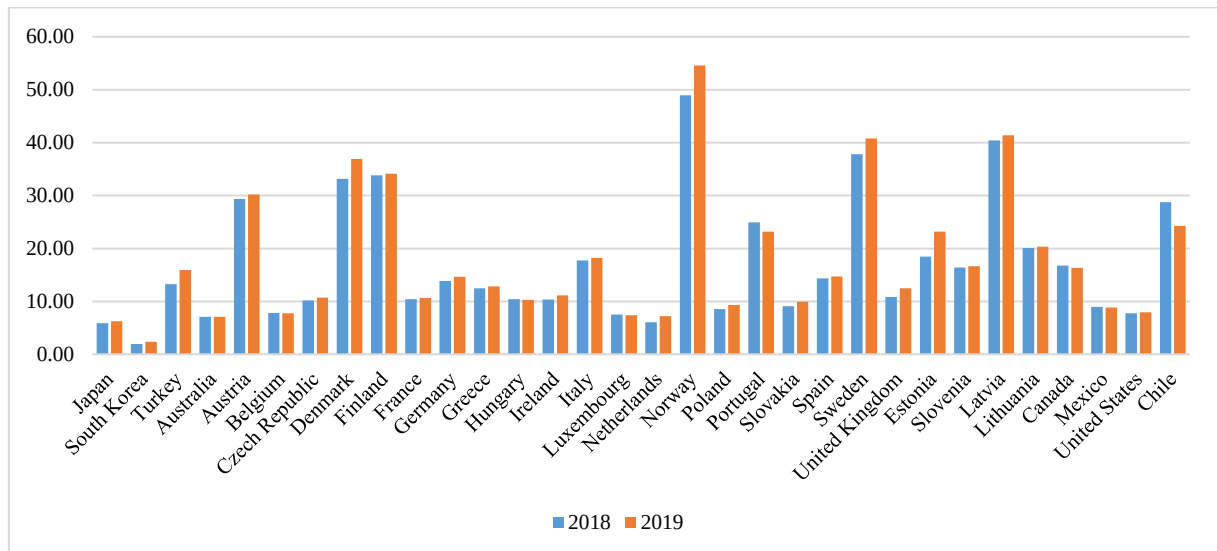


Fig. 6. Renewable energy, as % of primary energy supply, 2018-2019

Source: OECD (2020).

Figure 6 presents the renewable energy (as % of primary energy supply) across the OECD countries. From the figure can be seen that Norway produces the biggest percentage of

the renewable energy, which is almost 50 % of the primary energy supply, while South Korea produces the lowest percentage of the renewable energy, which seeks about 2 % of the primary energy supply. Additionally, from the figure can be seen that countries as Norway, Sweden, Latvia, Denmark, and Finland produce the biggest percentage of renewable energy across the OECD countries, while Australia, Japan, South Korea, Netherlands, and Luxembourg produce the lowest percentage of the renewable energy.

The other indicator is patents on environment-related technologies, which are the key elements of innovation output, as patent indicators reflect the inventive performance of countries, regions, technologies, companies, and others. Also, patents can be used to track the level of diffusion of knowledge across the technology areas, countries, companies, and others. In the research indicators of patents on environment-related technologies is interpreted as a factor that positively affects the circular economy. It is assumed that the greatest number of patents, the greatest circular economy in the country.

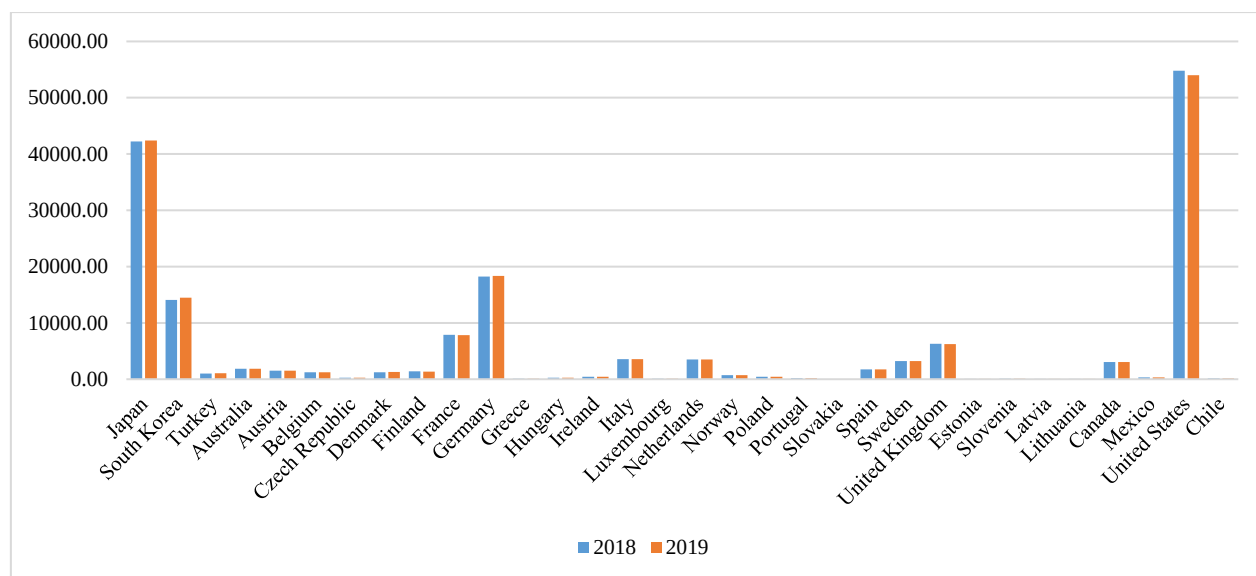


Fig. 7. Patents in environment-related technologies, number, 2018-2019

Source: OECD (2020).

Figure 7 presents the patents in environment-related technologies number across the OECD countries. From the figure can be seen that the leader countries regarding patent in environment-related technologies are the United states and Japan, which release more than 4000 patents every year. Countries as Estonia, Latvia, Lithuania, Luxembourg, and Slovakia release the lowest number of patents in environment-related technologies, which is less than 100 patents every year.

The other indicator is gross domestic expenditures on R&D (as % of GDP), which shows the total spending on research and development activities carried out by all companies, research institutes, universities, and others. The indicator includes the R&D funded from abroad

but excludes domestic funds for R&D performed outside the country. In the research this indicator is interpreted as factor that positively affect the circular economy. It is assumed that the greatest number of expenditures on R&D, the greatest circular economy in the country.

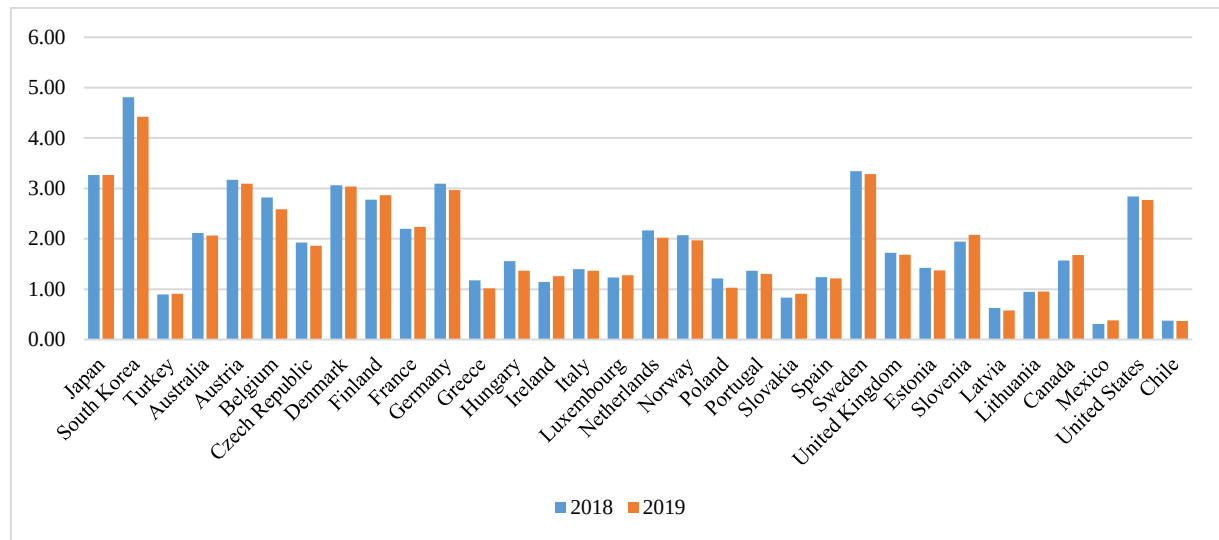


Fig. 8. Gross domestic expenditures on R&D, as % of GDP, 2018-2019

Source: UNESCO Institute for Statistics (2020).

Figure 8 present the gross domestic expenditures on R&D (as % of GDP) across the OECD countries. From the figure can be seen that South Korea spends the biggest percentage on R&D, which is higher than 4 %, while Mexico spends the lowest percentage on R&D, which is less than 1 %. The top countries that spend more than 3 % of GDP to R&D is Japan, South Korea, Austria, Denmark, Germany, and Sweden. According to the data, Mexico, Chile, Latvia, Lithuania, Slovakia, and Turkey devote less than 1 % of GDP to R&D.

The other indicator is CO₂ emission (tonnes per capita), which refers to emission steaming from the burning of fossil fuels and the manufacture. CO₂ emission includes carbon dioxide produced during the consumption of solid, liquid, and gas fuels. CO₂ emission contributes to the natural greenhouse effect, which may negatively affect life on the Earth (Crippa et al., 2020). In the research, it is interpreted as a factor that negatively affects the circular economy. It is assumed that the lowest amount of CO₂ per capita, the greatest circular economic in the country. Figure 9 presents the CO₂ tonnes per capita across the OECD countries. From the figure can be seen that the greatest share of CO₂ per capita is in Australia, Luxembourg, Estonia, Canada, and the United States, which is more than 15 tonnes per capita. The lowest share of CO₂ is in France, Portugal, Sweden, Latvia, Lithuania, and Mexico, which is less than 5 tonnes per capita in 2019. Analysing indicators of CO₂ emission intensity across the OECD countries, it is necessary to take into consideration the natural forest fires, which results in higher CO₂ emission intensity in the country.

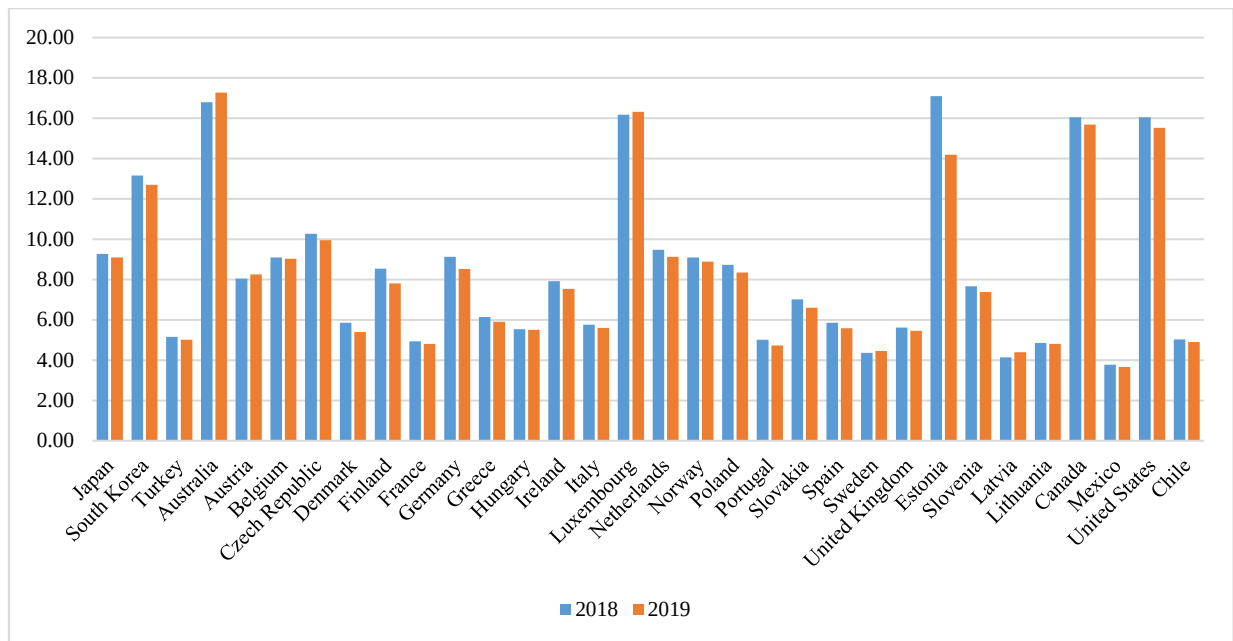


Fig. 9. CO₂ emission per capita, Tonnes/capita, 2018-2019

Source: European Commission (2020).

The other indicator is number of passenger cars in use (cars per 1000 capita), which shows the proportion of passenger cars in use per 1000 capita. In the research this indicator is interpreted as a factor that negatively affects the circular economy. It is assumed that the greatest amount of number of passenger cars in use per 1000 capita, the weakest circular economic in the country.

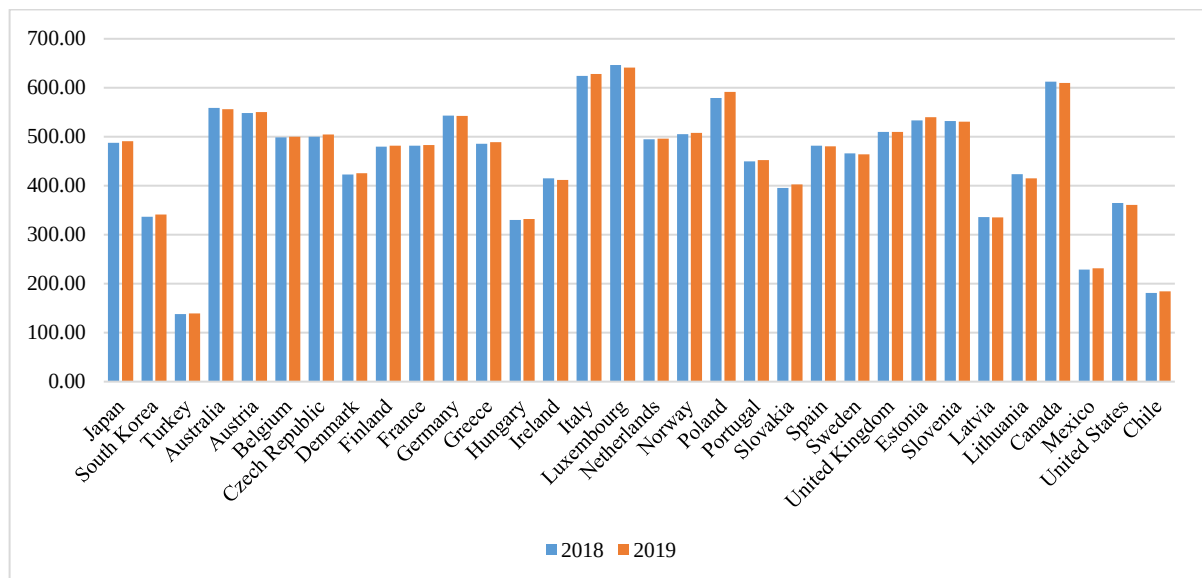


Fig. 10. Number of cars in use per 1000 capita, 2018-2019

Source: OICA (2020).

Figure 10 presents the numbers of passenger cars in use per 1000 capita across OECD countries. From the figure can be seen the biggest number of passenger cars in use per 1000 capita is in Australia, Italy, Luxembourg, Poland, and Canada, which is more than 555 cars per

1000 capita in 2019. The lowest number of passenger cars in use is in Turkey, Hungary, Latvia, Mexico, and Chile, which is less than 335 cars per 1000 capita in 2019. Analysing this indicator, it is necessary to take into consideration the economic development level. The greater the economic development level in the country, the greater the standards of living, which might result in the number of passenger cars in use.

The other indicator is gross domestic product (USD/capita), which refers to the total value of all goods and services produced within a country during a specific time of period and divided by the number of people living there. This criterion reflects the economic performance and it is a useful tool to make a cross-country comparison of average living standards and economic wellbeing (FocusEconomics, 2017). Therefore, in the research GDP per capita is understood as an indicator that has positively affected the economic growth. In research, it is assumed the bigger amount of GDP per capita leads the greater circular economy in the country.

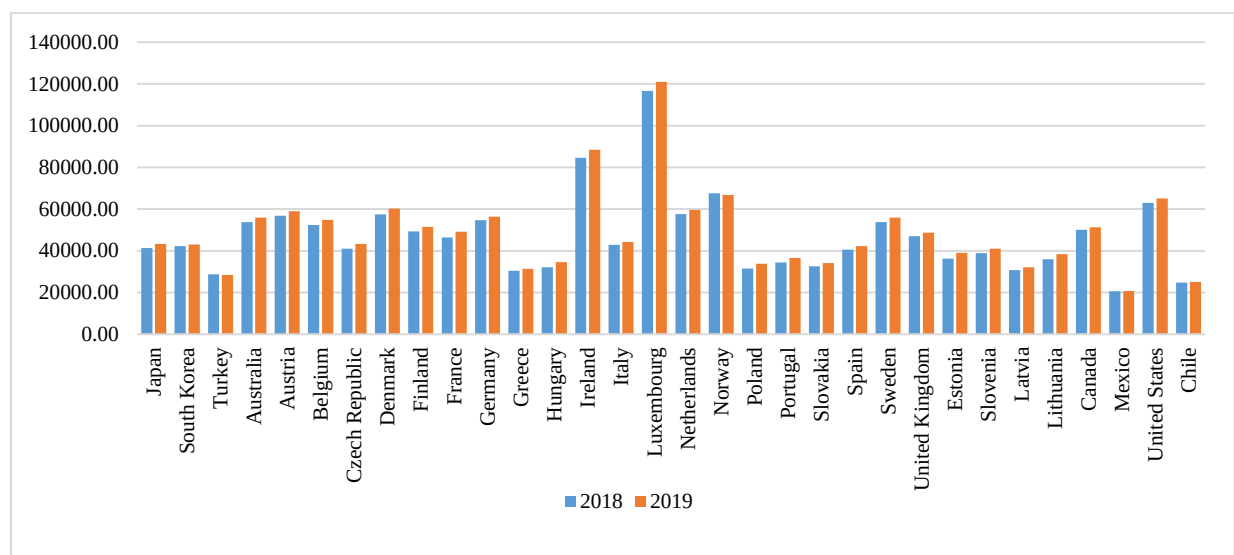


Fig. 11. Gross domestic product, USD/capita, 2018-2019

Source: OECD (2020).

Figure 11 presents GDP indicator across the OECD countries. From the figure can be noticed that Luxembourg, Ireland, United States, Norway, and Denmark have the greatest GDP per capita, while Mexico, Chile, Turkey, Greece, and Poland have the lowest GDP per capita. The greatest GDP per capita seeks around 121 thousand USD per capita, while the lowest seeks around 20 thousand USD per capita. In Hungary, Poland, Portugal, Estonia, and Lithuania increases in GDP in 2019 were more than 6 % compared to 2018, while in Turkey and Norway GDP decrease in 2019.

The other indicator is unemployment rate, as % of labour force, which shows the number of unemployed people of working age who are without work but are available for work and have taken specific steps to find work. In the research the unemployment rate criterion is interpreted as a factor that cause negative effect on the circular economy. It is assumed the

bigger number of unemployment rate, that lower circular economy in the country. Figure 12 presents the unemployment rate as % of labour force in OECD countries. From the figure can be seen that Greece as the biggest percentage of unemployment, which is more than 15 %, while Finland has the lowest unemployment rate, which is around 2 %. Countries as Turkey, Greece, Italy, and Spain have the biggest unemployment rate, which is more than 10 %, while Japan, Czech Republic, Germany, Netherlands, and Poland have the lowest percentage of unemployment. According to the data, in all OECD countries, except Turkey, Luxembourg, Sweden, Lithuania, and Mexico, unemployment decreases in 2019 compared with 2018.

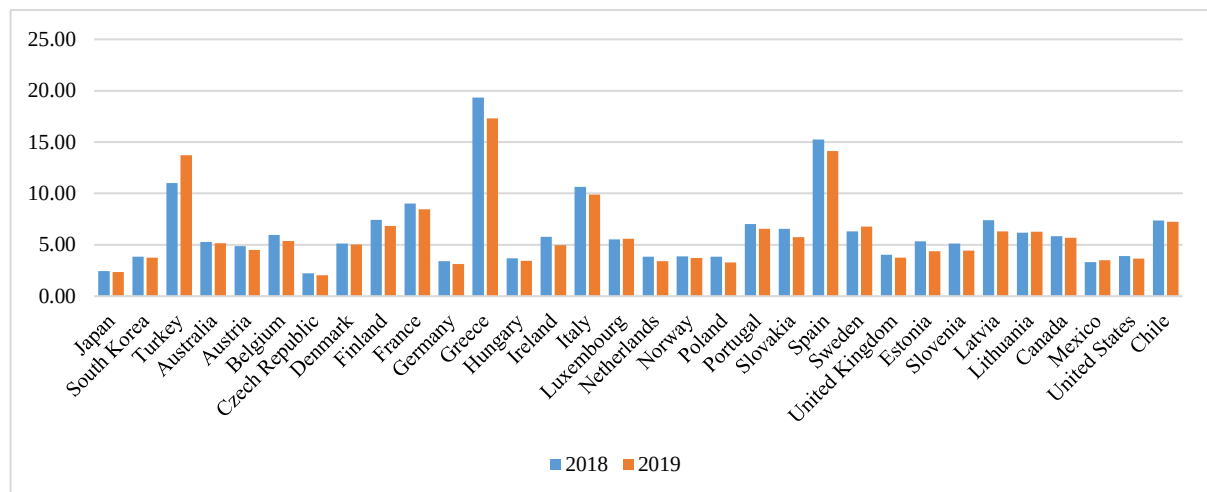


Fig. 12. Unemployment rate as % of labour force, 2018-2019

Source: OECD (2020).

The other indicator is poverty rate (%), which show the number of people whose income are below the poverty line. This criterion negatively affects the economic growth, cause additional economic costs, which are clustered around the loss of economic productivity, increased health and crime costs, and others. Due to that reason in the research the poverty rate is interpreted as a factor that cause negative effect on the circular economy. It is assumed that the bigger poverty ratio, that lower circular economy in the country.

Figure 13 presents the poverty rate across OECD countries. From the figure can be seen the biggest poverty rate is in Mexico, which seeks almost 44 %, while the lowest poverty is in Denmark, which seeks less than 6 %. From the data can be seen that in Belgium, Finland, Greece, Hungary, Ireland, Norway, Poland, Portugal, Slovakia, Spain, United Kingdom, Slovenia, and Canada poverty rate decrease in 2019 compared with 2018, while in the remaining OECD countries poverty rate remain the same or increase.

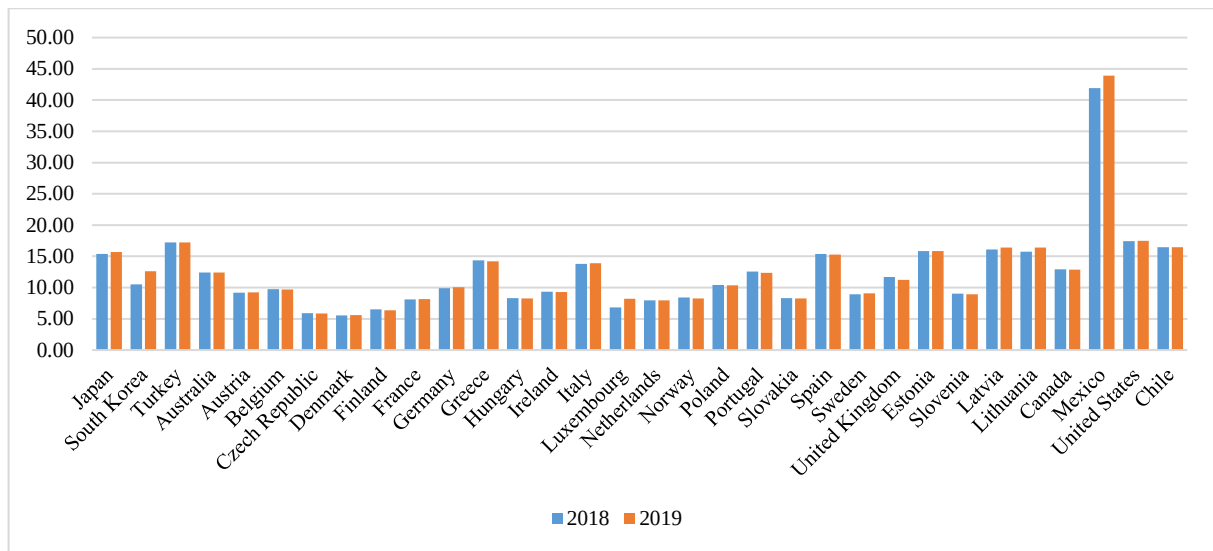


Fig. 13. Poverty rate, %, 2018-2019

Source: OECD, 2020.

The other indicator is household disposable income (gross adjusted, USD per capita), which shows household disposable income, which is adjusted for inflation. The criterion is defined as the total income received (salaries, wages, mixed-income, net property income) after deduction of taxes on income and wealth and social contributions and includes social benefits. This criterion does not include in kind-transfer, which are related to the education and health provided free by the government (OECD, 2019). The criterion reflects the purchasing power of households and their ability to invest in goods and services or save for the future. Adjusted gross disposable income per capita is calculated as the adjusted gross disposable income divided by the purchasing power parities of the actual individual consumption of household and by the total resident population (Eurostat, 2019). In the research this criterion is interpreted as factor that positively affects the circular economy. It is assumed that the greater adjusted gross disposable income, the bigger effect on the circular economic in the country.

Figure 14 presents the gross adjusted household disposable income across OECD countries. From the figure can be seen, that the greatest amount of household disposable income has the United States, Luxembourg, Germany, Australia, and Norway, while the lowest have Chile, Mexico, Turkey, Greece, and Hungary. The greatest amount of household disposable income is around 49 thousand UDS per capita, while the lowest – around 16 thousand USD per capita. In Hungary, Estonia, Slovenia, Latvia, and Lithuania is a notable significant decrease in household disposable income in 2019 compared with 2019, which is from 8 to 13 %. In the Czech Republic, Finland, Portugal, Slovenia, and Sweden are notable significant increases in household disposable income in 2019, which is greater than 6 %.

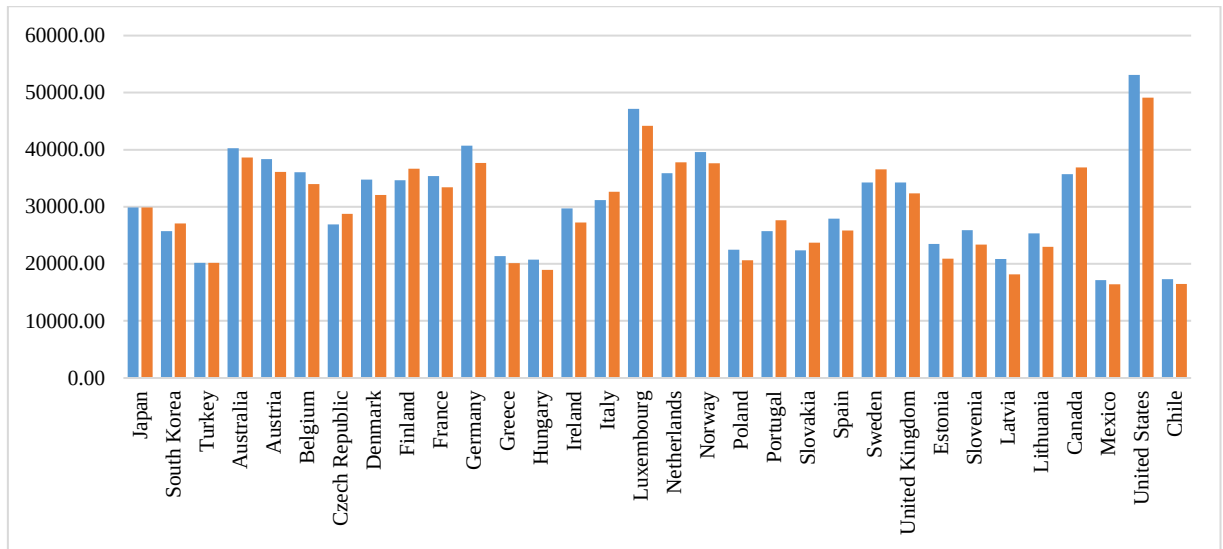


Fig. 14. Household disposable income Gross adjusted, USD per capita, 2018-2019

Source: OECD (2020).

The other indicator is household with Internet access (%), which is defined as the percentage of households who had access to the Internet. According many scientists, household with Internet access highly contributes to the mart economy, which in principle stimulates the innovation and creativity combined with the scientific research, technology. In the research the criterion is interpreted as a factor that positively affects the circular economy. It is assumed that the greatest percentage of households with Internet access, the greatest circular economic in the country.

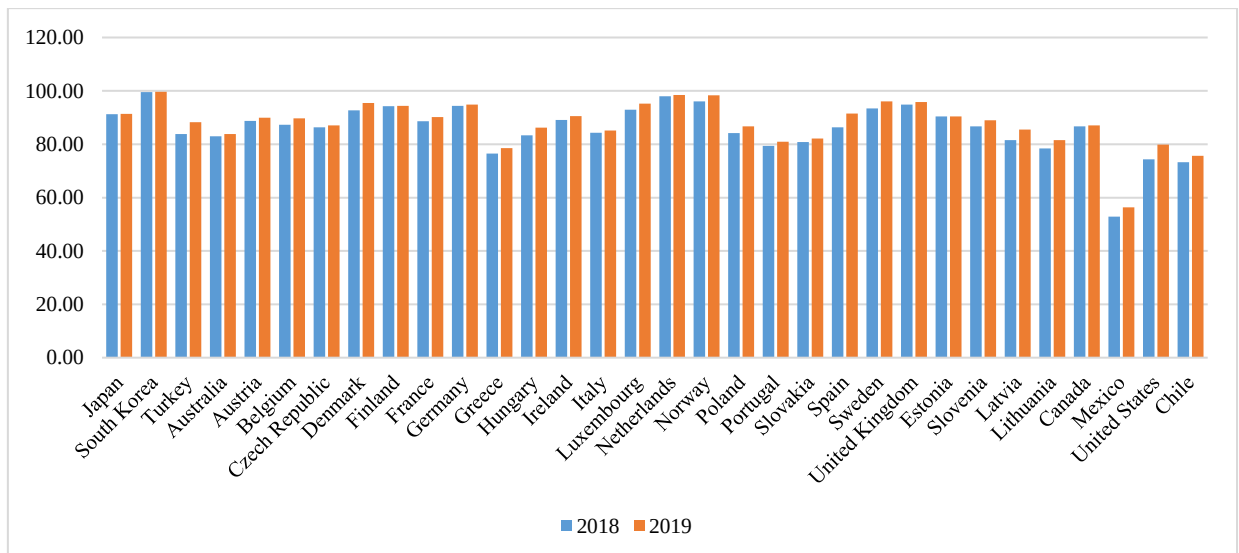


Fig. 15. Households with Internet access, %, 2018-2019

Source: OECD (2020).

Figure 15 presents the households with Internet access across the OECD countries. From the figure can be seen, that the biggest percentage of households with Internet access is

in South Korea, Netherlands, Norway, Sweden, and United Kingdom, which is higher than 95 % in 2018, while the lowest percentage is in Greece, Mexico, The United States, and Chile, which is less than 80 % in 2019.

The other indicator is municipal waste (tonnes per 1000 capita), which defined as waste collected and treated by or for municipalities. Municipal waste includes waste from households, bulky, commerce and trade, office buildings, institutions, small business, yard and garden and other waste. Municipal waste does not include waste from sewage networks and treatments, construction, and demolition activities waste. In the research the criterion is interpreted as factor that negatively affect the circular economy. It is assumed that the bigger amount of collected municipal waste, the lower circular economy development in the country.

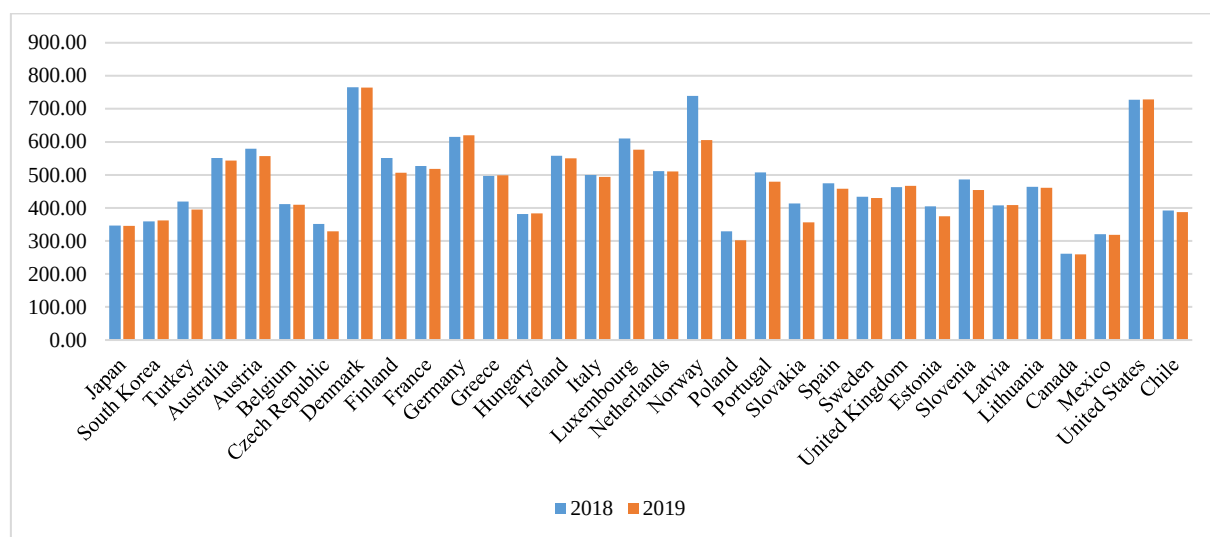


Fig. 16. Municipal waste generated, Tonnes per 1000 capita, 2018-2019

Source: OECD (2020).

Figure 16 presents the collected municipal waste across the OECD countries. From the figure can be seen that the greatest amount is collected in Denmark, Norway, the United States, Germany, and Luxembourg, while the lowest amount is collected in Canada, Poland, Czech Republic, Mexico, and Japan. The greatest amount is collected in Denmark, which reaches around 764 tonnes per 1000 capita, while the lowest amount is collected in Canada, which is around 260 tonnes per 1000 capita. In all OCDE countries, except South Korea, Germany, Greece, Hungary, United Kingdom, Latvia, and the United States the municipal waste generated amount increases in 2019 compared to 2018.

To conclude, according to the theoretical background, all indicators listed above have a significant impact on the circular economy. Some of the indicators have a positive impact on the circular economy, some of them have a negative impact. Indicators that have a positive impact on the circular economy are gross domestic product (USD/capita), gross adjusted

household disposable income (USD/capita), gross domestic expenditure on R&D (as % of GDP), patents in environment-related technologies, renewable energy (as % of primary energy supply), households with Internet access (%). Indicators that have a negative impact on the circular economy are unemployment rate (as % of labour force), poverty rate (%), municipal waste generated (tonnes/1000 capita), electricity production (MWh/1000 capita), air pollution exposure (exposure PM2.5, ($\mu\text{g}/\text{m}^3$)), CO₂ emission per capita (tonnes/capita), and number of passenger cars (cars/1000 capita).

3.2. Determination of importance weights of circular economy indicators using Analytic Hierarchy Process (AHP) method

Analytic Hierarchy Process (AHP) method was used to determine the weights of indicators of the circular economy. According to the theoretical background, the hierarchical model was created with defined criteria, sub-criteria, and alternatives (see in Table 8). The first level of the hierarchical model presents the goal, which is assessment of the circular economy, while the second level presents the 6 specific areas of the circular economy: economic prosperity, zero-waste economy, innovative economy, energy-efficient and renewable energy-based economy, low carbon economy, and smart economy. The third level consists of the 13 indicators, while the potential countries are presented in the fourth level of alternatives.

Table 8. Hierarchical model for the assessment of the circular economy

Goal	CE specific area	Indicator	Alternatives
Assessment of the circular economy	Energy-efficient and renewable energy-based economy	Air pollution exposure	Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Japan, South Korea, Luxembourg, Mexico, Netherlands, Norway, Poland, Portugal, Slovakia, Spain, Sweden, Turkey, United Kingdom, United States, Chile, Estonia, Slovenia, Latvia, Lithuania
		Electricity consumption	
		Renewable energy	
	Innovative economy	Patents in environment-related technologies	
		Gross domestic expenditure on R&D	
	Low carbon economy	CO ₂ emission intensity	
		Number of passenger cars in use	
	Economic prosperity	Gross Domestic Product	
		Unemployment rate	
		Poverty rate	
		Household disposable income Gross adjusted	
	Smart economy	Households with Internet access	
	Zero-waste economy	Municipal waste generated	

Source: composed by author.

Based on this hierarchical model the survey was created (see in Appendix 1). Survey consists of 78 responses. The assessment of the significance of the criteria is performed in

cooperation with experts and evaluated according to the Saaty's scale, which are divided into 6 evaluation levels: same relevance, a little more relevant, considerably more relevant, a lot more relevant, extremely relevant, and intermediate values (see in Table 9).

Table 9. Saaty's scale of evaluation

Importance	Definition	Explanation
1	Same relevance	Two factors contribute equally to the purpose
3	A little more relevant	Experience and judgement slightly favour one factor over another
5	Considerably more relevant	Experience and judgement strongly favour one factor over another
7	A lot more relevant	One factor is favoured very strongly over another
9	Extremely relevant	The evidence one factor over another is of the highest possible order of affirmation
2, 4, 6, 8	Intermediate values	Sometimes one needs to interpolate a compromise judgement numerically because there is no good word to describe it

Source: compared by author based on Starčević et al. (2019).

The choice of experts is used to determine the relative weight of each criterion, which is one of the most effective means of solving multi-criteria problems. In the research, the 6 experts were interviewed by the survey. According to scientists, it is enough to have up to 10 experts in the research (Iljins, Skvarciany, & Gaile-Sarkane, 2015). Experts that have participated in the research have PhD education in economics or engineering and work in academic scientific and governments spheres as for example associate professor, government official, and researcher.

Table 10. List of experts

No.	Education	Role	Year of expertise
1	PhD Economics	Associate Professor	10
2	PhD Economics	Associate Professor	7
3	PhD Economics	Researcher	6
4	PhD Economics	Associate Professor	6
5	PhD Engineering	Associate Professor	12
6	PhD Engineering	Government Official	0

Source: based on author.

First of all, according to the survey's results the pairwise comparison calculations were made (see in Appendix 3, Appendix 4, Appendix 5, Appendix 6, Appendix 7, Appendix 7). Second, according to the pairwise comparison calculations the standardized matrixes and averages were calculated (see in Appendix 9, Appendix 10, Appendix 11, Appendix 12, Appendix 13, Appendix 13). Third, consistency ratio (CR) were tested accordingly to the random index (RI) and consistency index (CI). Due to in the research 13 criteria are used, RI index is equal 1,56 (see in Appendix 14) while CI were calculated accordingly lamda max (Shaoa et al., 2020). According to the literature review consistency ratio (CR) must be less than or equal 0,2 (Lepikhina, Skachkova, & Mihaelyan, 2018, Аксенов, Блащук, & Чернухин, 2010). This

means if consistency ratio is less than or equal 0,2, consistency is acceptable, if not it is necessary to revise the subjective judgment.

Table 11 presents the calculated weights of factors of the circular economy according to the AHP method and consistency ratio (CR). From the table below it can be seen that consistency ratio of expert no. 5 is equal 0.31, meaning that consistency is not acceptable, and it is necessary to revise the subjective judgment. Due to that, expert no. 5 answer will be eliminated and do not included in the further research. Moreover, weights of factors of the circular economy will be determined according to the expert no.1, expert no.2, expert no.3, expert no. 5, and expert no. 6 answers.

Table 11. Calculated weights of factors of the circular economy and consistency ratio (CR)

Experts	Gross Domestic Product	Unemployment rate	Poverty rate	Household disposable income Gross	Municipal waste generated	Patents in environment-related	Gross domestic expenditure on R&D	Electricity consumption	Renewable energy	Air pollution exposure	CO ₂ emission	Number of passenger cars in use	Households with Internet access	CR
Expert no. 1	0.03	0.02	0.17	0.02	0.14	0.20	0.04	0.06	0.16	0.05	0.05	0.04	0.02	0.07
Expert no. 2	0.01	0.01	0.01	0.01	0.12	0.05	0.06	0.12	0.12	0.12	0.12	0.12	0.12	0.05
Expert no. 3	0.01	0.02	0.04	0.04	0.19	0.03	0.04	0.05	0.06	0.11	0.20	0.19	0.02	0.08
Expert no. 4	0.02	0.01	0.02	0.08	0.11	0.11	0.18	0.10	0.11	0.08	0.09	0.03	0.06	0.10
Expert no. 5	0.08	0.03	0.01	0.02	0.08	0.03	0.03	0.11	0.24	0.11	0.19	0.04	0.03	0.31
Expert no. 6	0.02	0.03	0.12	0.03	0.11	0.01	0.09	0.10	0.17	0.12	0.16	0.02	0.03	0.17

Source: based on author.

Table 12 presents the final weights of factors of the circular economy that will be used in the research and further calculations.

Table 12. Final weights of factors of the circular economy

	Gross Domestic Product	Unemployment rate	Poverty rate	Household disposable income Gross adjusted	Municipal waste generated	Patents in environment-related technologies	Gross domestic expenditure on R&D	Electricity consumption	Renewable energy	Air pollution exposure	CO ₂ emission	Number of passenger cars in use	Households with Internet access
Expert no. 1	0.03	0.02	0.17	0.02	0.14	0.20	0.04	0.06	0.16	0.05	0.05	0.04	0.02
Expert no. 2	0.01	0.01	0.01	0.01	0.12	0.05	0.06	0.12	0.12	0.12	0.12	0.12	0.12
Expert no. 3	0.01	0.02	0.04	0.04	0.19	0.03	0.04	0.05	0.06	0.11	0.20	0.19	0.02
Expert no. 4	0.02	0.01	0.02	0.08	0.11	0.11	0.18	0.10	0.11	0.08	0.09	0.03	0.06
Expert no. 6	0.02	0.03	0.12	0.03	0.11	0.01	0.09	0.10	0.17	0.12	0.16	0.02	0.03
Weights	0.02	0.02	0.05	0.04	0.14	0.10	0.08	0.08	0.11	0.09	0.11	0.10	0.06

Source: based on author.

From the table can be seen that gross domestic product criteria has weight of 2 % on the circular economy, unemployment rate – 2 %, poverty rate – 5 %, household disposable income gross adjusted – 4 %, municipal waste generated – 14 %, patents in environment-related technologies – 10 %, gross domestic expenditure on R&D – 8 %, electricity production – 8 %, renewable energy – 11 %, air pollution exposure – 9 %, CO₂ emission – 11 %, number of passenger cars in use – 10 %, households with Internet access – 6 %.

To sum up, in the research weights were determined according to the five experts' answers. According to the results, the significant impact on the circular economy have municipal waste generated (14 %), renewable energy (11 %), CO₂ emission (11 %), patents in environment-related technologies (10 %), number of passenger cars in use (10 %), a slightly smaller impact have capital air pollution exposure (9 %), gross domestic expenditure on R&D (8 %), electricity production (8 %), poverty rate (6 %), and households with Internet access (6 %), while the weakest impact on the circular economy have household disposable income gross adjusted (4 %), gross domestic product (2 %), and unemployment rate (2 %). Additionally, according to the expert's results, specific area of the circular economy of innovative economy, low carbon economy, and energy-efficient and renewable energy-based economy have the greatest impact on the circular economy, while smart economy specific area of the circular economy has the lowest impact.

3.3. Circular economy assessment results using Technique for Order of Preference by Similarly to Ideal Solution (TOPSIS)

The technique for order of preference by similarly to ideal solution (TOPSIS) calculation was carried out to assess the circle economy in OECD countries for the period of 2018-2019. First, to carry out the TOPSIS calculation, it is necessary for all indicators assign the importance weights. In cooperation with experts and AHP method, weights were assigned: gross domestic product – 2 %, unemployment rate – 2 %, poverty rate – 5 %, household disposable income gross adjusted – 4 %, municipal waste generated – 14 %, patents in environment-related technologies – 10 %, gross domestic expenditure on R&D – 8 %, electricity production – 8 %, renewable energy – 11 %, air pollution exposure – 9 %, CO₂ emission – 11 %, number of passenger cars in use – 10 %, and households with Internet access – 6 %. Second, normalized matrix, which transforms criteria dimensions in non-dimensional criteria, was calculated. The normalized matrix calculation can be seen in Appendix 15, Source: based on author.

Appendix 16. The third, weighted normalized matrix was calculated (see in Source: based on author.

Appendix 17, Appendix 18). The next step was the calculation of the ideal best (V^+) and anti-ideal best (V^-) values. These values were calculated according to the maximum or minimum criteria values of all alternatives. The ideal best (V^+) and anti-ideal best (V^-) values can be seen in Appendix 19, Appendix 20). Further step was calculation of the Euclidean distance from the ideal best values (SI^+) and anti-ideal best (SI^-) values. According to the Euclidean distance was calculated performance scores (PI) for all alternatives (see in Appendix 21). The performance score shows the information regarding circular economy, meaning the higher the performance scores the greater circular economy is in the country. The results of the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) can be seen in Table 13.

Table 13. Performance scores get by TOPSIS method, 2018-2019. Note: PI – performance score

Country	2018		2019		Country	2018		2019	
	PI	Rank	PI	Rank		PI	Rank	PI	Rank
Japan	0,62	1	0,63	1	Hungary	0,49	14	0,49	17
Sweden	0,55	2	0,57	2	Italy	0,48	19	0,49	18
Norway	0,52	6	0,55	3	Ireland	0,48	22	0,49	19
Germany	0,52	5	0,54	4	Belgium	0,49	17	0,49	20
Finland	0,52	4	0,54	5	Netherlands	0,48	20	0,49	21
Denmark	0,52	7	0,54	6	Spain	0,48	23	0,49	22
Latvia	0,53	3	0,53	7	Czech Republic	0,48	21	0,49	23
Austria	0,51	8	0,52	8	Slovakia	0,48	25	0,49	24
Portugal	0,50	9	0,51	9	Greece	0,47	26	0,48	25
United Kingdom	0,49	13	0,51	10	Turkey	0,47	27	0,48	26
Lithuania	0,50	12	0,50	11	Poland	0,46	28	0,47	27
South Korea	0,50	10	0,50	12	Canada	0,49	16	0,47	28
France	0,49	15	0,50	13	United States	0,46	29	0,47	29
Chile	0,50	11	0,50	14	Luxembourg	0,45	32	0,46	30
Estonia	0,48	24	0,50	15	Mexico	0,46	30	0,46	31
Slovenia	0,48	18	0,50	16	Australia	0,45	31	0,46	32

Source: composed by author according to the TOPSIS calculations.

Table 13 displays the performance scores (PI) got by TOPSIS method calculation and presents the rankings of the OECD countries regarding circular economy in the period of 2018-2019. From the table can be seen Japan has the highest performance scores in the period of 2018-2019, while the Australia has the lowest performance scores in the period of 2018-2019. This means, that Japan has the strongest circular economy, while Australia has the weakest circular economy across the OECD countries in 2018-2019. The top 5 countries that have the strongest circular economies in 2018 are Japan, Sweden, Latvia, Finland, and Germany, while Luxembourg, Australia, Mexico, the United States, and Poland have the weakest circular economy compared to OECD countries. The top 5 countries that have the strongest circular

economies in 2019 are Japan, Sweden, Norway, Germany, and Finland, while Australia, Mexico, Luxembourg, the United States, and Canada have the weakest circular economy across OECD countries.

In figure below can be seen the performance scores regarding circular economy in 2018-2019. From the figure can be seen that there are slight changes between periods of 2018-2019. According to the data, performance scores of the circular economies slightly increase in almost all OECD countries, except in South Korea, Chile, Hungary, Belgium, Canada, and Mexico. In those countries circular economy performance scores decrease or remain the same as in 2018.

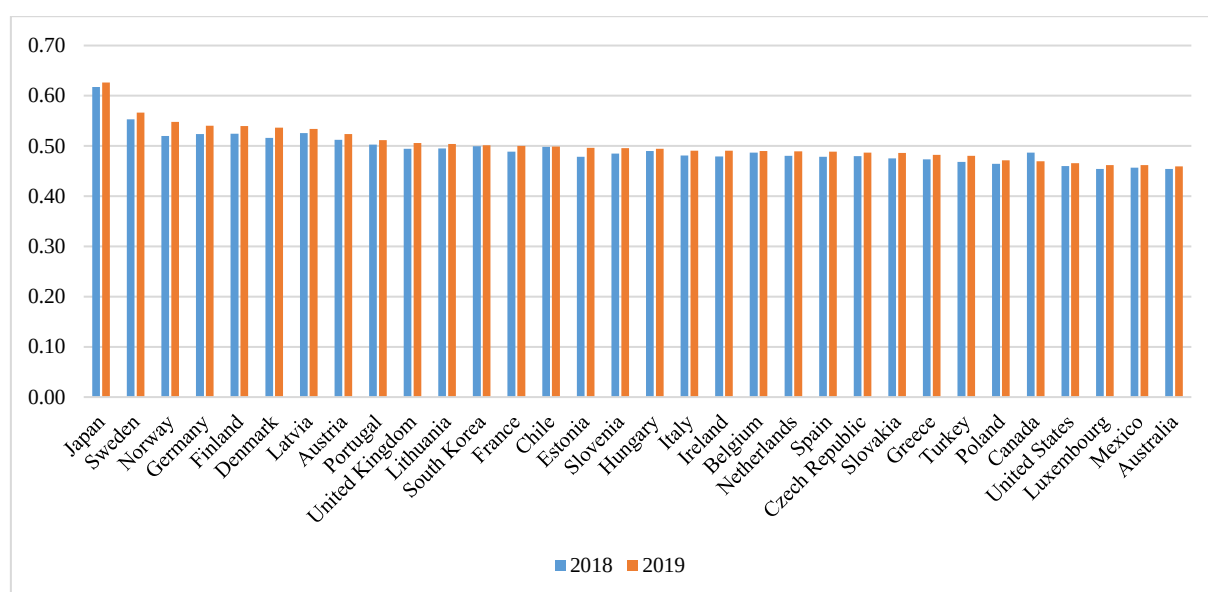


Fig. 17. Performance scores got by TOPSIS during 2018-2019

Source: composed by author according to the TOPSIS calculations.

The calculation of the circular economy from the region perspectives of OECD countries were carried out (see in Appendix 22, Appendix 23, Appendix 24, Appendix 25, Appendix 26, Appendix 27, Appendix 28). Table 14 displays the performance scores (PI) of OECD regions got by TOPSIS method calculation and presents the rankings of the regions of OECD regarding circular economy in the period of 2018-2019.

Table 14. Performance scores get by TOPSIS method according OECD regions, 2018-2019. Note: PI – performance score

Region	2018		2019	
	PI	Rank	PI	Rank
Asia	0,57	1	0,61	1
Europe	0,54	3	0,57	2
South America	0,55	2	0,55	3
North America	0,47	4	0,47	4
Australia	0,42	5	0,43	5

Source: composed by author according to the TOPSIS calculations.

From the table below can be seen the Asia has the highest performance scores in the period of 2018-2019, while the Australia has the lowest performance scores in the period of 2018-2019. This means, that Asia has the strongest circular economy, while the Australia has the weakest circular economy compared to the remaining OECD regions in 2018-2019. According to the results, ranking remain the same in 2019 as in 2018. Additionally, Europe is the second region from the list economy.

In figure below can be seen the performance scores of the regions of OECD regarding circular economy in 2018-2019. From the figure can be seen that there are slight changes between periods of 2018-2019. According to the data, performance score of the circular economy slightly increase in Asia, Europe, North America, and Australia, while in South America the performance score decreases in 2019 compared to 2018.

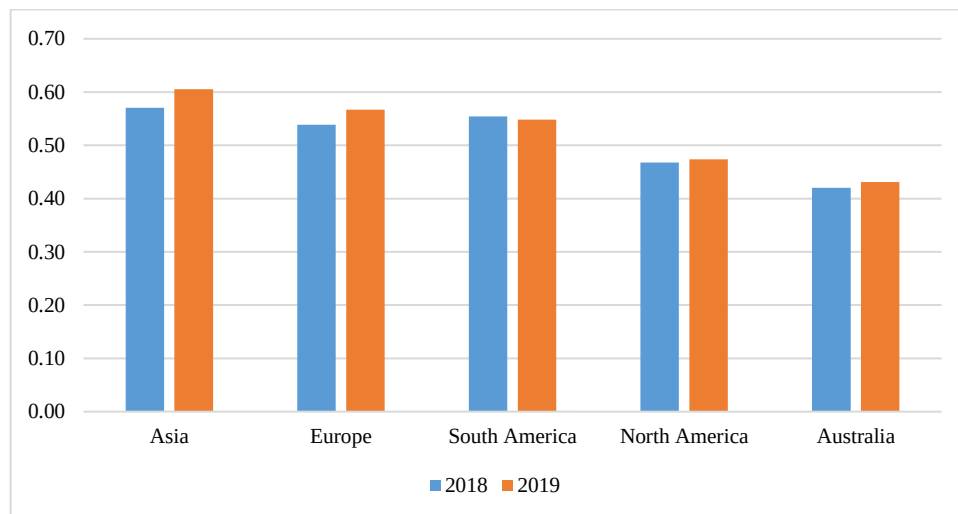


Fig. 18. Performance scores of OECD regions got by TOPSIS during 2018-2019

Source: composed by author according to the TOPSIS calculations.

Based on the results of TOPSIS method calculation, analysis of the strongest and weakest circular economy was made (see in Fig. 19). According to the TOPSIS results, Japan has the strongest circular economy, while Australia has the weakest circular economy. In the figure below can be seen that Japan has a significant bigger number of patents in environment-related technologies, bigger percentage of households with internet access and gross domestic expenditures on R&D. Also, Japan has a lower unemployment rate, generate less municipal waste, has smaller CO₂ emission intensity. Australia has bigger amount of gross domestic product, household's disposable income gross adjusted, produce bigger percentage of renewable energy, besides has lower air pollution exposure, and produce the lower amount of electricity.

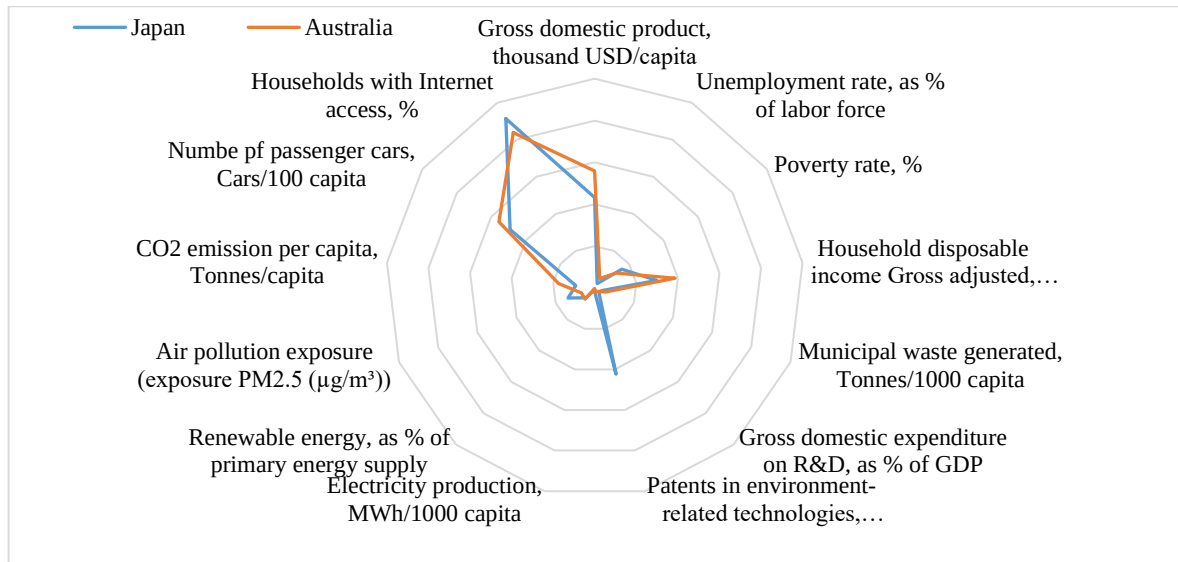


Fig. 19. Circular economy analysis between the United States and Mexico, 2019

Source: composed by author according to the TOPSIS calculations.

To conclude, according to the TOPSIS calculation results, Japan, Sweden, Latvia, Finland, and Germany, have the strongest circular economy in 2018, while the strongest circular economy in 2019 have Japan, Sweden, Norway, Germany, and Finland. The weakest circular economy in 2018 have Luxembourg, Australia, Mexico, the United States, and Poland, while in 2019 Australia, Mexico, Luxembourg, the United States, and Canada. From the region perspective, Asia has the strongest circular economy, while Australia have the weakest circular economy in 2018-2019.

3.4. Circular economy assessment results using Evaluation based on Distance from Average Solution (EDAS)

The evaluation based on distance from average solution (EDAS) calculation was carried out to assess the circular economy in OECD countries for the period of 2018-2019. In EDAS calculation importance weights will be the same as in TOPSIS calculation. First, it is necessary to determine beneficial and non-beneficial criteria. According to the literature review and criteria analysis, beneficial and non-beneficial criteria were identified. In the research criteria of gross domestic product, household disposable income gross adjusted, gross domestic expenditure on R&D, patents in environment-related technologies, renewable energy, and households with Internet access were interpreted as beneficial criteria, while unemployment rate, poverty rate, municipal waste generated, electricity consumption, air pollution exposure, CO₂ emission, and number of passenger cars in use as non-beneficial criteria. Third, the average solution was determined (see in Appendix 29, Appendix 30). Fourth, the positive distance from

average (PDA) and the negative distance from average (NDA) were calculated (see in Appendix 31, Appendix 32, Appendix 33, Appendix 34, Appendix 35, Appendix 36, Appendix 37, Appendix 38). After that, values of SP_i and SN_i were normalized (see in Appendix 39, Appendix 40). Furthermore, the appraisal score (AS_i) for all alternatives were calculated. Lastly, the alternatives were ranked according to the values of AS_i .

Table 15 display the appraisal scores get by evaluation based on distance from average solution (EDAS) method calculation regarding assessment of the circular economy in OECD countries, 2018-2019. From the table can be seen that Japan has the greatest appraisal scores, while Mexico has the lowest appraisal scores in 2018-2019. This means that Japan has the strongest circular economy compared with the OCED countries, while Mexico has the weakest circular economy among OECD countries. The top 5 countries that have the strongest circular economy in 2018 are Japan, Sweden, Finland, Germany, and Denmark, while Japan, Sweden, Norway, Finland, and Denmark in 2019. The top 5 weakest circular economies in 2018 have Mexico, Poland, Australia, Turkey, and Luxembourg, while Mexico, Australia, Poland, Luxembourg, and Greece in 2019.

Table 15. Appraisal scores get by EDAS method, 2018-2019. Note: AS – appraisal score

Country	2018		2019		Country	2018		2019	
	AS	Rank	AS	Rank		AS	Rank	AS	Rank
Japan	0,76	1	0,77	1	Netherlands	0,50	17	0,50	17
Sweden	0,66	2	0,67	2	Belgium	0,50	15	0,50	18
Norway	0,59	6	0,62	3	Estonia	0,46	25	0,49	19
Finland	0,59	3	0,61	4	Slovenia	0,48	20	0,49	20
Denmark	0,59	5	0,60	5	Czech Republic	0,48	22	0,48	21
Germany	0,59	4	0,60	6	Chile	0,50	18	0,48	22
Latvia	0,58	7	0,57	7	Slovakia	0,46	26	0,47	23
Austria	0,56	8	0,56	8	Spain	0,47	23	0,47	24
South Korea	0,53	9	0,53	9	Italy	0,46	24	0,46	25
Portugal	0,53	10	0,53	10	Canada	0,48	21	0,44	26
United Kingdom	0,52	11	0,53	11	Turkey	0,43	29	0,44	27
France	0,51	12	0,52	12	Greece	0,44	27	0,44	28
Lithuania	0,51	13	0,51	13	Luxembourg	0,43	28	0,43	29
Ireland	0,49	19	0,50	14	Poland	0,42	31	0,42	30
Hungary	0,51	14	0,50	15	Australia	0,42	30	0,42	31
United States	0,50	16	0,50	16	Mexico	0,39	32	0,39	32

Source: composed by author according to the EDAS calculations.

In figure below can be seen the appraisal scores regarding circular economy evolution during 2018-2019.

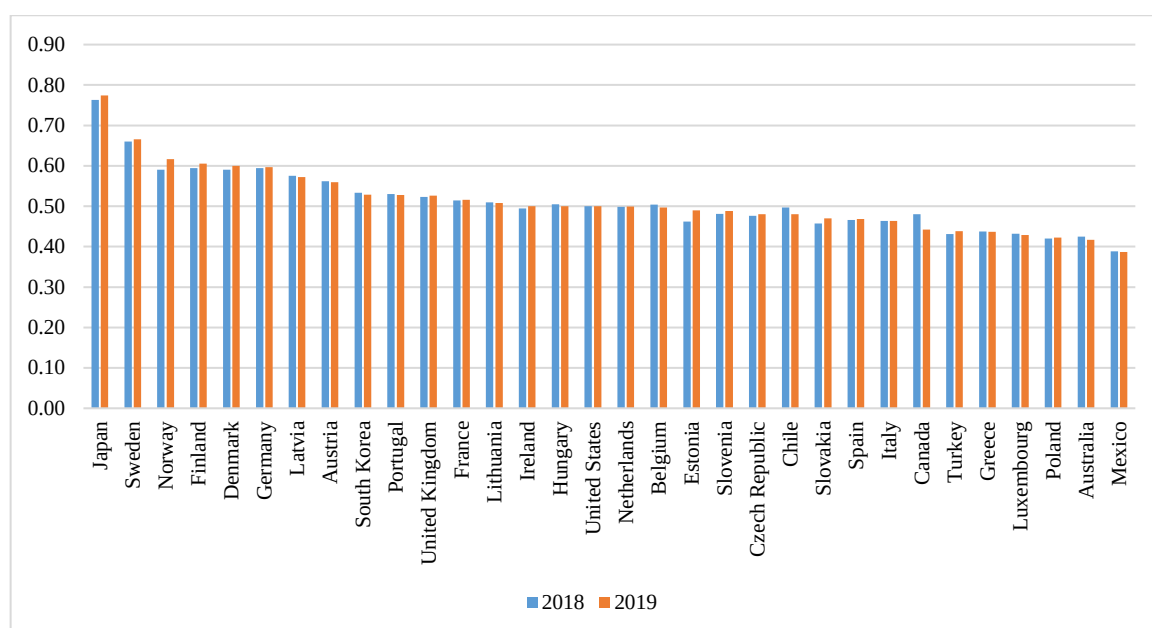


Fig. 20. Appraisal scores get by EDAS, 2018-2019

Source: composed by author according to the EDAS calculations.

From the figure above can be seen that there is a slight difference between periods of 2018-2019. However, in some countries as Japan, Sweden, Norway, Finland, Denmark, Ireland, Estonia, Slovenia, Slovakia, and Turkey the appraisal scores slightly increase, meaning that circular economy became a stronger in 2019. Additionally, in some countries as Belgium, Chile, Canada, and Australia appraisal scores slightly reduce, meaning that circular economy became weaker in 2019. In the remaining OECD countries circular economy in 2019 remain the same as in 2018.

The calculation of the circular economy from the region perspectives of OECD countries were carried out (see in Appendix 41, Appendix 42, Appendix 43, Appendix 44, Appendix 45, Appendix 46, Appendix 47, Appendix 48, Appendix 49, Appendix 50, Appendix 51, Appendix 52).

Table 16. Appraisal scores get by EDAS method, 2018-2019. Note: AS – appraisal score

Region	2018		2019	
	AS	Rank	AS	Rank
Asia	0,67	1	0,73	1
Europe	0,58	2	0,65	2
South America	0,55	3	0,55	3
North America	0,34	4	0,33	4
Australia	0,24	5	0,26	5

Source: composed by author according to the EDAS calculations.

Table 16 displays the appraisal scores (AS) of OECD regions got by EDAS method calculation and presents the rankings of the regions of OECD regarding the circular economy

in the period of 2018-2019. From the table below can be seen the Asia has the highest appraisal scores in the period of 2018-2019, while the Australia has the lowest appraisal scores in the period of 2018-2019. This means, that Asia has the strongest circular economy, while the Australia has the weakest circular economy compared to the remaining OECD regions in 2018-2019. According to the results, rankings remain the same in 2019 as in 2018.

In figure below can be seen the appraisal scores of the regions of OECD regarding circular economy in 2018-2019. From the figure can be seen that there are slight changes between periods of 2018-2019. According to the data, performance score of the circular economy slightly increase in Asia, Europe, North America, while in Australia and South America the performance score decreases in 2019 compared to 2018.

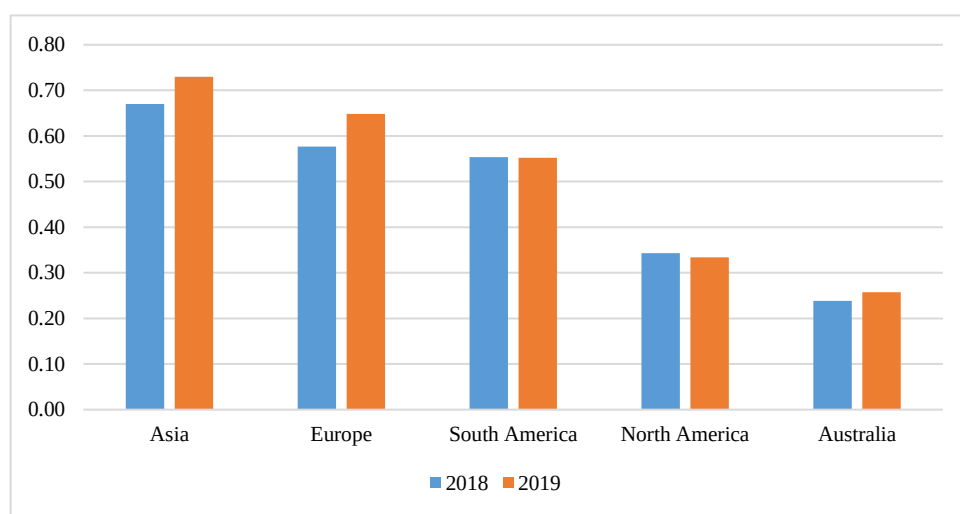


Fig. 21. Appraisal scores of OECD regions got by EDAS during 2018-2019

Source: composed by author according to the TOPSIS calculations.

Based on the results of EDAS method calculation, analysis of the strongest and weakest circular economy was made (see in Fig. 22). According to the EDAS results, Japan has the strongest circular economy, while Mexico has the weakest circular economy. In the figure below can be seen that Japan has the greatest performance in all beneficial criteria as gross domestic product, household disposable income, gross domestic expenditures on R&D, patents in environment-related technologies, renewable energy, and households with Internet access, and in some non-beneficial criteria as municipal waste, CO₂ emission, and number of passenger cars in use. Additionally, from the figure can be seen that Mexico has significantly smaller all beneficial criteria, and bigger non-beneficial criteria as unemployment rate, poverty rate, electricity consumption, and air pollution exposure.

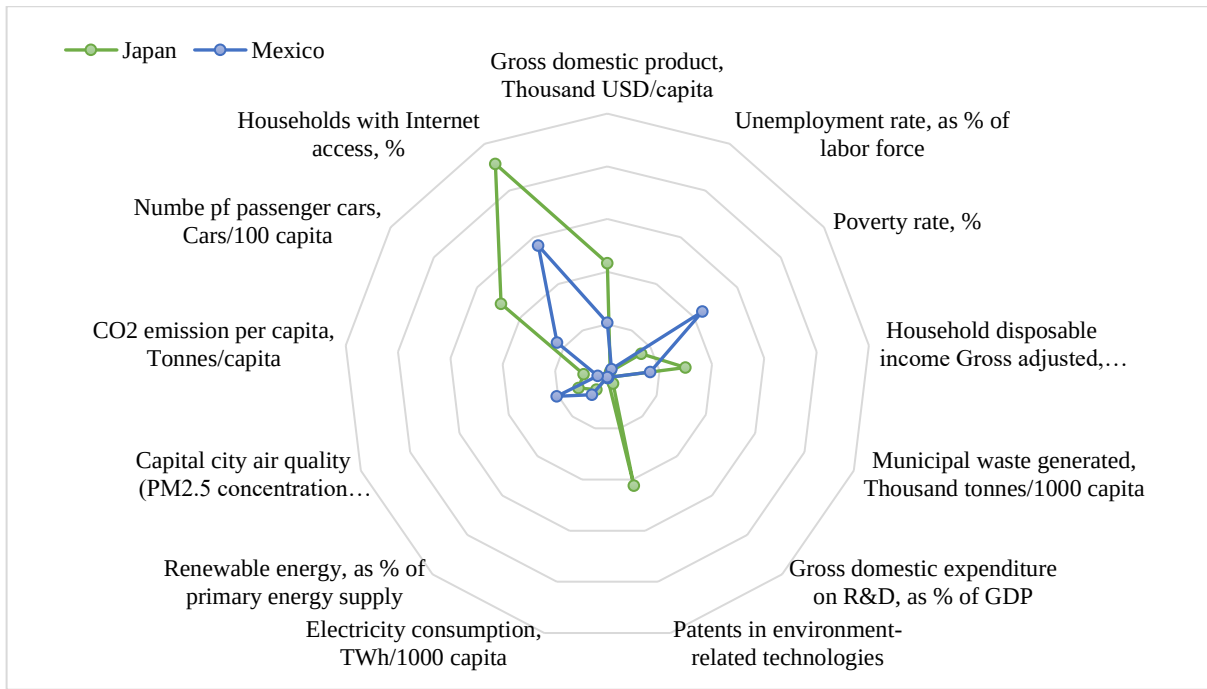


Fig. 22. Circular economy analysis between Japan and Mexico, 2019

Source: composed by author according to the EDAS calculations.

To sum up, according to the EDAS calculation results, Japan, United States, Sweden, Germany, and Finland have the strongest circular economy in 2018-2019. Countries as Mexico, Poland, Greece, Luxembourg, and Chile have the weakest circular economy in 2018, while Mexico, Greece, Luxembourg, Chile, and Australia have the weakest circular economy in 2019. From regional perspective, Asia has the strongest circular economy in the period of 2018-2019, while the Australia has the weakest circular economy in the period of 2018-2019. Based on the results, countries that have greater values in beneficial and smaller values in non-beneficial criteria have a stronger circular economy and vice versa.

3.5. Assessment of the circular economy as one of the models of sustainable development using fixed effect regression model

In this part will be answered to the hypotheses raised according to the literature review. In the research several hypotheses were raised:

1. Hypothesis 1. The circular economy has a significant impact on sustainable development.
2. Hypothesis 2. The circular economy has not a significant impact on sustainable development.
3. Hypothesis 3. The circular economy only partially affects sustainable development.

4. Hypothesis 4. The most significant circular economic indicators have significant impact on sustainable development.

According to the comparative analysis results and meta-regression results, hypotheses will be rejected or accepted.

First, comparative analysis between the results of evaluation based on distance from average solution (EDAS) calculations and Sustainable Development Goals Index (SDGI) will be performed. In this case EDAS sub-method results will be compared, because EDAS sub-method generate more accurate solutions in solving real-life problems. It is worth to note, that comparative analysis only includes the newest data of 2019. The comparative analysis is presented in the Table 17.

Table 17. Comparative analysis between the results of EDAS and Sustainable Development Goals Index (SDGI), 2019

Country	EDAS performance scores	EDAS rank	SDGI (0-100)	SDI rank
Japan	0.77	1	78.92	13
Sweden	0.67	2	84.99	2
Norway	0.62	3	80.66	8
Finland	0.61	4	82.82	3
Denmark	0.60	5	85.22	1
Germany	0.60	6	81.07	6
Latvia	0.57	7	77.13	19
Austria	0.56	8	81.07	5
South Korea	0.53	9	78.33	15
Portugal	0.53	10	76.43	21
United Kingdom	0.53	11	79.38	12
France	0.52	12	81.49	4
Lithuania	0.51	13	75.10	26
Ireland	0.50	14	78.22	16
Hungary	0.50	15	76.89	20
United States	0.50	16	74.52	28
Netherlands	0.50	17	80.38	9
Belgium	0.50	18	78.89	14
Estonia	0.49	19	80.22	10
Slovenia	0.49	20	79.41	11
Czech Republic	0.48	21	80.74	7
Chile	0.48	22	75.61	25
Slovakia	0.47	23	76.21	22
Spain	0.47	24	77.84	18
Italy	0.46	25	75.79	24
Canada	0.44	26	77.89	17
Turkey	0.44	27	68.49	32
Greece	0.44	28	71.41	30
Luxembourg	0.43	29	74.78	27
Poland	0.42	30	75.93	23
Australia	0.42	31	73.89	29
Mexico	0.39	32	68.51	31

Source: composed by author.

From the table above can be seen that only few rankings of EDAS calculation are the same to SDGI rankings. Countries with the same rankings are Sweden and Germany.

Additionally, only a few rankings of EDAS calculations and SDGI rankings are similar (vary ± 3 positions). Countries with the similar rankings are Finland, Austria, United Kingdom, Ireland, Chile, Slovakia, Italy, Greece, Luxembourg, Australia, and Mexico. Major discrepancies occur in Japan, Latvia, Portugal, Lithuania, the United States, and Czech Republic, because the rankings differ in more than 10 positions comparing EDAS and SDGI rankings.

According to the comparative analysis results between EDAS assessment of the circular economy and SDGI, it cannot be stated that the circular economy is a model that helps to achieve sustainable development, due to the discrepancies in analysis. It could be concluded that countries, which have strong sustainable development, not always have a strong circular economy, and vice versa. This might occur due to the inaccuracies between the methodology of the SDGI and the circular economy. SDGI methodology includes three dimensions of economic, environmental, and society, while the circular economy does not well integrate the society. Additionally, some variance could be due to the different countries' policies implementation regarding the circular economy and sustainable development. For deeper analysis, research with meta-regression will be performed.

According to the scientists recommendations, the fixed effect regression model will be used (Borenstein et al., 2007). The fixed effect regression calculation was carried out to assess the circular economy as one of the models of sustainable development in OECD countries. In fixed effect regression only data for 4 years will be included. It is worth to note, that SDGI index was launch in 2015, however due to the changes in SDGI measurements only 2016-2019 period will be included into regression model. In fixed effect regression analysis independent variable will be SDGI index, while dependent variables will be air pollution exposure (exposure to PM_{2.5}, ($\mu\text{g}/\text{m}^3$)), electricity production (GWh), renewable energy (% of primary energy supply), number of patents in environment-related technologies, gross domestic expenditures on R&D (as % of GDP), CO₂ emission intensity (tonnes/capita), number of passenger cars in use (cars/1000 population), gross domestic product (USD/capita), unemployment rate (% of labour force), poverty rate (%), household disposable income gross adjusted (USD/capita), households with Internet access (%), and municipal waste generated (tonnes/1000 capita).

First, the Hausman test was checked. This test helps to determine which meta-regression model – random effect or fixed effect – is more appropriate for the current data. The null hypothesis of the Hausman test is GLS estimates are consistent meaning random effect model is more preferred. The alternative hypothesis is that the fixed effect model is more preferred. According to the get results, the null hypothesis was rejected, because p value is less than 0,05. This means that fixed effect model for the current data is more preferred.

Second, the normality test was checked according to the Kolmogorov-Smirnov test (see in Appendix 53). The null hypothesis for this test states that data is normally distributed, while the alternative hypothesis states that data are not normally distributed. According to this test, 6 variables are normally distributed (significance value is bigger than 0,05), while the remaining 7 variables are not normally distributed (significance value is lower than 0,05). Normally distributed indicators are GDP, unemployment rate, gross domestic expenditures on R&D, patents in environment-related technologies, renewable energy, and air pollution exposure. Variables that are not normally distributed are poverty rate, household disposable income gross adjusted, municipal waste generated, electricity production, CO₂ emission per capita, number of passenger cars in use, and household with Internet access.

Third, autocorrelation was tested. Due to that majority of the data are not normally distributed, the Spearman correlation method was applied (see in Appendix 54). According to the Spearman correlation results, municipal waste generated, and electricity production do not have statistically significant relationship with SDGI (p value is bigger than 0,05). Due to that reason, both municipal waste generated and electricity production variable will be eliminated from fixed effect regression model. According to the Spearman correlation, GDP, households with Internet access, and gross domestic expenditures on R&D have a strong positive relationship, household disposable income gross adjusted has a moderate positive relationship, patents in environment-related technologies, renewable energy, CO₂ emission per capita, and the number of passenger car have weak positive relationship. Additionally, poverty rate has a strong negative relationship, unemployment rate and air pollution exposure have a weak negative relationship.

Fourth, fixed effect regression was calculated (see in Table 18). According to the fixed effect regression results, variables as GDP, household's disposable income gross adjusted, and patents in environment-related technologies are not statistically significant indicators, meaning that they do not have impact on SDGI (see in Appendix 55). Due to that reason, those three variables will be eliminated from the fixed effect regression. Table 18 presents the final fixed effect regression estimates. From the table below can be seen that unemployment rate, poverty rate, air pollution exposure, and CO₂ emission per capita are statistically significant indicators and they do have a negative impact on SDGI. The results could be interpreted as if unemployment rate increase by 1, SDGI decrease by 0,03, if poverty rate increase by 1, the SDGI decrease by 0,04, if air pollution exposure rate increase by 1, SDGI decrease by 0,02, and CO₂ emission intensity increase by 1, the SDGI decrease by 0,03. Furthermore, indicators as gross domestic expenditure on R&D, renewable energy, number of passenger cars in use, and households with Internet access are statistically significant indicators and they do have a

positive impact on SDGI. The results could be interpreted as if gross domestic expenditures on R&D increase by 1, the SDGI increase by 0,03, if renewable energy increase by 1, the SDGI increase by 0,01, if number of passenger cars in use increase by 1, the SDGI increase by 0,03, and if households with Internet access increase by 1, the SDGI increase by 0,14.

Table 18. Estimates of Fixed Effects regression

Parameter	Estimate	Std. Error	df	t	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Intercept	3,750832	0,148876	126,996	25,194	0,000	3,456233	4,045431
LN_Unempl.	-0,032889	0,005128	99,913	-6,413	0,000	-0,043063	-0,022715
LN_Poverty	-0,039218	0,007755	119,465	-5,057	0,000	-0,054573	-0,023864
LN_RD	0,025695	0,005685	94,848	4,520	0,000	0,014409	0,036981
LN_Re.energy	0,014074	0,004698	106,827	2,996	0,003	0,004762	0,023387
LN_Air.quality	-0,023677	0,007495	95,223	-3,159	0,002	-0,038556	-0,008798
LN_CO ₂	-0,033726	0,007469	108,867	-4,515	0,000	-0,048530	-0,018922
LN_No.cars	0,031477	0,008874	121,995	3,547	0,001	0,013911	0,049043
LN_Internet	0,141683	0,027190	126,202	5,211	0,000	0,087875	0,195490

Note: unempl.=unemployment rate, poverty= poverty rate, disp.income= household disposable income gross adjusted, RD=gross domestic expenditure on R&D, patents=patents in environment-related technologies, re.energy=renewable energy, air.quality=air pollution exposure, CO₂=CO₂ emission per capita, no.cars=number of passenger cars, Internet=households with Internet access.

Source: composed by author.

According to the fixed effect regression results, the final regression equation is presented below:

$$\begin{aligned}
 \ln (SDGI_{c,t}) = & 3,75 - 0,03 \times \ln (Unempl_{c,t}) - 0,04 \times \ln (Poverty_{c,t}) + \\
 & 0,03 \times \ln (RD_{c,t}) + 0,01 \times \ln (Re.energy_{c,t}) - 0,02 \times \ln (Air.quality_{c,t}) \\
 & - 0,03 \times \ln (CO_{2,c,t}) + 0,03 \times \ln (No.cars_{c,t}) + 0,14 \times \ln (Internet_{c,t}) + \varepsilon
 \end{aligned} \quad (27)$$

where:

c – country,

t – year.

According to the fixed effect regression results, hypothesis 1 (the circular economy has a significant impact on sustainable development) was rejected, due to not all the circular economy indicators have a significant impact on sustainable development. Moreover, hypothesis 2 (the circular economy has not a significant impact on sustainable development) was also rejected, because some of the circular economy indicators have a significant impact on sustainable development. Furthermore, hypothesis 3 (the circular economy only partially affects sustainable development) was accepted, because some of the indicators have a statistically significant impact on sustainable development. Indicators as the unemployment

rate, poverty rate, gross domestic expenditures on R&D, renewable energy, air pollution exposure, CO₂ emission intensity, number of passenger cars in use, and households with Internet access have a significant impact on sustainable development. Additionally, hypothesis 4 (the most significant circular economy indicators have a significant impact on sustainable development) was rejected. The most significant circular indicators according to the AHP method (weights are more or equal to 10 %) are municipal waste generated, renewable energy, CO₂ emission intensity, patents in environment-related technologies, and the number of passenger cars in use. According to the autocorrelation results, statistically significant results do not exist between municipal waste generated indicators and SDGI. According to the fixed effect results, renewable energy, CO₂ emission intensity, and the number of passenger cars in use have a statistically significant impact on SDGI, while patents in environment-related technologies do not have a statistically significant impact.

To conclude, according to the research results, 1 of the 4 hypotheses was accepted. According to the comparative analysis results, it cannot be assumed that countries with a strong circular economy have strong sustainable development, and countries with a weak circular economy have a weak sustainable development. According to the fixed effect regression results, the assumption could be made that the circular economy only partially affects sustainable development, meaning that not all circular economy indicators have an impact on sustainable development.

CONCLUSIONS

1. The circular economy could be explained as a new economic system that replaces the end-of-life concept with the main principles of reducing, reusing, recycling, and recovering. The circular economy aims to efficiently utilise resources through long-term value creation, waste minimisation, and reduction of closed loops products considering environmental protection. Additionally, the circular economy tries to maintain economic prosperity with a high contribution to environmental quality, social equity, and future generation. The circular economy offers an opportunity to reinvent the economy, making it more sustainable and competitive, ensuring and promoting more innovative and efficient ways of producing and consuming, protecting a business against scarcity of resources, boosting economic growth, and creating jobs. The circular economy concept is seen as the precondition to sustainability by considering all sustainability dimensions of the economy, environment, and society. The circular economy positively contributes to improving resource productivity and decreasing import dependency, reducing environmental impact, increasing economic growth and innovation opportunities. Moreover, the circular economy is seen as one of the sustainability business models, which significantly contributes to the core sustainability concepts. Thus, the circular economy and sustainable development are highly related and received increasing attention at international and national policy levels. The concepts of the circular economy in the world are diverse. The circular economy focusing not only on the efficiency of primary and secondary raw materials and resources, but also on a wide range of questions and issues, that are raised and actively discussed among scientists and researchers. Thus, there are many specific areas of the circular economy, such as bioeconomy, energy-efficient and renewable energy-based economy, resource and material-efficient economy, innovative economy, low carbon economy, zero-waste economy, and others. All these specific areas could be assigned to the circular economy loops, which are raw materials extractions, product design, production and remanufacturing, consumption, and waste management.

2. In the research three different methods have been used. The first method is Analytic Hierarchy Process (AHP) method, which is a broadly applied in multi-criteria decision-making method to determine the weights of criteria and priorities of alternatives in a structured manner based on the pairwise comparison. AHP method together with expert's assistance helped to identify the importance weights of the circular economy. The second method is Multi-Criteria Decision Analysis (MCDA) method, which assisted to estimate the best alternative from among a finite set of decision alternatives. This method assumes that country, which has a stronger circular economy, must be near the best scores on indexes and

far from the worst scores, and vice versa. In the research two sub-methods of Multi-Criteria Decision Analysis (MCDA) have been used. The first sub-method was the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) and the second the Evaluation based on Distance from Average Solution (EDAS) sub-method. TOPSIS prioritizes the alternatives by similarity to the ideal solution which has very low sensitivity to the weighting technique. By this sub-method, the best alternative should have shortest distance from the ideal point and the farthest distance from the anti-ideal point. EDAS is an innovative and useful sub-method to assess the multi-criteria decision method problems especially in case of conflicting criteria. This method includes positive and negative distances from the average solutions, not the ideal and anti-ideal solutions. The third method was meta-regression with the fixed effect. The fixed-effect model assumes that all meta-analysis studies have a common true effect size. With this method the circular economy as one of the modes of sustainable development has been assessed.

3. In the section of empirical results of the assessment of the circular economy as one of the models of sustainable development are provided with the results of used methods in the research. According to the AHP method results, the importance weights were determined by the 5 experts answers. According to the results, the greatest impact on the circular economy have municipal waste generated (14 %), renewable energy (11 %), CO₂ emission (11 %), patents in environment-related technologies (10 %), number of passenger cars in use (10 %), a slightly smaller impact have air pollution exposure (9 %), gross domestic expenditure on R&D (8 %), electricity production (8 %), the poverty rate (5 %), and households with Internet access (6 %), while the weakest impact on the circular economy has household disposable income gross adjusted (4 %), gross domestic product (2 %), and unemployment rate (2 %). Additionally, according to the AHP method and expert's results, specific areas of the circular economy as innovative economy, low carbon economy, and energy-efficient and renewable energy-based economy have the most significant impact on the circular economy, while the smart economy specific area of the circular economy has the lowest impact on the circular economy. According to the TOPSIS sub-method calculation results, the performance scores of the circular economies were determined. According to the results, Japan, Sweden, Latvia, Finland, and Germany have the strongest circular economy in 2018, while Japan, Sweden, Norway, Germany, and Finland had the strongest circular economy in 2019. Also, Luxembourg, Australia, Mexico, the United States, and Poland have the weakest circular economy in 2018, while Australia, Mexico, Luxembourg, the United States, and Canada had the lowest circular economy in 2019. According to the EDAS sub-method calculation results, Japan, Sweden, Finland, Germany, and Denmark have the strongest circular economy in 2018, while Japan,

Sweden, Norway, Finland, and Denmark in 2019. Additionally, Mexico, Poland, Australia, Turkey, and Luxembourg have the weakest circular economy in 2019, while Mexico, Australia, Poland, Luxembourg, and Greece in 2019. According to the TOPSIS and EDAS calculation results, from regional perspective Asia has the strongest circular economy in the period of 2018-2019, while Australia has the weakest circular economy in the period of 2018-2019. According to both EDAS and TOPSIS sub-methods, results were found quite similar. Furthermore, according to the fixed effect regression results, GDP, household's disposable income gross adjusted, and patents in environment-related technologies are not statistically significant indicators, meaning that they do not have an impact on sustainable development. Additionally, unemployment rate, poverty rate, air pollution exposure, and CO₂ emission per capita are statistically significant indicators and they do have a negative impact on SDGI, while indicators as gross domestic expenditure on R&D, renewable energy, number of passenger cars in use, and households with Internet access are statistically significant indicators and they do have a positive impact on SDGI. According to the fixed effect regression results, hypothesis 1 (the circular economy has a significant impact on sustainable development), hypothesis 2 (the circular economy has not a significant impact on sustainable development), and hypothesis 4 (the most significant circular economy indicators have a significant impact on sustainable development) were rejected, while hypothesis 3 (the circular economy only partially affects sustainable development) was accepted. The assumption could be made that the circular economy only partially affects sustainable development, meaning that not all circular economy indicators have an impact on sustainable development. Results may have been affected due to the different methodologies of the circular economy and sustainable development because sustainable development includes economic, environmental, and social dimensions, while the circular economy does not well integrate social dimension.

Gintarė Volskytė



Recommendations

According to the results, it can be assumed that not always countries with a strong circular economy, have a strong sustainable development, and opposite, countries with a weak circular economy have a weak sustainable development. It largely depends on the countries policies implementation – on which concept country pays more attention to and where it is more focused. In any case, it is recommended to include the circular economy into the countries' policies and strategies, because circular economy not only partially effects sustainable development but also offers an opportunity to reinvent the economy making it more sustainable and competitive, ensures and promotes innovations and effectiveness, boosts economic growth, and creates new job opportunities.

Future Research Directions. Research needs to be done in other countries, not only in OECD countries.

Gintarė Volskytė



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APPENDICES

Appendix 1. Survey used in the research

A	Extremely favours		Very strongly favours		Strongly favours		Slightly favours		Equal		Slightly favours		Strongly favours		Very strongly favours		Extremely favours	B
Gross Domestic Product	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Unemployment rate
Gross Domestic Product	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Poverty rate
Gross Domestic Product	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Household disposable income
Gross Domestic Product	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Municipal waste generated
Gross Domestic Product	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Patents in environment-related technologies
Gross Domestic Product	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Gross domestic expenditures on R&D
Gross Domestic Product	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Electricity consumption
Gross Domestic Product	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Renewable energy
Gross Domestic Product	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Air pollution exposure
Gross Domestic Product	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	CO ₂ emission
Gross Domestic Product	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Number of passenger cars in use
Gross Domestic Product	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Households with Internet access
Unemployment rate	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Poverty rate
Unemployment rate	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Household disposable income
Unemployment rate	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Municipal waste generated
Unemployment rate	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Patents in environment-related technologies
Unemployment rate	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Gross domestic expenditures on R&D
Unemployment rate	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Electricity consumption
Unemployment rate	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Renewable energy
Unemployment rate	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Air pollution exposure
Unemployment rate	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	CO ₂ emission intensity
Unemployment rate	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Number of passenger cars in use
Unemployment rate	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Households with Internet access
Poverty rate	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Household disposable income
Poverty rate	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Municipal waste generated
Poverty rate	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Patents in environment-related technologies
Poverty rate	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Gross domestic expenditures on R&D
Poverty rate	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Electricity consumption
Poverty rate	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Renewable energy
Poverty rate	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Air pollution exposure
Poverty rate	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	CO ₂ emission intensity
Poverty rate	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Number of passenger cars in use
Poverty rate	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Households with Internet access
Household disposable income	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Municipal waste generated
Household disposable income	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Patents in environment-related technologies

Household disposable income	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Gross domestic expenditures on R&D
Household disposable income	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Electricity consumption
Household disposable income	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Renewable energy
Household disposable income	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Air pollution exposure
Household disposable income	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	CO ₂ emission intensity
Household disposable income	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Number of passenger cars in use
Household disposable income	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Households with Internet access
Municipal waste generated	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Patents in environment-related technologies
Municipal waste generated	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Gross domestic expenditures on R&D
Municipal waste generated	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Electricity consumption
Municipal waste generated	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Renewable energy
Municipal waste generated	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Air pollution exposure
Municipal waste generated	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	CO ₂ emission intensity
Municipal waste generated	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Number of passenger cars in use
Municipal waste generated	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Households with Internet access
Patents in environment-related technologies	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Gross domestic expenditures on R&D
Patents in environment-related technologies	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Electricity consumption
Patents in environment-related technologies	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Renewable energy
Patents in environment-related technologies	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Air pollution exposure
Patents in environment-related technologies	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	CO ₂ emission intensity
Patents in environment-related technologies	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Number of passenger cars in use
Patents in environment-related technologies	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Households with Internet access
Gross domestic expenditures on R&D	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Electricity consumption
Gross domestic expenditures on R&D	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Renewable energy
Gross domestic expenditures on R&D	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Air pollution exposure
Gross domestic expenditures on R&D	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	CO ₂ emission intensity
Gross domestic expenditures on R&D	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Number of passenger cars in use
Gross domestic expenditures on R&D	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Households with Internet access
Electricity consumption	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Renewable energy
Electricity consumption	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Air pollution exposure
Electricity consumption	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	CO ₂ emission intensity
Electricity consumption	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Number of passenger cars in use
Electricity consumption	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Households with Internet access
Renewable energy	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Air pollution exposure
Renewable energy	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	CO ₂ emission intensity
Renewable energy	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Number of passenger cars in use

Renewable energy	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Households with Internet access
Air pollution exposure	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	CO ₂ emission intensity
Air pollution exposure	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Number of passenger cars in use
Air pollution exposure	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Households with Internet access
CO ₂ emission intensity	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Number of passenger cars in use
CO ₂ emission intensity	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Households with Internet access
Number of passenger cars in use	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Households with Internet access

Source: based on author.

Appendix 2. Pairwise comparison matrix of expert no. 1

	Gross Domestic Product	Unemployment rate	Poverty rate	Household disposable income Gross adjusted	Municipal waste generated	Patents in environment-related technologies	Gross domestic expenditure on R&D	Electricity consumption	Renewable energy	Air pollution exposure	CO ₂ emission	Number of passenger cars in use	Households with Internet access
Gross Domestic Product	1	1.00	0.33	3.00	0.20	0.14	0.33	0.14	0.14	0.33	0.33	0.33	3.00
Unemployment rate	1.00	1	0.14	1.00	0.20	0.20	0.33	0.33	0.14	0.33	0.33	0.33	1.00
Poverty rate	3.00	7.00	1	7.00	1.00	1.00	7.00	5.00	1.00	3.00	5.00	5.00	7.00
Household disposable income Gross adjusted	0.33	1.00	0.14	1	0.20	0.14	0.20	0.20	0.20	0.33	0.33	0.33	1.00
Municipal waste generated	5.00	5.00	1.00	5.00	1	0.33	7.00	5.00	1.00	3.00	3.00	3.00	7.00
Patents in environment-related technologies	7.00	5.00	1.00	7.00	3.00	1	5.00	3.00	1.00	7.00	7.00	7.00	7.00
Gross domestic expenditure on R&D	3.00	3.00	0.14	5.00	0.14	0.20	1	1.00	0.14	1.00	1.00	1.00	1.00
Electricity consumption	7.00	3.00	0.20	5.00	0.20	0.33	1.00	1	0.33	1.00	1.00	1.00	1.00
Renewable energy	7.00	7.00	1.00	5.00	1.00	1.00	7.00	3.00	1	5.00	5.00	5.00	5.00
Air pollution exposure	3.00	3.00	0.33	3.00	0.33	0.14	1.00	1.00	0.20	1	1.00	1.00	3.00
CO ₂ emission	3.00	3.00	0.20	3.00	0.33	0.14	1.00	1.00	0.20	1.00	1	1.00	3.00
Number of passenger cars in use	3.00	3.00	0.20	3.00	0.33	0.14	1.00	1.00	0.20	1.00	1.00	1	1.00
Households with Internet access	0.33	1.00	0.14	1.00	0.14	0.14	1.00	1.00	0.20	0.33	0.33	1	1

Source: based on author.

Appendix 3. Pairwise comparison matrix of expert no. 2

	Gross Domestic Product	Unemployment rate	Poverty rate	Household disposable income Gross adjusted	Municipal waste generated	Patents in environment-related technologies	Gross domestic expenditure on R&D	Electricity consumption	Renewable energy	Air pollution exposure	CO ₂ emission	Number of passenger cars in use	Households with Internet access
Gross Domestic Product	1.00	1.00	1.00	1.00	0.11	0.14	0.14	0.11	0.11	0.11	0.11	0.11	0.11
Unemployment rate	1.00	1.00	1.00	1.00	0.11	0.11	0.14	0.11	0.11	0.11	0.11	0.11	0.11
Poverty rate	1.00	1.00	1.00	1.00	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
Household disposable income Gross adjusted	1.00	1.00	1.00	1.00	0.11	0.14	0.14	0.11	0.11	0.11	0.11	0.11	0.11
Municipal waste generated	9.00	9.00	9.00	9.00	1.00	4.00	4.00	1.00	1.00	1.00	1.00	1.00	1.00
Patents in environment-related technologies	7.00	9.00	9.00	7.00	0.25	1.00	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Gross domestic expenditure on R&D	7.00	7.00	9.00	7.00	0.25	4.00	1.00	0.25	0.25	0.25	0.25	0.25	0.25
Electricity consumption	9.00	9.00	9.00	9.00	1.00	4.00	4.00	1.00	1.00	1.00	1.00	1.00	1.00
Renewable energy	9.00	9.00	9.00	9.00	1.00	4.00	4.00	1.00	1.00	1.00	1.00	1.00	1.00
Air pollution exposure	9.00	9.00	9.00	9.00	1.00	4.00	4.00	1.00	1.00	1.00	1.00	1.00	1.00
CO ₂ emission	9.00	9.00	9.00	9.00	1.00	4.00	4.00	1.00	1.00	1.00	1.00	1.00	1.00
Number of passenger cars in use	9.00	9.00	9.00	9.00	1.00	4.00	4.00	1.00	1.00	1.00	1.00	1.00	1.00
Households with Internet access	9.00	9.00	9.00	9.00	1.00	4.00	4.00	1.00	1.00	1.00	1.00	1.00	1.00

Source: based on author.

Appendix 4. Pairwise comparison matrix of expert no. 3

	Gross Domestic Product	Unemployment rate	Poverty rate	Household disposable income Gross adjusted	Municipal waste generated	Patents in environment-related technologies	Gross domestic expenditure on R&D	Electricity consumption	Renewable energy	Air pollution exposure	CO ₂ emission	Number of passenger cars in use	Households with Internet access
Gross Domestic Product	1.00	0.33	0.20	0.20	0.11	0.20	0.33	0.20	0.14	0.11	0.11	0.14	0.50
Unemployment rate	3.00	1.00	0.33	0.20	0.11	0.20	0.33	0.20	0.14	0.11	0.11	0.14	0.50
Poverty rate	5.00	3.00	1.00	1.00	0.20	1.00	0.50	1.00	0.50	0.33	0.14	0.14	3.00
Household disposable income Gross adjusted	5.00	5.00	1.00	1.00	0.25	2.00	1.00	1.00	0.50	0.33	0.14	0.14	3.00
Municipal waste generated	9.00	9.00	5.00	4.00	1.00	7.00	7.00	7.00	7.00	1.00	1.00	1.00	9.00
Patents in environment-related technologies	5.00	5.00	1.00	0.50	0.14	1.00	0.33	0.33	0.33	0.20	0.17	0.17	3.00
Gross domestic expenditure on R&D	3.00	3.00	2.00	1.00	0.14	3.00	1.00	0.33	0.33	0.25	0.17	0.17	3.00
Electricity consumption	5.00	5.00	1.00	1.00	0.14	3.00	3.00	1.00	1.00	0.33	0.20	0.20	4.00
Renewable energy	7.00	7.00	2.00	2.00	0.14	3.00	3.00	1.00	1.00	0.33	0.25	0.25	4.00
Air pollution exposure	9.00	9.00	3.00	3.00	1.00	5.00	4.00	3.00	3.00	1.00	0.25	0.25	4.00
CO ₂ emission	9.00	9.00	7.00	7.00	1.00	6.00	6.00	5.00	4.00	4.00	1.00	1.00	9.00
Number of passenger cars in use	7.00	7.00	7.00	7.00	1.00	6.00	6.00	5.00	4.00	4.00	1.00	1.00	9.00
Households with Internet access	2.00	2.00	0.33	0.33	0.11	0.33	0.33	0.25	0.25	0.25	0.11	0.11	1.00

Source: based on author.

Appendix 5. Pairwise comparison matrix of expert no. 4

	Gross Domestic Product	Unemployment rate	Poverty rate	Household disposable income Gross adjusted	Municipal waste generated	Patents in environment-related technologies	Gross domestic expenditure on R&D	Electricity consumption	Renewable energy	Air pollution exposure	CO ₂ emission	Number of passenger cars in use	Households with Internet access
Gross Domestic Product	1.00	3.00	5.00	0.33	0.20	0.20	0.14	0.14	0.14	0.20	0.20	0.33	0.20
Unemployment rate	0.33	1.00	0.33	0.20	0.20	0.14	0.14	0.20	0.20	0.20	0.20	0.33	0.20
Poverty rate	0.20	3.00	1.00	0.33	0.20	0.33	0.14	0.14	0.14	0.20	0.20	0.20	0.14
Household disposable income Gross adjusted	3.00	5.00	3.00	1.00	1.00	0.33	0.50	0.33	0.33	3.00	2.00	3.00	3.00
Municipal waste generated	5.00	5.00	5.00	1.00	1.00	1.00	1.00	1.00	1.00	3.00	1.00	3.00	3.00
Patents in environment-related technologies	5.00	7.00	3.00	3.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	5.00	3.00
Gross domestic expenditure on R&D	7.00	7.00	7.00	2.00	1.00	1.00	1.00	3.00	3.00	5.00	3.00	7.00	3.00
Electricity consumption	7.00	5.00	7.00	3.00	1.00	1.00	0.33	1.00	1.00	1.00	1.00	5.00	1.00
Renewable energy	7.00	5.00	7.00	3.00	1.00	1.00	0.33	1.00	1.00	1.00	1.00	5.00	3.00
Air pollution exposure	5.00	5.00	5.00	0.33	0.33	1.00	0.20	1.00	1.00	1.00	1.00	5.00	3.00
CO ₂ emission	5.00	5.00	5.00	0.50	1.00	1.00	0.33	1.00	1.00	1.00	1.00	7.00	3.00
Number of passenger cars in use	3.00	3.00	5.00	0.33	0.33	0.20	0.14	0.20	0.20	0.20	0.14	1.00	0.20
Households with Internet access	5.00	5.00	7.00	0.33	0.33	0.33	0.33	1.00	0.33	0.33	0.33	5.00	1.00

Source: based on author.

Appendix 6. Pairwise comparison matrix of expert no. 5

	Gross Domestic Product	Unemployment rate	Poverty rate	Household disposable income Gross adjusted	Municipal waste generated	Patents in environment-related technologies	Gross domestic expenditure on R&D	Electricity consumption	Renewable energy	Air pollution exposure	CO ₂ emission	Number of passenger cars in use	Households with Internet access
Gross Domestic Product	1.00	5.00	5.00	4.00	4.00	7.00	6.00	2.00	0.13	0.20	0.13	3.00	3.00
Unemployment rate	0.20	1.00	1.00	1.00	1.00	3.00	3.00	0.17	0.13	0.14	0.13	1.00	1.00
Poverty rate	0.20	1.00	1.00	0.33	0.33	0.50	0.50	0.14	0.13	0.17	0.13	0.25	0.25
Household disposable income Gross adjusted	0.25	1.00	3.00	1.00	0.17	0.33	0.33	0.17	0.13	0.13	0.13	0.17	0.33
Municipal waste generated	0.25	1.00	3.00	6.00	1.00	0.33	0.33	4.00	0.13	3.00	0.17	8.00	8.00
Patents in environment-related technologies	0.14	0.33	2.00	3.00	3.00	1.00	0.25	0.17	0.13	0.17	0.17	0.50	0.50
Gross domestic expenditure on R&D	0.17	0.33	2.00	3.00	3.00	4.00	1.00	0.25	0.13	0.17	0.13	0.17	0.50
Electricity consumption	0.50	6.00	7.00	6.00	0.25	6.00	4.00	1.00	0.13	6.00	0.33	6.00	7.00
Renewable energy	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	1.00	3.00	2.00	8.00	8.00
Air pollution exposure	5.00	7.00	6.00	8.00	0.33	6.00	6.00	0.17	0.33	1.00	0.17	6.00	6.00
CO ₂ emission	8.00	8.00	8.00	8.00	6.00	6.00	8.00	3.00	0.50	6.00	1.00	8.00	8.00
Number of passenger cars in use	0.33	1.00	4.00	6.00	0.13	2.00	6.00	0.17	0.13	0.17	0.13	1.00	1.00
Households with Internet access	0.33	1.00	4.00	3.00	0.13	2.00	2.00	0.14	0.13	0.17	0.13	1.00	1.00

Source: based on author.

Appendix 7. Pairwise comparison matrix of expert no. 6

	Gross Domestic Product	Unemployment rate	Poverty rate	Household disposable income Gross adjusted	Municipal waste generated	Patents in environment-related technologies	Gross domestic expenditure on R&D	Electricity consumption	Renewable energy	Air pollution exposure	CO ₂ emission	Number of passenger cars in use	Households with Internet access
Gross Domestic Product	1	0.33	0.33	0.33	0.20	1.00	0.20	0.17	0.17	0.17	0.17	0.50	2.00
Unemployment rate	3.00	1	0.25	1.00	0.17	5.00	0.33	0.20	0.13	0.14	0.13	6.00	3.00
Poverty rate	3.00	4.00	1	5.00	0.50	9.00	2.00	4.00	2.00	0.50	0.33	6.00	7.00
Household disposable income Gross adjusted	3.00	1.00	0.20	1	0.17	7.00	0.20	0.20	0.13	0.17	0.14	1.00	0.20
Municipal waste generated	5.00	6.00	2.00	6.00	1	7.00	0.25	0.50	0.33	3.00	0.33	5.00	7.00
Patents in environment-related technologies	1.00	0.20	0.11	0.14	0.14	1	0.13	0.13	0.13	0.13	0.13	2.00	0.14
Gross domestic expenditure on R&D	5.00	3.00	0.50	5.00	4.00	8.00	1	0.50	0.33	0.50	0.50	6.00	6.00
Electricity consumption	6.00	5.00	0.25	5.00	2.00	8.00	2.00	1	0.13	0.50	1.00	6.00	7.00
Renewable energy	6.00	8.00	0.50	8.00	3.00	8.00	3.00	8.00	1	1.00	1.00	8.00	8.00
Air pollution exposure	6.00	7.00	2.00	6.00	0.33	8.00	2.00	2.00	1.00	1	0.50	7.00	7.00
CO ₂ emission	6.00	8.00	3.00	7.00	3.00	8.00	2.00	1.00	1.00	2.00	1	8.00	8.00
Number of passenger cars in use	2.00	0.17	0.17	1.00	0.20	0.50	0.17	0.17	0.13	0.14	0.13	1	1.00
Households with Internet access	0.50	0.33	0.14	5.00	0.14	7.00	0.17	0.14	0.13	0.14	0.13	1	1

Source: based on author.

Appendix 8. Standardized matrix of expert no. 1

	Gross Domestic Product	Unemployment rate	Poverty rate	Household disposable income Gross adjusted	Municipal waste generated	Patents in environment-related technologies	Gross domestic expenditure on R&D	Electricity consumption	Renewable energy	Air pollution exposure	CO ₂ emission	Number of passenger cars in use	Households with Internet access	Average
Gross Domestic Product	0.02	0.02	0.06	0.06	0.02	0.03	0.01	0.01	0.02	0.01	0.01	0.01	0.07	0.03
Unemployment rate	0.02	0.02	0.02	0.02	0.02	0.04	0.01	0.01	0.02	0.01	0.01	0.01	0.02	0.02
Poverty rate	0.07	0.16	0.17	0.14	0.12	0.20	0.21	0.22	0.17	0.12	0.19	0.19	0.17	0.17
Household disposable income Gross adjusted	0.01	0.02	0.02	0.02	0.02	0.03	0.01	0.01	0.03	0.01	0.01	0.01	0.02	0.02
Municipal waste generated	0.11	0.12	0.17	0.10	0.12	0.07	0.21	0.22	0.17	0.12	0.11	0.11	0.17	0.14
Patents in environment-related technologies	0.16	0.12	0.17	0.14	0.37	0.20	0.15	0.13	0.17	0.29	0.27	0.26	0.17	0.20
Gross domestic expenditure on R&D	0.07	0.07	0.02	0.10	0.02	0.04	0.03	0.04	0.02	0.04	0.04	0.04	0.02	0.04
Electricity consumption	0.16	0.07	0.03	0.10	0.02	0.07	0.03	0.04	0.06	0.04	0.04	0.04	0.02	0.06
Renewable energy	0.16	0.16	0.17	0.10	0.12	0.20	0.21	0.13	0.17	0.21	0.19	0.19	0.12	0.16
Air pollution exposure	0.07	0.07	0.06	0.06	0.04	0.03	0.03	0.04	0.03	0.04	0.04	0.04	0.07	0.05
CO ₂ emission	0.07	0.07	0.03	0.06	0.04	0.03	0.03	0.04	0.03	0.04	0.04	0.04	0.07	0.05
Number of passenger cars in use	0.07	0.07	0.03	0.06	0.04	0.03	0.03	0.04	0.03	0.04	0.04	0.04	0.02	0.04
Households with Internet access	0.01	0.02	0.02	0.02	0.02	0.03	0.03	0.04	0.03	0.01	0.01	0.04	0.02	0.02

Source: based on author.

Appendix 9. Standardized matrix of expert no. 2

	Gross Domestic Product	Unemployment rate	Poverty rate	Household disposable income Gross adjusted	Municipal waste generated	Patents in environment-related technologies	Gross domestic expenditure on R&D	Electricity consumption	Renewable energy	Air pollution exposure	CO ₂ emission	Number of passenger cars in use	Households with Internet access	Average
Gross Domestic Product	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Unemployment rate	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Poverty rate	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Household disposable income Gross adjusted	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Municipal waste generated	0.11	0.11	0.11	0.11	0.13	0.12	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.12
Patents in environment-related technologies	0.09	0.11	0.11	0.09	0.03	0.03	0.01	0.03	0.03	0.03	0.03	0.03	0.03	0.05
Gross domestic expenditure on R&D	0.09	0.08	0.11	0.09	0.03	0.12	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.06
Electricity consumption	0.11	0.11	0.11	0.11	0.13	0.12	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.12
Renewable energy	0.11	0.11	0.11	0.11	0.13	0.12	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.12
Air pollution exposure	0.11	0.11	0.11	0.11	0.13	0.12	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.12
CO ₂ emission	0.11	0.11	0.11	0.11	0.13	0.12	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.12
Number of passenger cars in use	0.11	0.11	0.11	0.11	0.13	0.12	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.12
Households with Internet access	0.11	0.11	0.11	0.11	0.13	0.12	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.12

Source: based on author.

Appendix 10. Standardized matrix of expert no. 3

	Gross Domestic Product	Unemployment rate	Poverty rate	Household disposable income Gross adjusted	Municipal waste generated	Patents in environment-related technologies	Gross domestic expenditure on R&D	Electricity consumption	Renewable energy	Air pollution exposure	CO ₂ emission	Number of passenger cars in use	Households with Internet access	Average
Gross Domestic Product	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.02	0.03	0.01	0.01
Unemployment rate	0.04	0.02	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.02	0.03	0.01	0.02
Poverty rate	0.07	0.05	0.03	0.04	0.04	0.03	0.02	0.04	0.02	0.03	0.03	0.03	0.06	0.04
Household disposable income Gross adjusted	0.07	0.08	0.03	0.04	0.05	0.05	0.03	0.04	0.02	0.03	0.03	0.03	0.06	0.04
Municipal waste generated	0.13	0.14	0.16	0.14	0.19	0.19	0.21	0.28	0.32	0.08	0.21	0.21	0.17	0.19
Patents in environment-related technologies	0.07	0.08	0.03	0.02	0.03	0.03	0.01	0.01	0.02	0.02	0.04	0.04	0.06	0.03
Gross domestic expenditure on R&D	0.04	0.05	0.06	0.04	0.03	0.08	0.03	0.01	0.02	0.02	0.04	0.04	0.06	0.04
Electricity consumption	0.07	0.08	0.03	0.04	0.03	0.08	0.09	0.04	0.05	0.03	0.04	0.04	0.08	0.05
Renewable energy	0.10	0.11	0.06	0.07	0.03	0.08	0.09	0.04	0.05	0.03	0.05	0.05	0.08	0.06
Air pollution exposure	0.13	0.14	0.10	0.11	0.19	0.13	0.12	0.12	0.14	0.08	0.05	0.05	0.08	0.11
CO ₂ emission	0.13	0.14	0.23	0.25	0.19	0.16	0.18	0.20	0.18	0.33	0.21	0.21	0.17	0.20
Number of passenger cars in use	0.10	0.11	0.23	0.25	0.19	0.16	0.18	0.20	0.18	0.33	0.21	0.21	0.17	0.19
Households with Internet access	0.03	0.03	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02

Source: based on author.

Appendix 11. Standardized matrix of expert no. 4

	Gross Domestic Product	Unemployment rate	Poverty rate	Household disposable income Gross adjusted	Municipal waste generated	Patents in environment-related technologies	Gross domestic expenditure on R&D	Electricity consumption	Renewable energy	Air pollution exposure	CO ₂ emission	Number of passenger cars in use	Households with Internet access	Average
Gross Domestic Product	0.02	0.05	0.08	0.02	0.02	0.02	0.03	0.01	0.01	0.01	0.02	0.01	0.01	0.02
Unemployment rate	0.01	0.02	0.01	0.01	0.02	0.02	0.03	0.02	0.02	0.01	0.02	0.01	0.01	0.01
Poverty rate	0.00	0.05	0.02	0.02	0.02	0.04	0.03	0.01	0.01	0.01	0.02	0.00	0.01	0.02
Household disposable income Gross adjusted	0.06	0.08	0.05	0.07	0.12	0.04	0.09	0.03	0.03	0.18	0.17	0.06	0.13	0.08
Municipal waste generated	0.09	0.08	0.08	0.07	0.12	0.12	0.18	0.09	0.10	0.18	0.08	0.06	0.13	0.11
Patents in environment-related technologies	0.09	0.12	0.05	0.20	0.12	0.12	0.18	0.09	0.10	0.06	0.08	0.11	0.13	0.11
Gross domestic expenditure on R&D	0.13	0.12	0.12	0.13	0.12	0.12	0.18	0.27	0.29	0.29	0.25	0.15	0.13	0.18
Electricity consumption	0.13	0.08	0.12	0.20	0.12	0.12	0.06	0.09	0.10	0.06	0.08	0.11	0.04	0.10
Renewable energy	0.13	0.08	0.12	0.20	0.12	0.12	0.06	0.09	0.10	0.06	0.08	0.11	0.13	0.11
Air pollution exposure	0.09	0.08	0.08	0.02	0.04	0.12	0.04	0.09	0.10	0.06	0.08	0.11	0.13	0.08
CO ₂ emission	0.09	0.08	0.08	0.03	0.12	0.12	0.06	0.09	0.10	0.06	0.08	0.15	0.13	0.09
Number of passenger cars in use	0.06	0.05	0.08	0.02	0.04	0.02	0.03	0.02	0.02	0.01	0.01	0.02	0.01	0.03
Households with Internet access	0.09	0.08	0.12	0.02	0.04	0.04	0.06	0.09	0.03	0.02	0.03	0.11	0.04	0.06

Source: based on author.

Appendix 12. Standardized matrix of expert no. 5

	Gross Domestic Product	Unemployment rate	Poverty rate	Household disposable income Gross adjusted	Municipal waste generated	Patents in environment-related technologies	Gross domestic expenditure on R&D	Electricity consumption	Renewable energy	Air pollution exposure	CO ₂ emission	Number of passenger cars in use	Households with Internet access	Average
Gross Domestic Product	0.04	0.12	0.09	0.07	0.15	0.15	0.13	0.10	0.04	0.01	0.03	0.07	0.07	0.08
Unemployment rate	0.01	0.02	0.02	0.02	0.04	0.06	0.07	0.01	0.04	0.01	0.03	0.02	0.02	0.03
Poverty rate	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.04	0.01	0.03	0.01	0.01	0.01
Household disposable income Gross adjusted	0.01	0.02	0.06	0.02	0.01	0.01	0.01	0.01	0.04	0.01	0.03	0.00	0.01	0.02
Municipal waste generated	0.01	0.02	0.06	0.10	0.04	0.01	0.01	0.21	0.04	0.15	0.04	0.19	0.18	0.08
Patents in environment-related technologies	0.01	0.01	0.04	0.05	0.11	0.02	0.01	0.01	0.04	0.01	0.04	0.01	0.01	0.03
Gross domestic expenditure on R&D	0.01	0.01	0.04	0.05	0.11	0.09	0.02	0.01	0.04	0.01	0.03	0.00	0.01	0.03
Electricity consumption	0.02	0.15	0.13	0.10	0.01	0.13	0.09	0.05	0.04	0.30	0.07	0.14	0.16	0.11
Renewable energy	0.33	0.20	0.15	0.14	0.29	0.17	0.18	0.41	0.32	0.15	0.42	0.19	0.18	0.24
Air pollution exposure	0.21	0.17	0.11	0.14	0.01	0.13	0.13	0.01	0.11	0.05	0.04	0.14	0.13	0.11
CO ₂ emission	0.33	0.20	0.15	0.14	0.22	0.13	0.18	0.15	0.16	0.30	0.21	0.19	0.18	0.19
Number of passenger cars in use	0.01	0.02	0.07	0.10	0.00	0.04	0.13	0.01	0.04	0.01	0.03	0.02	0.02	0.04
Households with Internet access	0.01	0.02	0.07	0.05	0.00	0.04	0.04	0.01	0.04	0.01	0.03	0.02	0.02	0.03

Source: based on author.

Appendix 13. Standardized matrix of expert no. 6

	Gross Domestic Product	Unemployment rate	Poverty rate	Household disposable income Gross adjusted	Municipal waste generated	Patents in environment-related technologies	Gross domestic expenditure on R&D	Electricity consumption	Renewable energy	Air pollution exposure	CO ₂ emission	Number of passenger cars in use	Households with Internet access	Average
Gross Domestic Product	0.02	0.01	0.03	0.01	0.01	0.01	0.01	0.01	0.03	0.02	0.03	0.01	0.03	0.02
Unemployment rate	0.06	0.02	0.02	0.02	0.01	0.06	0.02	0.01	0.02	0.02	0.02	0.10	0.05	0.06
Poverty rate	0.06	0.09	0.10	0.10	0.03	0.12	0.15	0.22	0.30	0.05	0.06	0.10	0.12	0.06
Household disposable income Gross adjusted	0.06	0.02	0.02	0.02	0.01	0.09	0.01	0.01	0.02	0.02	0.03	0.02	0.00	0.06
Municipal waste generated	0.11	0.14	0.19	0.12	0.07	0.09	0.02	0.03	0.05	0.32	0.06	0.09	0.12	0.11
Patents in environment-related technologies	0.02	0.00	0.01	0.00	0.01	0.01	0.01	0.01	0.02	0.01	0.02	0.03	0.00	0.02
Gross domestic expenditure on R&D	0.11	0.07	0.05	0.10	0.27	0.10	0.07	0.03	0.05	0.05	0.09	0.10	0.10	0.11
Electricity consumption	0.13	0.11	0.02	0.10	0.13	0.10	0.15	0.06	0.02	0.05	0.18	0.10	0.12	0.13
Renewable energy	0.13	0.18	0.05	0.16	0.20	0.10	0.22	0.44	0.15	0.11	0.18	0.14	0.14	0.13
Air pollution exposure	0.13	0.16	0.19	0.12	0.02	0.10	0.15	0.11	0.15	0.11	0.09	0.12	0.12	0.13
CO ₂ emission	0.13	0.18	0.29	0.14	0.20	0.10	0.15	0.06	0.15	0.21	0.18	0.14	0.14	0.13
Number of passenger cars in use	0.04	0.00	0.02	0.02	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.04
Households with Internet access	0.01	0.01	0.01	0.10	0.01	0.09	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.01

Source: based on author.

Appendix 14. Random average consistency indexes for various n .

n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.84	1.56	1.57	1.59

Source: based on author according Shaoa et al. (2020).

Appendix 15. Result of calculation of normalized matrix in TOPSIS model, 2018

Country	Gross domestic product, USD/capita	Unemployment rate, as % of labour force	Poverty rate, %	Household disposable income Gross adjusted, USD/capita	Municipal waste generated, Tonnes/1000 capita	Gross domestic expenditure on R&D, as % of GDP	Patents in environment-related technologies	Electricity consumption, GWh	Renewable energy, as % of primary energy supply	Air pollution exposure (PM2.5 (µg/m ³))	CO ₂ emission per capita, Tonnes/capita	Number of passenger cars, Cars/1000 capita	Households with Internet access, %
Australia	0,19	0,13	0,16	0,22	0,20	0,17	0,03	0,05	0,06	0,08	0,32	0,21	0,17
Austria	0,20	0,12	0,12	0,21	0,21	0,26	0,02	0,01	0,25	0,15	0,15	0,21	0,18
Belgium	0,18	0,15	0,12	0,20	0,15	0,23	0,02	0,02	0,07	0,16	0,17	0,19	0,18
Canada	0,18	0,14	0,17	0,20	0,00	0,13	0,04	0,14	0,14	0,09	0,30	0,23	0,18
Czech Republic	0,14	0,05	0,08	0,15	0,13	0,16	0,00	0,02	0,09	0,21	0,19	0,19	0,18
Denmark	0,20	0,13	0,07	0,19	0,27	0,25	0,02	0,01	0,29	0,12	0,11	0,16	0,19
Finland	0,17	0,18	0,08	0,19	0,20	0,23	0,02	0,01	0,29	0,07	0,16	0,18	0,19
France	0,16	0,22	0,10	0,20	0,19	0,18	0,11	0,12	0,09	0,14	0,09	0,18	0,18
Germany	0,19	0,08	0,13	0,23	0,22	0,25	0,25	0,13	0,12	0,15	0,17	0,20	0,19
Greece	0,11	0,47	0,18	0,12	0,18	0,10	0,00	0,01	0,11	0,18	0,12	0,18	0,16
Hungary	0,11	0,09	0,11	0,12	0,14	0,13	0,00	0,01	0,09	0,20	0,10	0,12	0,17
Ireland	0,30	0,14	0,12	0,17	0,20	0,09	0,01	0,01	0,09	0,10	0,15	0,16	0,18
Italy	0,15	0,26	0,18	0,17	0,18	0,12	0,05	0,06	0,15	0,20	0,11	0,23	0,17
Japan	0,15	0,06	0,20	0,17	0,12	0,27	0,57	0,22	0,05	0,17	0,17	0,18	0,19
South Korea	0,15	0,09	0,13	0,14	0,13	0,40	0,19	0,12	0,02	0,33	0,25	0,13	0,20
Luxembourg	0,41	0,14	0,09	0,26	0,22	0,10	0,00	0,00	0,06	0,12	0,30	0,24	0,19
Mexico	0,07	0,08	0,54	0,10	0,12	0,03	0,00	0,07	0,08	0,25	0,07	0,09	0,11
Netherlands	0,20	0,09	0,10	0,20	0,18	0,18	0,05	0,02	0,05	0,15	0,18	0,19	0,20
Norway	0,24	0,10	0,11	0,22	0,27	0,17	0,01	0,03	0,42	0,08	0,17	0,19	0,20
Poland	0,11	0,09	0,13	0,13	0,12	0,10	0,01	0,04	0,07	0,28	0,16	0,22	0,17
Portugal	0,12	0,17	0,16	0,14	0,18	0,11	0,00	0,01	0,22	0,10	0,09	0,17	0,16
Slovakia	0,11	0,16	0,11	0,12	0,15	0,07	0,00	0,01	0,08	0,23	0,13	0,15	0,17
Spain	0,14	0,37	0,20	0,16	0,17	0,10	0,02	0,06	0,12	0,12	0,11	0,18	0,18
Sweden	0,19	0,16	0,11	0,19	0,16	0,28	0,04	0,03	0,33	0,07	0,08	0,17	0,19

Turkey	0,10	0,27	0,22	0,11	0,15	0,07	0,01	0,06	0,11	0,33	0,10	0,05	0,17
United Kingdom	0,17	0,10	0,15	0,19	0,17	0,14	0,09	0,07	0,09	0,12	0,11	0,19	0,19
United States	0,22	0,10	0,22	0,30	0,26	0,23	0,74	0,93	0,07	0,09	0,30	0,14	0,15
Chile	0,09	0,18	0,21	0,10	0,14	0,03	0,00	0,02	0,25	0,29	0,09	0,07	0,15
Estonia	0,13	0,13	0,20	0,13	0,15	0,12	0,00	0,00	0,16	0,07	0,32	0,20	0,18
Slovenia	0,14	0,13	0,12	0,14	0,17	0,16	0,00	0,00	0,14	0,21	0,14	0,20	0,18
Latvia	0,11	0,18	0,21	0,12	0,15	0,05	0,00	0,00	0,35	0,16	0,08	0,13	0,17
Lithuania	0,13	0,15	0,20	0,14	0,17	0,08	0,00	0,00	0,17	0,13	0,09	0,16	0,16

Source: based on author.

Appendix 16. Results of calculation of normalized matrix in TOPSIS model, 2019

Country	Gross domestic product, USD/capita	Unemployment rate, as % of labour force	Poverty rate, %	Household disposable income Gross adjusted, USD/capita	Municipal waste generated, Tonnes/1000 capita	Gross domestic expenditure on R&D, as % of GDP	Patents in environment-related technologies	Electricity consumption, GWh	Renewable energy, as % of primary energy supply	Air pollution exposure (PM2.5 (µg/m³))	CO ₂ emission per capita, Tonnes/capita	Number of passenger cars, Cars/1000 capita	Households with Internet access, %
Australia	0,19	0,13	0,16	0,22	0,20	0,18	0,03	0,06	0,06	0,08	0,34	0,21	0,17
Austria	0,20	0,12	0,12	0,21	0,21	0,26	0,02	0,02	0,25	0,15	0,16	0,21	0,18
Belgium	0,19	0,14	0,12	0,20	0,15	0,22	0,02	0,02	0,06	0,16	0,18	0,19	0,18
Canada	0,17	0,15	0,16	0,21	0,10	0,14	0,04	0,14	0,13	0,09	0,31	0,23	0,17
Czech Republic	0,15	0,05	0,07	0,17	0,12	0,16	0,00	0,02	0,09	0,21	0,19	0,19	0,17
Denmark	0,20	0,13	0,07	0,19	0,28	0,26	0,02	0,01	0,30	0,12	0,11	0,16	0,19
Finland	0,17	0,18	0,08	0,21	0,19	0,24	0,02	0,01	0,28	0,07	0,15	0,18	0,19
France	0,17	0,22	0,10	0,19	0,19	0,19	0,11	0,12	0,09	0,14	0,09	0,18	0,18
Germany	0,19	0,08	0,13	0,22	0,23	0,25	0,25	0,13	0,12	0,15	0,17	0,20	0,19
Greece	0,11	0,45	0,18	0,12	0,18	0,09	0,00	0,01	0,11	0,18	0,12	0,18	0,16
Hungary	0,12	0,09	0,10	0,11	0,14	0,12	0,00	0,01	0,08	0,20	0,11	0,12	0,17
Ireland	0,30	0,13	0,12	0,16	0,20	0,11	0,01	0,01	0,09	0,10	0,15	0,15	0,18
Italy	0,15	0,25	0,17	0,19	0,18	0,12	0,05	0,06	0,15	0,19	0,11	0,24	0,17
Japan	0,15	0,06	0,20	0,17	0,13	0,28	0,58	0,21	0,05	0,17	0,18	0,18	0,18

South Korea	0,15	0,10	0,16	0,16	0,13	0,37	0,20	0,12	0,02	0,34	0,25	0,13	0,20
Luxembourg	0,41	0,14	0,10	0,25	0,21	0,11	0,00	0,00	0,06	0,12	0,32	0,24	0,19
Mexico	0,07	0,09	0,55	0,09	0,12	0,03	0,00	0,07	0,07	0,25	0,07	0,09	0,11
Netherlands	0,20	0,09	0,10	0,22	0,19	0,17	0,05	0,03	0,06	0,15	0,18	0,19	0,20
Norway	0,23	0,10	0,10	0,22	0,22	0,17	0,01	0,03	0,45	0,08	0,17	0,19	0,20
Poland	0,11	0,08	0,13	0,12	0,11	0,09	0,01	0,03	0,08	0,28	0,16	0,22	0,17
Portugal	0,12	0,17	0,15	0,16	0,18	0,11	0,00	0,01	0,19	0,10	0,09	0,17	0,16
Slovakia	0,12	0,15	0,10	0,14	0,13	0,08	0,00	0,01	0,08	0,23	0,13	0,15	0,16
Spain	0,14	0,36	0,19	0,15	0,17	0,10	0,02	0,06	0,12	0,12	0,11	0,18	0,18
Sweden	0,19	0,17	0,11	0,21	0,16	0,28	0,04	0,04	0,34	0,07	0,09	0,17	0,19
Turkey	0,10	0,35	0,22	0,12	0,15	0,08	0,01	0,06	0,13	0,33	0,10	0,05	0,18
United Kingdom	0,17	0,10	0,14	0,19	0,17	0,14	0,09	0,07	0,10	0,12	0,11	0,19	0,19
United States	0,22	0,09	0,22	0,28	0,27	0,23	0,73	0,93	0,07	0,09	0,30	0,14	0,16
Chile	0,08	0,19	0,21	0,10	0,14	0,03	0,00	0,02	0,20	0,29	0,10	0,07	0,15
Estonia	0,13	0,11	0,20	0,12	0,14	0,12	0,00	0,00	0,19	0,07	0,28	0,20	0,18
Slovenia	0,14	0,11	0,11	0,13	0,17	0,18	0,00	0,00	0,14	0,21	0,14	0,20	0,18
Latvia	0,11	0,16	0,21	0,10	0,15	0,05	0,00	0,00	0,34	0,16	0,09	0,13	0,17
Lithuania	0,13	0,16	0,21	0,13	0,17	0,08	0,00	0,00	0,17	0,13	0,09	0,16	0,16

Source: based on author.

Appendix 17. Calculation of weighted normalized matrix by TOPSIS, 2018

Country	Gross domestic product, USD/capita	Unemployment rate, as % of labour force	Poverty rate, %	Household disposable income Gross adjusted, USD/capita	Municipal waste generated, Tonnes/1000 capita	Gross domestic expenditure on R&D, as % of GDP	Patents in environment-related technologies	Electricity consumption, GWh	Renewable energy, as % of primary energy supply	Air pollution exposure (PM2.5 (µg/m³))	CO ₂ emission per capita, Tonnes/capita	Number of passenger cars, Cars/1000 capita	Households with Internet access, %
Australia	0,0038	0,0026	0,0079	0,0090	0,0277	0,0139	0,0025	0,0043	0,0067	0,0074	0,0348	0,0210	0,0102
Austria	0,0040	0,0024	0,0059	0,0086	0,0291	0,0209	0,0021	0,0011	0,0278	0,0136	0,0167	0,0206	0,0109
Belgium	0,0037	0,0029	0,0062	0,0081	0,0207	0,0186	0,0017	0,0012	0,0074	0,0141	0,0189	0,0187	0,0107
Canada	0,0035	0,0029	0,0083	0,0080	0,0000	0,0103	0,0042	0,0109	0,0159	0,0078	0,0333	0,0230	0,0106

Czech Republic	0,0029	0,0011	0,0038	0,0060	0,0176	0,0127	0,0003	0,0015	0,0096	0,0188	0,0213	0,0188	0,0106
Denmark	0,0040	0,0025	0,0036	0,0078	0,0385	0,0202	0,0017	0,0005	0,0315	0,0108	0,0121	0,0159	0,0114
Finland	0,0035	0,0036	0,0042	0,0078	0,0277	0,0183	0,0019	0,0012	0,0321	0,0062	0,0177	0,0180	0,0116
France	0,0033	0,0044	0,0052	0,0079	0,0265	0,0145	0,0106	0,0097	0,0099	0,0126	0,0102	0,0181	0,0109
Germany	0,0038	0,0017	0,0063	0,0091	0,0309	0,0204	0,0246	0,0107	0,0132	0,0132	0,0189	0,0204	0,0116
Greece	0,0021	0,0095	0,0092	0,0048	0,0250	0,0078	0,0002	0,0009	0,0118	0,0160	0,0127	0,0182	0,0094
Hungary	0,0023	0,0018	0,0053	0,0046	0,0192	0,0102	0,0003	0,0005	0,0099	0,0184	0,0115	0,0124	0,0102
Ireland	0,0060	0,0028	0,0060	0,0066	0,0280	0,0076	0,0006	0,0005	0,0099	0,0087	0,0164	0,0156	0,0109
Italy	0,0030	0,0052	0,0088	0,0070	0,0251	0,0092	0,0048	0,0048	0,0168	0,0176	0,0119	0,0234	0,0103
Japan	0,0029	0,0012	0,0099	0,0067	0,0174	0,0215	0,0570	0,0176	0,0056	0,0150	0,0192	0,0183	0,0112
South Korea	0,0030	0,0019	0,0067	0,0058	0,0181	0,0317	0,0190	0,0098	0,0018	0,0301	0,0273	0,0126	0,0122
Luxembourg	0,0082	0,0027	0,0044	0,0105	0,0306	0,0081	0,0001	0,0000	0,0071	0,0111	0,0335	0,0243	0,0114
Mexico	0,0015	0,0016	0,0268	0,0038	0,0161	0,0021	0,0004	0,0056	0,0085	0,0223	0,0078	0,0086	0,0065
Netherlands	0,0041	0,0019	0,0051	0,0080	0,0257	0,0143	0,0047	0,0019	0,0057	0,0132	0,0196	0,0186	0,0120
Norway	0,0048	0,0019	0,0054	0,0088	0,0371	0,0136	0,0010	0,0024	0,0464	0,0074	0,0188	0,0190	0,0118
Poland	0,0022	0,0019	0,0067	0,0050	0,0165	0,0080	0,0006	0,0028	0,0081	0,0251	0,0181	0,0217	0,0103
Portugal	0,0024	0,0034	0,0080	0,0058	0,0255	0,0090	0,0003	0,0010	0,0237	0,0090	0,0104	0,0169	0,0097
Slovakia	0,0023	0,0032	0,0053	0,0050	0,0208	0,0055	0,0001	0,0004	0,0086	0,0205	0,0145	0,0148	0,0099
Spain	0,0029	0,0075	0,0098	0,0062	0,0239	0,0082	0,0024	0,0046	0,0136	0,0110	0,0121	0,0181	0,0106
Sweden	0,0038	0,0031	0,0057	0,0077	0,0218	0,0220	0,0043	0,0027	0,0359	0,0063	0,0090	0,0175	0,0115
Turkey	0,0020	0,0054	0,0110	0,0045	0,0211	0,0059	0,0014	0,0051	0,0126	0,0301	0,0107	0,0052	0,0103
United Kingdom	0,0033	0,0020	0,0075	0,0077	0,0233	0,0114	0,0085	0,0055	0,0103	0,0111	0,0116	0,0191	0,0116
United States	0,0044	0,0019	0,0111	0,0119	0,0365	0,0187	0,0740	0,0740	0,0073	0,0085	0,0333	0,0137	0,0091
Chile	0,0017	0,0036	0,0105	0,0039	0,0197	0,0025	0,0002	0,0014	0,0273	0,0259	0,0104	0,0068	0,0090
Estonia	0,0026	0,0026	0,0101	0,0052	0,0203	0,0094	0,0000	0,0002	0,0175	0,0066	0,0355	0,0200	0,0111
Slovenia	0,0027	0,0025	0,0058	0,0058	0,0244	0,0128	0,0002	0,0003	0,0155	0,0188	0,0159	0,0200	0,0106
Latvia	0,0022	0,0036	0,0103	0,0047	0,0205	0,0042	0,0000	0,0001	0,0384	0,0142	0,0086	0,0126	0,0100
Lithuania	0,0025	0,0030	0,0101	0,0057	0,0233	0,0062	0,0001	0,0001	0,0191	0,0116	0,0100	0,0159	0,0096

Source: based on author.

Appendix 18. Calculation of weighted normalized matrix by TOPSIS, 2019

Country	Gross domestic product, USD/capita	Unemployment rate, as % of labour force	Poverty rate, %	Household disposable income Gross adjusted, USD/capita	Municipal waste generated, Tonnes/1000 capita	Gross domestic expenditure on R&D, as % of GDP	Patents in environment-related technologies	Electricity consumption, GWh	Renewable energy, as % of primary energy supply	Air pollution exposure (PM2.5 (µg/m ³))	CO ₂ emission per capita, Tonnes/capita	Number of passenger cars, Cars/1000 capita	Households with Internet access, %
Australia	0,0038	0,0027	0,0078	0,0089	0,0281	0,0141	0,0025	0,0045	0,0064	0,0075	0,0371	0,0208	0,0101
Austria	0,0040	0,0023	0,0058	0,0083	0,0288	0,0210	0,0021	0,0013	0,0273	0,0135	0,0177	0,0206	0,0108
Belgium	0,0037	0,0028	0,0061	0,0078	0,0212	0,0175	0,0017	0,0016	0,0070	0,0141	0,0194	0,0187	0,0108
Canada	0,0035	0,0029	0,0080	0,0085	0,0135	0,0114	0,0041	0,0111	0,0148	0,0078	0,0337	0,0228	0,0105
Czech Republic	0,0029	0,0010	0,0037	0,0066	0,0170	0,0126	0,0003	0,0015	0,0097	0,0188	0,0214	0,0189	0,0104
Denmark	0,0041	0,0026	0,0035	0,0074	0,0395	0,0206	0,0017	0,0005	0,0334	0,0108	0,0116	0,0159	0,0115
Finland	0,0035	0,0035	0,0040	0,0085	0,0262	0,0194	0,0018	0,0012	0,0309	0,0062	0,0168	0,0180	0,0113
France	0,0033	0,0044	0,0051	0,0077	0,0268	0,0152	0,0107	0,0097	0,0097	0,0126	0,0103	0,0181	0,0108
Germany	0,0038	0,0016	0,0063	0,0087	0,0321	0,0201	0,0250	0,0105	0,0132	0,0132	0,0183	0,0203	0,0114
Greece	0,0021	0,0089	0,0089	0,0046	0,0258	0,0069	0,0002	0,0008	0,0116	0,0158	0,0127	0,0183	0,0094
Hungary	0,0023	0,0018	0,0052	0,0044	0,0198	0,0093	0,0003	0,0006	0,0093	0,0184	0,0118	0,0124	0,0103
Ireland	0,0060	0,0026	0,0058	0,0063	0,0284	0,0086	0,0006	0,0005	0,0101	0,0087	0,0162	0,0154	0,0109
Italy	0,0030	0,0051	0,0087	0,0075	0,0256	0,0093	0,0049	0,0050	0,0165	0,0175	0,0120	0,0235	0,0102
Japan	0,0029	0,0012	0,0098	0,0069	0,0179	0,0221	0,0576	0,0170	0,0057	0,0151	0,0195	0,0184	0,0110
South Korea	0,0029	0,0019	0,0079	0,0062	0,0187	0,0300	0,0196	0,0099	0,0021	0,0304	0,0273	0,0128	0,0120
Luxembourg	0,0082	0,0029	0,0051	0,0102	0,0298	0,0087	0,0001	0,0000	0,0067	0,0112	0,0350	0,0240	0,0114
Mexico	0,0014	0,0018	0,0275	0,0038	0,0165	0,0026	0,0004	0,0056	0,0080	0,0222	0,0079	0,0087	0,0068
Netherlands	0,0040	0,0018	0,0050	0,0087	0,0264	0,0137	0,0048	0,0021	0,0065	0,0133	0,0196	0,0186	0,0118
Norway	0,0045	0,0019	0,0052	0,0087	0,0313	0,0133	0,0010	0,0023	0,0494	0,0074	0,0191	0,0190	0,0118
Poland	0,0023	0,0017	0,0065	0,0048	0,0156	0,0070	0,0006	0,0028	0,0085	0,0252	0,0179	0,0221	0,0104
Portugal	0,0025	0,0034	0,0077	0,0064	0,0248	0,0088	0,0003	0,0009	0,0209	0,0090	0,0102	0,0169	0,0097
Slovakia	0,0023	0,0030	0,0052	0,0055	0,0184	0,0062	0,0001	0,0005	0,0090	0,0205	0,0142	0,0151	0,0099
Spain	0,0029	0,0073	0,0096	0,0060	0,0237	0,0083	0,0024	0,0047	0,0133	0,0111	0,0120	0,0180	0,0110
Sweden	0,0038	0,0035	0,0057	0,0084	0,0223	0,0223	0,0044	0,0029	0,0369	0,0063	0,0096	0,0174	0,0115

Turkey	0,0019	0,0071	0,0108	0,0047	0,0205	0,0062	0,0014	0,0052	0,0144	0,0297	0,0108	0,0052	0,0106
United Kingdom	0,0033	0,0019	0,0070	0,0075	0,0242	0,0114	0,0085	0,0055	0,0113	0,0111	0,0117	0,0191	0,0115
United States	0,0044	0,0019	0,0109	0,0113	0,0377	0,0188	0,0733	0,0741	0,0072	0,0085	0,0333	0,0135	0,0096
Chile	0,0017	0,0037	0,0103	0,0038	0,0200	0,0025	0,0002	0,0014	0,0219	0,0262	0,0105	0,0069	0,0091
Estonia	0,0026	0,0023	0,0099	0,0048	0,0194	0,0093	0,0001	0,0001	0,0209	0,0066	0,0305	0,0202	0,0109
Slovenia	0,0028	0,0023	0,0056	0,0054	0,0235	0,0141	0,0002	0,0003	0,0151	0,0189	0,0159	0,0199	0,0107
Latvia	0,0022	0,0032	0,0103	0,0042	0,0212	0,0039	0,0000	0,0001	0,0374	0,0141	0,0094	0,0126	0,0103
Lithuania	0,0026	0,0032	0,0103	0,0053	0,0239	0,0065	0,0000	0,0001	0,0184	0,0116	0,0103	0,0156	0,0098

Source: based on author.

Appendix 19. Ideal and anti-ideal values by TOPSIS, 2018

Options	Gross domestic product, USD/capita	Unemployment rate, as % of labour force	Poverty rate, %	Household disposable income Gross adjusted, USD/capita	Municipal waste generated, Tonnes/1000 capita	Gross domestic expenditure on R&D, as % of GDP	Patents in environment-related technologies	Electricity consumption, GWh	Renewable energy, as % of primary energy supply	Air pollution exposure (PM2.5 (µg/m³))	CO ₂ emission per capita, Tonnes/capita	Number of passenger cars, Cars/1000 capita	Households with Internet access, %
V+	0,0082	0,0011	0,0036	0,0119	0,0000	0,0317	0,0740	0,0000	0,0464	0,0062	0,0078	0,0052	0,0122
V-	0,0015	0,0095	0,0268	0,0038	0,0385	0,0021	0,0000	0,0740	0,0018	0,0301	0,0355	0,0243	0,0065

Source: based on author.

Appendix 20. Ideal and anti-ideal values by TOPSIS, 2019

Options	Gross domestic product, USD/capita	Unemployment rate, as % of labour force	Poverty rate, %	Household disposable income Gross adjusted, USD/capita	Municipal waste generated, Tonnes/1000 capita	Gross domestic expenditure on R&D, as % of GDP	Patents in environment-related technologies	Electricity consumption, GWh	Renewable energy, as % of primary energy supply	Air pollution exposure (PM2.5 (µg/m³))	CO ₂ emission per capita, Tonnes/capita	Number of passenger cars, Cars/1000 capita	Households with Internet access, %
V+	0,0082	0,0010	0,0035	0,0113	0,0135	0,0300	0,0733	0,0000	0,0494	0,0062	0,0079	0,0052	0,0120
V-	0,0014	0,0089	0,0275	0,0038	0,0395	0,0025	0,0000	0,0741	0,0021	0,0304	0,0371	0,0240	0,0068

Source: based on author.

Appendix 21. TOPSIS calculation of the Euclidean distance from the ideal best (SI+) and anti ideal-best (SI-), calculation of the performance scores (PI), 2018-2019

Country	2018			2019			Country	2018			2019		
	SI+	SI-	PI	SI+	SI-	PI		SI+	SI-	PI	SI+	SI-	PI
Australia	0,0939	0,0783	0,4544	0,0921	0,0784	0,4597	Mexico	0,0948	0,0798	0,4570	0,0938	0,0804	0,4616
Austria	0,0831	0,0873	0,5123	0,0794	0,0874	0,5240	Netherlands	0,0885	0,0819	0,4806	0,0858	0,0823	0,4895
Belgium	0,0882	0,0836	0,4868	0,0869	0,0836	0,4903	Norway	0,0859	0,0930	0,5198	0,0786	0,0952	0,5478
Canada	0,0862	0,0818	0,4869	0,0865	0,0767	0,4698	Poland	0,0924	0,0803	0,4648	0,0913	0,0814	0,4713
Czech Republic	0,0897	0,0828	0,4800	0,0883	0,0837	0,4866	Portugal	0,0859	0,0870	0,5030	0,0834	0,0874	0,5117
Denmark	0,0852	0,0908	0,5158	0,0796	0,0921	0,5365	Slovakia	0,0919	0,0832	0,4750	0,0895	0,0847	0,4864
Finland	0,0817	0,0901	0,5246	0,0775	0,0910	0,5400	Spain	0,0878	0,0805	0,4785	0,0852	0,0814	0,4885
France	0,0819	0,0783	0,4887	0,0791	0,0792	0,5003	Sweden	0,0758	0,0937	0,5529	0,0724	0,0945	0,5662
Germany	0,0720	0,0791	0,5235	0,0679	0,0798	0,5403	Turkey	0,0912	0,0803	0,4684	0,0881	0,0814	0,4803
Greece	0,0913	0,0821	0,4734	0,0890	0,0829	0,4820	United Kingdom	0,0829	0,0811	0,4945	0,0801	0,0820	0,5059
Hungary	0,0889	0,0854	0,4901	0,0878	0,0859	0,4946	United States	0,0965	0,0822	0,4598	0,0937	0,0817	0,4657
Ireland	0,0913	0,0839	0,4788	0,0879	0,0847	0,4907	Chile	0,0873	0,0868	0,4985	0,0864	0,0861	0,4991

Italy	0,0860	0,0797	0,4808	0,0833	0,0803	0,4909	Estonia	0,0913	0,0837	0,4782	0,0866	0,0853	0,4963
Japan	0,0561	0,0905	0,6173	0,0548	0,0917	0,6261	Slovenia	0,0888	0,0836	0,4849	0,0860	0,0846	0,4959
South Korea	0,0807	0,0805	0,4993	0,0795	0,0800	0,5013	Latvia	0,0836	0,0925	0,5255	0,0807	0,0926	0,5343
Luxembourg	0,0978	0,0814	0,4544	0,0950	0,0816	0,4621	Lithuania	0,0877	0,0861	0,4954	0,0852	0,0866	0,5041

Source: based on author.

Appendix 22. Results of calculation of normalized matrix in TOPSIS model, 2018

Country	Gross domestic product, USD/capita	Unemployment rate, as % of labour force	Poverty rate, %	Household disposable income Gross adjusted, USD/capita	Municipal waste generated, Tonnes/1000 capita	Gross domestic expenditure on R&D, as % of GDP	Patents in environment-related technologies	Electricity consumption, GWh	Renewable energy, as % of primary energy supply	Air pollution exposure (PM2.5 (µg/m³))	CO ₂ emission per capita, Tonnes/capita	Number of passenger cars, Cars/1000 capita	Households with Internet access, %
Asia	0,39	0,43	0,40	0,37	0,38	0,68	0,70	0,33	0,19	0,61	0,38	0,35	0,50
Australia	0,56	0,40	0,34	0,58	0,56	0,48	0,07	0,13	0,19	0,18	0,69	0,61	0,45
Europe	0,51	0,49	0,28	0,44	0,51	0,42	0,08	0,07	0,50	0,32	0,32	0,53	0,48
North America	0,46	0,33	0,66	0,51	0,35	0,36	0,71	0,93	0,30	0,31	0,49	0,44	0,39
South America	0,26	0,55	0,45	0,25	0,40	0,08	0,01	0,04	0,77	0,63	0,21	0,20	0,40

Source: based on author.

Appendix 23. Results of calculation of normalized matrix in TOPSIS model, 2019

Country	Gross domestic product, USD/capita	Unemployment rate, as % of labour force	Poverty rate, %	Household disposable income Gross adjusted, USD/capita	Municipal waste generated, Tonnes/1000 capita	Gross domestic expenditure on R&D, as % of GDP	Patents in environment-related technologies	Electricity consumption, GWh	Renewable energy, as % of primary energy supply	Air pollution exposure (PM2.5 (µg/m³))	CO ₂ emission per capita, Tonnes/capita	Number of passenger cars, Cars/1000 capita	Households with Internet access, %
Asia	0,38	0,50	0,41	0,38	0,37	0,67	0,71	0,33	0,23	0,61	0,37	0,35	0,50
Australia	0,56	0,39	0,34	0,58	0,54	0,48	0,07	0,14	0,20	0,18	0,71	0,60	0,45
Europe	0,51	0,45	0,28	0,44	0,48	0,42	0,08	0,07	0,57	0,32	0,31	0,53	0,48
North America	0,46	0,32	0,67	0,51	0,44	0,37	0,70	0,93	0,32	0,31	0,48	0,44	0,40
South America	0,25	0,54	0,44	0,25	0,39	0,09	0,01	0,04	0,69	0,63	0,20	0,20	0,40

Source: based on author.

Appendix 24. Calculation of weighted normalized matrix by TOPSIS, 2018

Country	Gross domestic product, USD/capita	Unemployment rate, as % of labour force	Poverty rate, %	Household disposable income Gross adjusted, USD/capita	Municipal waste generated, Tonnes/1000 capita	Gross domestic expenditure on R&D, as % of GDP	Patents in environment-related technologies	Electricity consumption, GWh	Renewable energy, as % of primary energy supply	Air pollution exposure (PM2.5 (µg/m³))	CO ₂ emission per capita, Tonnes/capita	Number of passenger cars, Cars/1000 capita	Households with Internet access, %
Asia	0,0078	0,0086	0,0198	0,0147	0,0534	0,0542	0,0698	0,0267	0,0206	0,0548	0,0415	0,0348	0,0300
Australia	0,0112	0,0079	0,0171	0,0234	0,0783	0,0384	0,0068	0,0107	0,0208	0,0162	0,0757	0,0607	0,0272
Europe	0,0101	0,0099	0,0142	0,0178	0,0710	0,0336	0,0080	0,0056	0,0553	0,0288	0,0350	0,0529	0,0288
North America	0,0093	0,0065	0,0332	0,0205	0,0497	0,0285	0,0709	0,0744	0,0327	0,0282	0,0539	0,0437	0,0234
South America	0,0051	0,0111	0,0227	0,0100	0,0557	0,0068	0,0006	0,0034	0,0843	0,0567	0,0227	0,0197	0,0241

Source: based on author.

Appendix 25. Calculation of weighted normalized matrix by TOPSIS, 2019

Country	Gross domestic product, USD/capita	Unemployment rate, as % of labour force	Poverty rate, %	Household disposable income Gross adjusted, USD/capita	Municipal waste generated, Tonnes/1000 capita	Gross domestic expenditure on R&D, as % of GDP	Patents in environment-related technologies	Electricity consumption, GWh	Renewable energy, as % of primary energy supply	Air pollution exposure (PM2.5 (µg/m³))	CO ₂ emission per capita, Tonnes/capita	Number of passenger cars, Cars/1000 capita	Households with Internet access, %
Asia	0,0077	0,0099	0,0205	0,0154	0,0515	0,0533	0,0707	0,0262	0,0257	0,0546	0,0404	0,0352	0,0299
Australia	0,0112	0,0077	0,0168	0,0231	0,0760	0,0386	0,0069	0,0110	0,0223	0,0163	0,0780	0,0604	0,0269
Europe	0,0102	0,0091	0,0140	0,0177	0,0672	0,0336	0,0080	0,0057	0,0626	0,0286	0,0336	0,0530	0,0288
North America	0,0092	0,0064	0,0333	0,0204	0,0610	0,0299	0,0700	0,0745	0,0347	0,0280	0,0525	0,0435	0,0239
South America	0,0050	0,0109	0,0222	0,0099	0,0542	0,0069	0,0006	0,0034	0,0762	0,0570	0,0221	0,0200	0,0243

Source: based on author.

Appendix 26. Ideal and anti-ideal values by TOPSIS, 2018

Options	Gross domestic product, USD/capita	Unemployment rate, as % of labour force	Poverty rate, %	Household disposable income Gross adjusted, USD/capita	Municipal waste generated, Tonnes/1000 capita	Gross domestic expenditure on R&D, as % of GDP	Patents in environment-related technologies	Electricity consumption, GWh	Renewable energy, as % of primary energy supply	Air pollution exposure (PM2.5 (µg/m³))	CO ₂ emission per capita, Tonnes/capita	Number of passenger cars, Cars/1000 capita	Households with Internet access, %
V+	0,0112	0,0065	0,0142	0,0234	0,0497	0,0542	0,0709	0,0034	0,0843	0,0162	0,0227	0,0197	0,0300
V-	0,0051	0,0111	0,0332	0,0100	0,0783	0,0068	0,0006	0,0744	0,0206	0,0567	0,0757	0,0607	0,0234

Source: based on author.

Appendix 27. Ideal and anti-ideal values by TOPSIS, 2019

Options	Gross domestic product, USD/capita	Unemployment rate, as % of labour force	Poverty rate, %	Household disposable income Gross adjusted, USD/capita	Municipal waste generated, Tonnes/1000 capita	Gross domestic expenditure on R&D, as % of GDP	Patents in environment-related technologies	Electricity consumption, GWh	Renewable energy, as % of primary energy supply	Air pollution exposure (PM2.5 (µg/m³))	CO ₂ emission per capita, Tonnes/capita	Number of passenger cars, Cars/1000 capita	Households with Internet access, %
V+	0,0112	0,0064	0,0140	0,0231	0,0515	0,0533	0,0707	0,0034	0,0762	0,0163	0,0221	0,0200	0,0299
V-	0,0050	0,0109	0,0333	0,0099	0,0760	0,0069	0,0006	0,0745	0,0223	0,0570	0,0780	0,0604	0,0239

Source: based on author.

Appendix 28. TOPSIS calculation of the Euclidean distance from the ideal best (SI+) and anti ideal-best (SI-), calculation of the performance scores (PI), 2018-2019

Region	2018				2019			
	SI+	SI-	PI	Rank	SI+	SI-	PI	Rank
Asia	0,0825	0,1097	0,5707	1	0,0723	0,1109	0,6053	1
Australia	0,1174	0,0850	0,4200	5	0,1124	0,0851	0,4309	5
Europe	0,0845	0,0987	0,5388	3	0,0785	0,1026	0,5667	2
North America	0,1024	0,0900	0,4679	4	0,0972	0,0875	0,4736	4
South America	0,0960	0,1192	0,5541	2	0,0952	0,1154	0,5480	3

Source: based on author.

Appendix 29. Collected data and calculated average solution (Av), 2018

Country	Gross domestic product, USD/capita	Unemployment rate, as % of labour force	Poverty rate, %	Household disposable income Gross adjusted, USD/capita	Municipal waste generated, Tonnes/1000 capita	Gross domestic expenditure on R&D, as % of GDP	Patents in environment-related technologies	Electricity consumption, GWh	Renewable energy, as % of primary energy supply	Air pollution exposure (PM2.5 (µg/m³))	CO ₂ emission per capita, Tonnes/capita	Number of passenger cars, Cars/1000 capita	Households with Internet access, %
Australia	53700,68	5,29	12,40	40236,66	550,82	2,12	1859,21	261,00	7,08	6,74	16,79	558,76	83,02
Austria	56837,72	4,88	9,20	38333,09	579,04	3,17	1528,36	68,60	29,33	12,38	8,05	548,51	88,78
Belgium	52350,27	5,96	9,72	36043,77	411,13	2,82	1254,03	75,10	7,79	12,82	9,10	498,87	87,27
Canada	50077,79	5,83	12,92	35722,91	0,00	1,57	3074,11	654,40	16,75	7,07	16,06	612,38	86,70
Czech Republic	41049,35	2,23	5,88	26913,59	351,10	1,93	243,21	88,03	10,15	17,17	10,27	500,30	86,36
Denmark	57408,51	5,11	5,55	34771,46	765,67	3,06	1257,70	30,38	33,16	9,87	5,86	423,04	92,66
Finland	49376,60	7,43	6,50	34679,28	551,37	2,77	1385,50	70,26	33,82	5,68	8,54	479,90	94,28
France	46397,96	9,03	8,10	35385,01	526,72	2,20	7879,51	581,94	10,39	11,49	4,93	482,01	88,56
Germany	54652,83	3,41	9,90	40698,94	615,31	3,09	18246,55	643,16	13,87	12,05	9,13	543,22	94,39
Greece	30354,31	19,33	14,36	21384,58	496,75	1,18	119,07	53,26	12,48	14,59	6,14	485,48	76,49
Hungary	32085,98	3,70	8,30	20758,98	381,46	1,55	251,50	32,00	10,41	16,74	5,53	329,93	83,31
Ireland	84575,44	5,78	9,34	29723,59	558,16	1,15	439,72	31,13	10,38	7,91	7,91	415,25	89,11
Italy	42908,65	10,63	13,80	31188,09	499,24	1,40	3566,69	289,71	17,72	16,03	5,76	624,09	84,34
Japan	41363,67	2,44	15,40	29910,55	346,54	3,26	42226,41	1057,75	5,88	13,66	9,27	487,58	91,28
South Korea	42240,27	3,85	10,50	25721,47	359,57	4,81	14071,59	590,11	1,94	27,45	13,16	336,60	99,48
Luxembourg	116622,24	5,52	6,84	47138,90	610,20	1,24	78,49	2,20	7,52	10,15	16,18	646,22	92,99
Mexico	20659,87	3,33	41,90	17160,13	320,61	0,31	304,37	335,58	8,98	20,36	3,77	228,67	52,86
Netherlands	57560,09	3,84	7,95	35914,17	511,04	2,16	3507,00	114,47	6,04	12,07	9,48	495,13	98,00
Norway	67639,11	3,88	8,40	39570,17	739,26	2,07	722,23	146,89	48,92	6,73	9,09	505,50	96,01
Poland	31471,21	3,84	10,40	22467,07	328,77	1,21	420,97	170,04	8,53	22,86	8,72	579,32	84,19
Portugal	34488,58	7,02	12,54	25754,86	507,75	1,37	192,03	59,64	24,94	8,22	5,00	449,93	79,43
Slovakia	32542,88	6,54	8,32	22347,75	413,84	0,83	64,60	26,97	9,11	18,66	7,01	395,35	80,84
Spain	40611,38	15,25	15,38	27934,32	474,85	1,24	1766,64	274,45	14,35	10,03	5,86	481,78	86,36
Sweden	53746,80	6,32	8,90	34279,48	433,95	3,34	3216,85	163,40	37,82	5,77	4,37	466,32	93,42
Turkey	28713,84	11,00	17,20	20156,86	419,50	0,89	1005,62	304,80	13,28	27,40	5,15	137,77	83,79

United Kingdom	46973,25	4,02	11,70	34241,87	463,23	1,72	6294,50	333,42	10,83	10,10	5,61	509,74	94,85
United States	62949,28	3,89	17,42	53122,80	727,66	2,84	54813,75	4455,44	7,73	7,79	16,05	365,01	74,22
Chile	24710,82	7,38	16,47	17291,21	391,90	0,37	165,13	82,31	28,77	23,64	5,03	181,32	73,30
Estonia	36299,86	5,35	15,82	23466,71	405,07	1,43	36,71	12,36	18,44	6,04	17,10	533,62	90,47
Slovenia	38876,86	5,13	9,02	25887,35	486,30	1,94	120,39	16,33	16,38	17,18	7,66	532,03	86,68
Latvia	30750,58	7,40	16,08	20849,44	407,37	0,63	26,03	6,73	40,44	12,92	4,14	335,85	81,58
Lithuania	36011,32	6,17	15,74	25367,52	464,23	0,94	37,35	3,51	20,08	10,58	4,85	423,86	78,38
Av	46750,25	6,27	12,25	30450,71	471,83	1,89	5317,99	344,86	16,98	13,19	8,49	456,04	86,04

Source: based on author.

Appendix 30. Collected data and calculated average solution (Av), 2019

Country	Gross domestic product, USD/capita	Unemployment rate, as % of labour force	Poverty rate, %	Household disposable income Gross adjusted, USD/capita	Municipal waste generated, Tonnes/1000 capita	Gross domestic expenditure on R&D, as % of GDP	Patents in environment-related technologies	Electricity consumption, GWh	Renewable energy, as % of primary energy supply	Air pollution exposure (PM2.5 (µg/m³))	CO ₂ emission per capita, Tonnes/capita	Number of passenger cars, Cars/1000 capita	Households with Internet access, %
Australia	55961.86	5.16	12.43	38653.45	543.05	2.07	1871.35	107.93	7.10	15.00	17.27	556.19	83.84
Austria	58942.64	4.50	9.24	36092.04	557.24	3.10	1537.08	120.71	30.19	12.30	8.25	550.19	89.91
Belgium	54897.74	5.36	9.70	33980.22	409.62	2.59	1256.75	102.54	7.76	14.10	9.03	499.94	89.73
Canada	51341.71	5.67	12.84	36881.61	259.65	1.68	3041.73	69.23	16.37	7.30	15.69	609.64	87.10
Czech Republic	43301.12	2.03	5.88	28761.01	329.02	1.86	240.72	180.84	10.72	11.50	9.94	504.91	87.00
Denmark	60194.51	5.04	5.58	32075.02	764.00	3.04	1265.78	172.76	36.93	9.60	5.39	425.42	95.43
Finland	51414.03	6.83	6.34	36648.65	506.81	2.87	1360.08	64.32	34.13	6.00	7.81	481.61	94.36
France	49144.87	8.47	8.14	33404.06	518.43	2.23	7848.75	153.46	10.68	14.70	4.81	482.81	90.17
Germany	56305.20	3.14	10.06	37705.35	619.88	2.97	18369.35	160.80	14.63	9.70	8.52	542.65	94.83
Greece	31412.88	17.30	14.21	20114.62	498.41	1.02	119.17	184.80	12.83	22.40	5.89	488.82	78.54
Hungary	34502.98	3.45	8.24	18968.39	383.32	1.36	253.38	231.96	10.31	14.00	5.51	332.02	86.20
Ireland	88496.48	4.95	9.31	27235.44	549.79	1.26	446.44	175.29	11.13	10.60	7.54	412.03	90.59
Italy	44217.70	9.89	13.90	32647.72	494.30	1.37	3583.81	200.32	18.24	12.90	5.60	628.28	85.17
Japan	43278.54	2.36	15.70	29910.55	345.64	3.26	42381.35	137.54	6.25	11.70	9.09	490.58	91.41
South Korea	43039.06	3.76	12.60	27081.38	361.83	4.42	14456.94	93.51	2.36	24.80	12.70	341.14	99.69

Luxembourg	120979.70	5.58	8.21	44186.74	576.29	1.28	81.63	74.96	7.39	9.90	16.31	640.91	95.20
Mexico	20703.39	3.49	43.90	16408.56	318.11	0.38	310.74	415.56	8.85	20.50	3.67	231.61	56.36
Netherlands	59512.49	3.41	7.96	37810.06	510.21	2.02	3502.40	208.83	7.18	10.70	9.13	496.30	98.40
Norway	66830.57	3.71	8.24	37623.81	605.28	1.97	717.58	42.78	54.59	7.50	8.89	508.19	98.38
Poland	33844.15	3.28	10.36	20627.71	301.82	1.03	429.41	256.56	9.35	17.30	8.35	591.26	86.75
Portugal	36579.20	6.55	12.35	27628.23	479.30	1.30	197.65	213.95	23.16	9.40	4.73	452.35	80.94
Slovakia	34072.07	5.76	8.28	23708.65	356.37	0.91	63.40	187.43	9.91	13.60	6.60	402.60	82.19
Spain	42170.63	14.12	15.28	25842.45	457.87	1.22	1763.41	196.97	14.70	9.20	5.58	480.61	91.44
Sweden	55855.53	6.78	9.10	36582.35	430.17	3.28	3250.05	85.71	40.78	6.10	4.45	464.41	96.06
Turkey	28424.25	13.71	17.22	20156.86	395.50	0.91	1055.26	328.46	15.95	18.40	5.01	139.51	88.30
United Kingdom	48745.12	3.74	11.22	32341.53	466.86	1.69	6264.13	220.58	12.49	11.40	5.45	509.87	95.85
United States	65143.42	3.67	17.46	49118.70	728.10	2.77	53987.63	84.93	7.92	9.00	15.52	361.08	79.88
Chile	25040.97	7.23	16.47	16472.50	387.29	0.37	168.99	259.62	24.27	27.70	4.90	184.22	75.64
Estonia	38967.75	4.38	15.82	20884.10	374.73	1.37	37.43	139.64	23.16	5.50	14.19	540.17	90.43
Slovenia	40962.50	4.43	8.92	23377.92	454.33	2.08	113.24	141.36	16.66	16.60	7.38	531.03	88.96
Latvia	32184.29	6.30	16.40	18157.82	408.81	0.58	24.30	271.32	41.38	13.30	4.38	335.29	85.45
Lithuania	38401.30	6.28	16.41	22972.59	461.40	0.95	35.99	233.60	20.36	15.80	4.81	415.40	81.52
Av	48589.65	5.95	12.43	29501.88	464.17	1.85	5313.62	172.45	17.74	13.08	8.20	457.22	87.99

Source: based on author.

Appendix 31. Positive distance from Average (PDA), 2018

Country	Gross domestic product, USD/capita	Unemployment rate, as % of labour force	Poverty rate, %	Household disposable income Gross adjusted, USD/capita	Municipal waste generated, Tonnes/1000 capita	Gross domestic expenditure on R&D, as % of GDP	Patents in environment-related technologies	Electricity consumption, GWh	Renewable energy, as % of primary energy supply	Air pollution exposure (PM2.5 (µg/m³))	CO ₂ emission per capita, Tonnes/capita	Number of passenger cars, Cars/1000 capita	Households with Internet access, %
Australia	0,15	0,16	0,00	0,32	0,00	0,12	0,00	0,24	0,00	0,49	0,00	0,00	0,00
Austria	0,22	0,22	0,25	0,26	0,00	0,67	0,00	0,80	0,73	0,06	0,05	0,00	0,03
Belgium	0,12	0,05	0,21	0,18	0,13	0,49	0,00	0,78	0,00	0,03	0,00	0,00	0,01
Canada	0,07	0,07	0,00	0,17	1,00	0,00	0,00	0,00	0,00	0,46	0,00	0,00	0,01
Czech Republic	0,00	0,64	0,52	0,00	0,26	0,02	0,00	0,74	0,00	0,00	0,00	0,00	0,00
Denmark	0,23	0,19	0,55	0,14	0,00	0,62	0,00	0,91	0,95	0,25	0,31	0,07	0,08

Finland	0,06	0,00	0,47	0,14	0,00	0,46	0,00	0,80	0,99	0,57	0,00	0,00	0,10
France	0,00	0,00	0,34	0,16	0,00	0,16	0,48	0,00	0,00	0,13	0,42	0,00	0,03
Germany	0,17	0,46	0,19	0,34	0,00	0,63	2,43	0,00	0,00	0,09	0,00	0,00	0,10
Greece	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,85	0,00	0,00	0,28	0,00	0,00
Hungary	0,00	0,41	0,32	0,00	0,19	0,00	0,00	0,91	0,00	0,00	0,35	0,28	0,00
Ireland	0,81	0,08	0,24	0,00	0,00	0,00	0,00	0,91	0,00	0,40	0,07	0,09	0,04
Italy	0,00	0,00	0,00	0,02	0,00	0,00	0,00	0,16	0,04	0,00	0,32	0,00	0,00
Japan	0,00	0,61	0,00	0,00	0,27	0,72	6,94	0,00	0,00	0,00	0,00	0,00	0,06
South Korea	0,00	0,39	0,14	0,00	0,24	1,54	1,65	0,00	0,00	0,00	0,00	0,26	0,16
Luxembourg	1,49	0,12	0,44	0,55	0,00	0,00	0,00	0,99	0,00	0,23	0,00	0,00	0,08
Mexico	0,00	0,47	0,00	0,00	0,32	0,00	0,00	0,03	0,00	0,00	0,56	0,50	0,00
Netherlands	0,23	0,39	0,35	0,18	0,00	0,14	0,00	0,67	0,00	0,08	0,00	0,00	0,14
Norway	0,45	0,38	0,31	0,30	0,00	0,09	0,00	0,57	1,88	0,49	0,00	0,00	0,12
Poland	0,00	0,39	0,15	0,00	0,30	0,00	0,00	0,51	0,00	0,00	0,00	0,00	0,00
Portugal	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,83	0,47	0,38	0,41	0,01	0,00
Slovakia	0,00	0,00	0,32	0,00	0,12	0,00	0,00	0,92	0,00	0,00	0,17	0,13	0,00
Spain	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,20	0,00	0,24	0,31	0,00	0,00
Sweden	0,15	0,00	0,27	0,13	0,08	0,76	0,00	0,53	1,23	0,56	0,49	0,00	0,09
Turkey	0,00	0,00	0,00	0,00	0,11	0,00	0,00	0,12	0,00	0,00	0,39	0,70	0,00
United Kingdom	0,00	0,36	0,04	0,12	0,02	0,00	0,18	0,03	0,00	0,23	0,34	0,00	0,10
United States	0,35	0,38	0,00	0,74	0,00	0,50	9,31	0,00	0,00	0,41	0,00	0,20	0,00
Chile	0,00	0,00	0,00	0,00	0,17	0,00	0,00	0,76	0,69	0,00	0,41	0,60	0,00
Estonia	0,00	0,15	0,00	0,00	0,14	0,00	0,00	0,96	0,09	0,54	0,00	0,00	0,05
Slovenia	0,00	0,18	0,26	0,00	0,00	0,03	0,00	0,95	0,00	0,00	0,10	0,00	0,01
Latvia	0,00	0,00	0,00	0,00	0,14	0,00	0,00	0,98	1,38	0,02	0,51	0,26	0,00
Lithuania	0,00	0,02	0,00	0,00	0,02	0,00	0,00	0,99	0,18	0,20	0,43	0,07	0,00

Source: based on author.

Appendix 32. Negative distance from Average (NDA), 2018

Country	Gross domestic product, USD/capita	Unemployment rate, as % of labour force	Poverty rate, %	Household disposable income Gross adjusted, USD/capita	Municipal waste generated, Tonnes/1000 capita	Gross domestic expenditure on R&D, as % of GDP	Patents in environment-related technologies	Electricity consumption, GWh	Renewable energy, as % of primary energy supply	Air pollution exposure (PM2.5 (µg/m³))	CO ₂ emission per capita, Tonnes/capita	Number of passenger cars, Cars/1000 capita	Households with Internet access, %
Australia	0,00	0,00	0,01	0,00	0,17	0,00	0,65	0,00	0,58	0,00	0,98	0,23	0,04
Austria	0,00	0,00	0,00	0,00	0,23	0,00	0,71	0,00	0,00	0,00	0,00	0,20	0,00
Belgium	0,00	0,00	0,00	0,00	0,00	0,00	0,76	0,00	0,54	0,00	0,07	0,09	0,00
Canada	0,00	0,00	0,05	0,00	0,00	0,17	0,42	0,90	0,01	0,00	0,89	0,34	0,00
Czech Republic	0,12	0,00	0,00	0,12	0,00	0,00	0,95	0,00	0,40	0,30	0,21	0,10	0,00
Denmark	0,00	0,00	0,00	0,00	0,62	0,00	0,76	0,00	0,00	0,00	0,00	0,00	0,00
Finland	0,00	0,18	0,00	0,00	0,17	0,00	0,74	0,00	0,00	0,00	0,01	0,05	0,00
France	0,01	0,44	0,00	0,00	0,12	0,00	0,00	0,69	0,39	0,00	0,00	0,06	0,00
Germany	0,00	0,00	0,00	0,00	0,30	0,00	0,00	0,87	0,18	0,00	0,08	0,19	0,00
Greece	0,35	2,08	0,17	0,30	0,05	0,38	0,98	0,00	0,26	0,11	0,00	0,06	0,11
Hungary	0,31	0,00	0,00	0,32	0,00	0,18	0,95	0,00	0,39	0,27	0,00	0,00	0,03
Ireland	0,00	0,00	0,00	0,02	0,18	0,39	0,92	0,00	0,39	0,00	0,00	0,00	0,00
Italy	0,08	0,69	0,13	0,00	0,06	0,26	0,33	0,00	0,00	0,22	0,00	0,37	0,02
Japan	0,12	0,00	0,26	0,02	0,00	0,00	0,00	2,07	0,65	0,04	0,09	0,07	0,00
South Korea	0,10	0,00	0,00	0,16	0,00	0,00	0,00	0,71	0,89	1,08	0,55	0,00	0,00
Luxembourg	0,00	0,00	0,00	0,00	0,29	0,35	0,99	0,00	0,56	0,00	0,91	0,42	0,00
Mexico	0,56	0,00	2,42	0,44	0,00	0,84	0,94	0,00	0,47	0,54	0,00	0,00	0,39
Netherlands	0,00	0,00	0,00	0,00	0,08	0,00	0,34	0,00	0,64	0,00	0,12	0,09	0,00
Norway	0,00	0,00	0,00	0,00	0,57	0,00	0,86	0,00	0,00	0,00	0,07	0,11	0,00
Poland	0,33	0,00	0,00	0,26	0,00	0,36	0,92	0,00	0,50	0,73	0,03	0,27	0,02
Portugal	0,26	0,12	0,02	0,15	0,08	0,28	0,96	0,00	0,00	0,00	0,00	0,00	0,08
Slovakia	0,30	0,04	0,00	0,27	0,00	0,56	0,99	0,00	0,46	0,41	0,00	0,00	0,06
Spain	0,13	1,43	0,26	0,08	0,01	0,35	0,67	0,00	0,15	0,00	0,00	0,06	0,00
Sweden	0,00	0,01	0,00	0,00	0,00	0,00	0,40	0,00	0,00	0,00	0,00	0,02	0,00
Turkey	0,39	0,75	0,40	0,34	0,00	0,53	0,81	0,00	0,22	1,08	0,00	0,00	0,03

United Kingdom	0,00	0,00	0,00	0,00	0,00	0,09	0,00	0,00	0,36	0,00	0,00	0,12	0,00
United States	0,00	0,00	0,42	0,00	0,54	0,00	0,00	11,92	0,54	0,00	0,89	0,00	0,14
Chile	0,47	0,18	0,34	0,43	0,00	0,80	0,97	0,00	0,00	0,79	0,00	0,00	0,15
Estonia	0,22	0,00	0,29	0,23	0,00	0,25	0,99	0,00	0,00	0,00	1,02	0,17	0,00
Slovenia	0,17	0,00	0,00	0,15	0,03	0,00	0,98	0,00	0,04	0,30	0,00	0,17	0,00
Latvia	0,34	0,18	0,31	0,32	0,00	0,67	1,00	0,00	0,00	0,00	0,00	0,00	0,05
Lithuania	0,23	0,00	0,29	0,17	0,00	0,50	0,99	0,00	0,00	0,00	0,00	0,00	0,09

Source: based on author.

Appendix 33. Positive distance from Average (PDA), 2019

Country	Gross domestic product, USD/capita	Unemployment rate, as % of labour force	Poverty rate, %	Household disposable income Gross adjusted, USD/capita	Municipal waste generated, Tonnes/1000 capita	Gross domestic expenditure on R&D, as % of GDP	Patents in environment-related technologies	Electricity consumption, GWh	Renewable energy, as % of primary energy supply	Air pollution exposure (PM2.5 (µg/m³))	CO ₂ emission per capita, Tonnes/capita	Number of passenger cars, Cars/1000 capita	Households with Internet access, %
Australia	0,15	0,13	0,00	0,31	0,00	0,12	0,00	0,22	0,00	0,48	0,00	0,00	0,00
Austria	0,21	0,24	0,26	0,22	0,00	0,67	0,00	0,78	0,70	0,07	0,00	0,00	0,02
Belgium	0,13	0,10	0,22	0,15	0,12	0,40	0,00	0,72	0,00	0,03	0,00	0,00	0,02
Canada	0,06	0,05	0,00	0,25	0,44	0,00	0,00	0,00	0,00	0,46	0,00	0,00	0,00
Czech Republic	0,00	0,66	0,53	0,00	0,29	0,01	0,00	0,74	0,00	0,00	0,00	0,00	0,00
Denmark	0,24	0,15	0,55	0,09	0,00	0,64	0,00	0,91	1,08	0,25	0,34	0,07	0,08
Finland	0,06	0,00	0,49	0,24	0,00	0,55	0,00	0,80	0,92	0,57	0,05	0,00	0,07
France	0,01	0,00	0,35	0,13	0,00	0,21	0,48	0,00	0,00	0,13	0,41	0,00	0,02
Germany	0,16	0,47	0,19	0,28	0,00	0,60	2,46	0,00	0,00	0,09	0,00	0,00	0,08
Greece	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,86	0,00	0,00	0,28	0,00	0,00
Hungary	0,00	0,42	0,34	0,00	0,17	0,00	0,00	0,90	0,00	0,00	0,33	0,27	0,00
Ireland	0,82	0,17	0,25	0,00	0,00	0,00	0,00	0,91	0,00	0,40	0,08	0,10	0,03
Italy	0,00	0,00	0,00	0,11	0,00	0,00	0,00	0,14	0,03	0,00	0,32	0,00	0,00
Japan	0,00	0,60	0,00	0,01	0,26	0,76	6,98	0,00	0,00	0,00	0,00	0,00	0,04
South Korea	0,00	0,37	0,00	0,00	0,22	1,39	1,72	0,00	0,00	0,00	0,00	0,25	0,13
Luxembourg	1,49	0,06	0,34	0,50	0,00	0,00	0,00	0,99	0,00	0,23	0,00	0,00	0,08

Mexico	0,00	0,41	0,00	0,00	0,31	0,00	0,00	0,02	0,00	0,00	0,55	0,49	0,00
Netherlands	0,22	0,43	0,36	0,28	0,00	0,09	0,00	0,64	0,00	0,08	0,00	0,00	0,12
Norway	0,38	0,38	0,34	0,28	0,00	0,06	0,00	0,60	2,08	0,49	0,00	0,00	0,12
Poland	0,00	0,45	0,17	0,00	0,35	0,00	0,00	0,52	0,00	0,00	0,00	0,00	0,00
Portugal	0,00	0,00	0,01	0,00	0,00	0,00	0,00	0,84	0,31	0,38	0,42	0,01	0,00
Slovakia	0,00	0,03	0,33	0,00	0,23	0,00	0,00	0,92	0,00	0,00	0,19	0,12	0,00
Spain	0,00	0,00	0,00	0,00	0,01	0,00	0,00	0,19	0,00	0,24	0,32	0,00	0,04
Sweden	0,15	0,00	0,27	0,24	0,07	0,77	0,00	0,50	1,30	0,56	0,46	0,00	0,09
Turkey	0,00	0,00	0,00	0,00	0,15	0,00	0,00	0,10	0,00	0,00	0,39	0,69	0,00
United Kingdom	0,00	0,37	0,10	0,10	0,00	0,00	0,18	0,04	0,00	0,23	0,34	0,00	0,09
United States	0,34	0,38	0,00	0,66	0,00	0,50	9,16	0,00	0,00	0,41	0,00	0,21	0,00
Chile	0,00	0,00	0,00	0,00	0,17	0,00	0,00	0,76	0,37	0,00	0,40	0,60	0,00
Estonia	0,00	0,26	0,00	0,00	0,19	0,00	0,00	0,98	0,31	0,55	0,00	0,00	0,03
Slovenia	0,00	0,26	0,28	0,00	0,02	0,12	0,00	0,95	0,00	0,00	0,10	0,00	0,01
Latvia	0,00	0,00	0,00	0,00	0,12	0,00	0,00	0,98	1,33	0,03	0,47	0,27	0,00
Lithuania	0,00	0,00	0,00	0,00	0,01	0,00	0,00	0,99	0,15	0,20	0,41	0,09	0,00

Source: based on author.

Appendix 34. Negative distance from Average (NDA), 2019

Country	Gross domestic product, USD/capita	Unemployment rate, as % of labour force	Poverty rate, %	Household disposable income Gross adjusted, USD/capita	Municipal waste generated, Tonnes/1000 capita	Gross domestic expenditure on R&D, as % of GDP	Patents in environment-related technologies	Electricity consumption, GWh	Renewable energy, as % of primary energy supply	Air pollution exposure (PM2.5 (µg/m³))	CO ₂ emission per capita, Tonnes/capita	Number of passenger cars, Cars/1000 capita	Households with Internet access, %
Australia	0,00	0,00	0,00	0,00	0,17	0,00	0,65	0,00	0,60	0,00	1,11	0,22	0,05
Austria	0,00	0,00	0,00	0,00	0,20	0,00	0,71	0,00	0,00	0,00	0,01	0,20	0,00
Belgium	0,00	0,00	0,00	0,00	0,00	0,00	0,76	0,00	0,56	0,00	0,10	0,09	0,00
Canada	0,00	0,00	0,03	0,00	0,00	0,09	0,43	0,93	0,08	0,00	0,91	0,33	0,01
Czech Republic	0,11	0,00	0,00	0,03	0,00	0,00	0,95	0,00	0,40	0,30	0,21	0,10	0,01
Denmark	0,00	0,00	0,00	0,00	0,65	0,00	0,76	0,00	0,00	0,00	0,00	0,00	0,00
Finland	0,00	0,15	0,00	0,00	0,09	0,00	0,74	0,00	0,00	0,00	0,00	0,05	0,00

France	0,00	0,42	0,00	0,00	0,12	0,00	0,00	0,69	0,40	0,00	0,00	0,06	0,00
Germany	0,00	0,00	0,00	0,00	0,34	0,00	0,00	0,83	0,18	0,00	0,04	0,19	0,00
Greece	0,35	1,91	0,14	0,32	0,07	0,45	0,98	0,00	0,28	0,09	0,00	0,07	0,11
Hungary	0,29	0,00	0,00	0,36	0,00	0,26	0,95	0,00	0,42	0,27	0,00	0,00	0,02
Ireland	0,00	0,00	0,00	0,08	0,18	0,32	0,92	0,00	0,37	0,00	0,00	0,00	0,00
Italy	0,09	0,66	0,12	0,00	0,06	0,26	0,33	0,00	0,00	0,21	0,00	0,37	0,03
Japan	0,11	0,00	0,26	0,00	0,00	0,00	0,00	1,95	0,65	0,04	0,11	0,07	0,00
South Korea	0,11	0,00	0,01	0,08	0,00	0,00	0,00	0,72	0,87	1,10	0,55	0,00	0,00
Luxembourg	0,00	0,00	0,00	0,00	0,24	0,31	0,98	0,00	0,58	0,00	0,99	0,40	0,00
Mexico	0,57	0,00	2,53	0,44	0,00	0,80	0,94	0,00	0,50	0,54	0,00	0,00	0,36
Netherlands	0,00	0,00	0,00	0,00	0,10	0,00	0,34	0,00	0,60	0,00	0,11	0,09	0,00
Norway	0,00	0,00	0,00	0,00	0,30	0,00	0,86	0,00	0,00	0,00	0,08	0,11	0,00
Poland	0,30	0,00	0,00	0,30	0,00	0,44	0,92	0,00	0,47	0,74	0,02	0,29	0,01
Portugal	0,25	0,10	0,00	0,06	0,03	0,30	0,96	0,00	0,00	0,00	0,00	0,00	0,08
Slovakia	0,30	0,00	0,00	0,20	0,00	0,51	0,99	0,00	0,44	0,42	0,00	0,00	0,07
Spain	0,13	1,37	0,23	0,12	0,00	0,34	0,67	0,00	0,17	0,00	0,00	0,05	0,00
Sweden	0,00	0,14	0,00	0,00	0,00	0,00	0,39	0,00	0,00	0,00	0,00	0,02	0,00
Turkey	0,42	1,31	0,39	0,32	0,00	0,51	0,80	0,00	0,10	1,05	0,00	0,00	0,00
United Kingdom	0,00	0,00	0,00	0,00	0,01	0,09	0,00	0,00	0,30	0,00	0,00	0,12	0,00
United States	0,00	0,00	0,40	0,00	0,57	0,00	0,00	11,90	0,55	0,00	0,89	0,00	0,09
Chile	0,48	0,22	0,32	0,44	0,00	0,80	0,97	0,00	0,00	0,81	0,00	0,00	0,14
Estonia	0,20	0,00	0,27	0,29	0,00	0,26	0,99	0,00	0,00	0,00	0,73	0,18	0,00
Slovenia	0,16	0,00	0,00	0,21	0,00	0,00	0,98	0,00	0,06	0,30	0,00	0,16	0,00
Latvia	0,34	0,06	0,32	0,38	0,00	0,69	1,00	0,00	0,00	0,00	0,00	0,00	0,03
Lithuania	0,21	0,06	0,32	0,22	0,00	0,49	0,99	0,00	0,00	0,00	0,00	0,00	0,07

Source: based on author.

Appendix 35. Weighted sum of PDA, 2018

Country	Gross domestic product, USD/capita	Unemployment rate, as % of labour force	Poverty rate, %	Household disposable income Gross adjusted, USD/capita	Municipal waste generated, Tonnes/1000 capita	Gross domestic expenditure on R&D, as % of GDP	Patents in environment-related technologies	Electricity consumption, GWh	Renewable energy, as % of primary energy supply	Air pollution exposure (PM2.5 (µg/m³))	CO ₂ emission per capita, Tonnes/capita	Number of passenger cars, Cars/1000 capita	Households with Internet access, %
Australia	0,00	0,00	0,00	0,01	0,00	0,01	0,00	0,02	0,00	0,04	0,00	0,00	0,00
Austria	0,00	0,00	0,01	0,01	0,00	0,05	0,00	0,06	0,08	0,01	0,01	0,00	0,00
Belgium	0,00	0,00	0,01	0,01	0,02	0,04	0,00	0,06	0,00	0,00	0,00	0,00	0,00
Canada	0,00	0,00	0,00	0,01	0,14	0,00	0,00	0,00	0,00	0,04	0,00	0,00	0,00
Czech Republic	0,00	0,01	0,03	0,00	0,04	0,00	0,00	0,06	0,00	0,00	0,00	0,00	0,00
Denmark	0,00	0,00	0,03	0,01	0,00	0,05	0,00	0,07	0,10	0,02	0,03	0,01	0,00
Finland	0,00	0,00	0,02	0,01	0,00	0,04	0,00	0,06	0,11	0,05	0,00	0,00	0,01
France	0,00	0,00	0,02	0,01	0,00	0,01	0,05	0,00	0,00	0,01	0,05	0,00	0,00
Germany	0,00	0,01	0,01	0,01	0,00	0,05	0,24	0,00	0,00	0,01	0,00	0,00	0,01
Greece	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,07	0,00	0,00	0,03	0,00	0,00
Hungary	0,00	0,01	0,02	0,00	0,03	0,00	0,00	0,07	0,00	0,00	0,04	0,03	0,00
Ireland	0,02	0,00	0,01	0,00	0,00	0,00	0,00	0,07	0,00	0,04	0,01	0,01	0,00
Italy	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,01	0,00	0,00	0,04	0,00	0,00
Japan	0,00	0,01	0,00	0,00	0,04	0,06	0,69	0,00	0,00	0,00	0,00	0,00	0,00
South Korea	0,00	0,01	0,01	0,00	0,03	0,12	0,16	0,00	0,00	0,00	0,00	0,03	0,01
Luxembourg	0,03	0,00	0,02	0,02	0,00	0,00	0,00	0,08	0,00	0,02	0,00	0,00	0,00
Mexico	0,00	0,01	0,00	0,00	0,04	0,00	0,00	0,00	0,00	0,00	0,06	0,05	0,00
Netherlands	0,00	0,01	0,02	0,01	0,00	0,01	0,00	0,05	0,00	0,01	0,00	0,00	0,01
Norway	0,01	0,01	0,02	0,01	0,00	0,01	0,00	0,05	0,21	0,04	0,00	0,00	0,01
Poland	0,00	0,01	0,01	0,00	0,04	0,00	0,00	0,04	0,00	0,00	0,00	0,00	0,00
Portugal	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,07	0,05	0,03	0,05	0,00	0,00
Slovakia	0,00	0,00	0,02	0,00	0,02	0,00	0,00	0,07	0,00	0,00	0,02	0,01	0,00
Spain	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,02	0,00	0,02	0,03	0,00	0,00
Sweden	0,00	0,00	0,01	0,01	0,01	0,06	0,00	0,04	0,14	0,05	0,05	0,00	0,01
Turkey	0,00	0,00	0,00	0,00	0,02	0,00	0,00	0,01	0,00	0,00	0,04	0,07	0,00

United Kingdom	0,00	0,01	0,00	0,00	0,00	0,00	0,02	0,00	0,00	0,02	0,04	0,00	0,01
United States	0,01	0,01	0,00	0,03	0,00	0,04	0,93	0,00	0,00	0,04	0,00	0,02	0,00
Chile	0,00	0,00	0,00	0,00	0,02	0,00	0,00	0,06	0,08	0,00	0,04	0,06	0,00
Estonia	0,00	0,00	0,00	0,00	0,02	0,00	0,00	0,08	0,01	0,05	0,00	0,00	0,00
Slovenia	0,00	0,00	0,01	0,00	0,00	0,00	0,00	0,08	0,00	0,00	0,01	0,00	0,00
Latvia	0,00	0,00	0,00	0,00	0,02	0,00	0,00	0,08	0,15	0,00	0,06	0,03	0,00
Lithuania	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,08	0,02	0,02	0,05	0,01	0,00

Source: based on author.

Appendix 36. Weighted sum of NDA, 2018

Country	Gross domestic product, USD/capita	Unemployment rate, as % of labour force	Poverty rate, %	Household disposable income Gross adjusted, USD/capita	Municipal waste generated, Tonnes/1000 capita	Gross domestic expenditure on R&D, as % of GDP	Patents in environment-related technologies	Electricity consumption, GWh	Renewable energy, as % of primary energy supply	Air pollution exposure (PM2.5 (µg/m³))	CO ₂ emission per capita, Tonnes/capita	Number of passenger cars, Cars/1000 capita	Households with Internet access, %
Australia	0,00	0,00	0,00	0,00	0,02	0,00	0,07	0,00	0,06	0,00	0,11	0,02	0,00
Austria	0,00	0,00	0,00	0,00	0,03	0,00	0,07	0,00	0,00	0,00	0,00	0,02	0,00
Belgium	0,00	0,00	0,00	0,00	0,00	0,00	0,08	0,00	0,06	0,00	0,01	0,01	0,00
Canada	0,00	0,00	0,00	0,00	0,00	0,01	0,04	0,07	0,00	0,00	0,10	0,04	0,00
Czech Republic	0,00	0,00	0,00	0,00	0,00	0,00	0,10	0,00	0,04	0,03	0,02	0,01	0,00
Denmark	0,00	0,00	0,00	0,00	0,09	0,00	0,08	0,00	0,00	0,00	0,00	0,00	0,00
Finland	0,00	0,00	0,00	0,00	0,02	0,00	0,07	0,00	0,00	0,00	0,00	0,01	0,00
France	0,00	0,01	0,00	0,00	0,02	0,00	0,00	0,05	0,04	0,00	0,00	0,01	0,00
Germany	0,00	0,00	0,00	0,00	0,04	0,00	0,00	0,07	0,02	0,00	0,01	0,02	0,00
Greece	0,01	0,04	0,01	0,01	0,01	0,03	0,10	0,00	0,03	0,01	0,00	0,01	0,01
Hungary	0,01	0,00	0,00	0,01	0,00	0,01	0,10	0,00	0,04	0,03	0,00	0,00	0,00
Ireland	0,00	0,00	0,00	0,00	0,03	0,03	0,09	0,00	0,04	0,00	0,00	0,00	0,00
Italy	0,00	0,01	0,01	0,00	0,01	0,02	0,03	0,00	0,00	0,02	0,00	0,04	0,00
Japan	0,00	0,00	0,01	0,00	0,00	0,00	0,00	0,17	0,07	0,00	0,01	0,01	0,00
South Korea	0,00	0,00	0,00	0,01	0,00	0,00	0,00	0,06	0,10	0,12	0,06	0,00	0,00
Luxembourg	0,00	0,00	0,00	0,00	0,04	0,03	0,10	0,00	0,06	0,00	0,10	0,05	0,00

Mexico	0,01	0,00	0,12	0,02	0,00	0,07	0,09	0,00	0,05	0,06	0,00	0,00	0,04
Netherlands	0,00	0,00	0,00	0,00	0,01	0,00	0,03	0,00	0,07	0,00	0,01	0,01	0,00
Norway	0,00	0,00	0,00	0,00	0,08	0,00	0,09	0,00	0,00	0,00	0,01	0,01	0,00
Poland	0,01	0,00	0,00	0,01	0,00	0,03	0,09	0,00	0,05	0,08	0,00	0,03	0,00
Portugal	0,01	0,00	0,00	0,01	0,01	0,02	0,10	0,00	0,00	0,00	0,00	0,00	0,01
Slovakia	0,01	0,00	0,00	0,01	0,00	0,04	0,10	0,00	0,05	0,05	0,00	0,00	0,01
Spain	0,00	0,03	0,01	0,00	0,00	0,03	0,07	0,00	0,02	0,00	0,00	0,01	0,00
Sweden	0,00	0,00	0,00	0,00	0,00	0,00	0,04	0,00	0,00	0,00	0,00	0,00	0,00
Turkey	0,01	0,02	0,02	0,01	0,00	0,04	0,08	0,00	0,02	0,12	0,00	0,00	0,00
United Kingdom	0,00	0,00	0,00	0,00	0,00	0,01	0,00	0,00	0,04	0,00	0,00	0,01	0,00
United States	0,00	0,00	0,02	0,00	0,08	0,00	0,00	0,95	0,06	0,00	0,10	0,00	0,02
Chile	0,01	0,00	0,02	0,02	0,00	0,06	0,10	0,00	0,00	0,09	0,00	0,00	0,02
Estonia	0,00	0,00	0,01	0,01	0,00	0,02	0,10	0,00	0,00	0,00	0,11	0,02	0,00
Slovenia	0,00	0,00	0,00	0,01	0,00	0,00	0,10	0,00	0,00	0,03	0,00	0,02	0,00
Latvia	0,01	0,00	0,02	0,01	0,00	0,05	0,10	0,00	0,00	0,00	0,00	0,00	0,01
Lithuania	0,00	0,00	0,01	0,01	0,00	0,04	0,10	0,00	0,00	0,00	0,00	0,00	0,01

Source: based on author.

Appendix 37. Weighted sum of PDA, 2019

Country	Gross domestic product, USD/capita	Unemployment rate, as % of labour force	Poverty rate, %	Household disposable income Gross adjusted, USD/capita	Municipal waste generated, Tonnes/1000 capita	Gross domestic expenditure on R&D, as % of GDP	Patents in environment-related technologies	Electricity consumption, GWh	Renewable energy, as % of primary energy supply	Air pollution exposure (PM2.5 (µg/m³))	CO ₂ emission per capita, Tonnes/capita	Number of passenger cars, Cars/1000 capita	Households with Internet access, %
Australia	0,00	0,00	0,00	0,01	0,00	0,01	0,00	0,02	0,00	0,04	0,00	0,00	0,00
Austria	0,00	0,00	0,01	0,01	0,00	0,05	0,00	0,06	0,08	0,01	0,00	0,00	0,00
Belgium	0,00	0,00	0,01	0,01	0,02	0,03	0,00	0,06	0,00	0,00	0,00	0,00	0,00
Canada	0,00	0,00	0,00	0,01	0,06	0,00	0,00	0,00	0,00	0,04	0,00	0,00	0,00
Czech Republic	0,00	0,01	0,03	0,00	0,04	0,00	0,00	0,06	0,00	0,00	0,00	0,00	0,00
Denmark	0,00	0,00	0,03	0,00	0,00	0,05	0,00	0,07	0,12	0,02	0,04	0,01	0,01
Finland	0,00	0,00	0,02	0,01	0,00	0,04	0,00	0,06	0,10	0,05	0,01	0,00	0,00

France	0,00	0,00	0,02	0,01	0,00	0,02	0,05	0,00	0,00	0,01	0,05	0,00	0,00
Germany	0,00	0,01	0,01	0,01	0,00	0,05	0,25	0,00	0,00	0,01	0,00	0,00	0,00
Greece	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,07	0,00	0,00	0,03	0,00	0,00
Hungary	0,00	0,01	0,02	0,00	0,02	0,00	0,00	0,07	0,00	0,00	0,04	0,03	0,00
Ireland	0,02	0,00	0,01	0,00	0,00	0,00	0,00	0,07	0,00	0,04	0,01	0,01	0,00
Italy	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,01	0,00	0,00	0,03	0,00	0,00
Japan	0,00	0,01	0,00	0,00	0,04	0,06	0,70	0,00	0,00	0,00	0,00	0,00	0,00
South Korea	0,00	0,01	0,00	0,00	0,03	0,11	0,17	0,00	0,00	0,00	0,00	0,03	0,01
Luxembourg	0,03	0,00	0,02	0,02	0,00	0,00	0,00	0,08	0,00	0,02	0,00	0,00	0,00
Mexico	0,00	0,01	0,00	0,00	0,04	0,00	0,00	0,00	0,00	0,00	0,06	0,05	0,00
Netherlands	0,00	0,01	0,02	0,01	0,00	0,01	0,00	0,05	0,00	0,01	0,00	0,00	0,01
Norway	0,01	0,01	0,02	0,01	0,00	0,01	0,00	0,05	0,23	0,04	0,00	0,00	0,01
Poland	0,00	0,01	0,01	0,00	0,05	0,00	0,00	0,04	0,00	0,00	0,00	0,00	0,00
Portugal	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,07	0,03	0,03	0,05	0,00	0,00
Slovakia	0,00	0,00	0,02	0,00	0,03	0,00	0,00	0,07	0,00	0,00	0,02	0,01	0,00
Spain	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,02	0,00	0,02	0,04	0,00	0,00
Sweden	0,00	0,00	0,01	0,01	0,01	0,06	0,00	0,04	0,14	0,05	0,05	0,00	0,01
Turkey	0,00	0,00	0,00	0,00	0,02	0,00	0,00	0,01	0,00	0,00	0,04	0,07	0,00
United Kingdom	0,00	0,01	0,00	0,00	0,00	0,00	0,02	0,00	0,00	0,02	0,04	0,00	0,01
United States	0,01	0,01	0,00	0,03	0,00	0,04	0,92	0,00	0,00	0,04	0,00	0,02	0,00
Chile	0,00	0,00	0,00	0,00	0,02	0,00	0,00	0,06	0,04	0,00	0,04	0,06	0,00
Estonia	0,00	0,01	0,00	0,00	0,03	0,00	0,00	0,08	0,03	0,05	0,00	0,00	0,00
Slovenia	0,00	0,01	0,01	0,00	0,00	0,01	0,00	0,08	0,00	0,00	0,01	0,00	0,00
Latvia	0,00	0,00	0,00	0,00	0,02	0,00	0,00	0,08	0,15	0,00	0,05	0,03	0,00
Lithuania	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,08	0,02	0,02	0,05	0,01	0,00

Source: based on author.

Appendix 38. Weighted sum of NDA, 2019

Country	Gross domestic product, USD/capita	Unemployment rate, as % of labour force	Poverty rate, %	Household disposable income Gross adjusted, USD/capita	Municipal waste generated, Tonnes/1000 capita	Gross domestic expenditure on R&D, as % of GDP	Patents in environment-related technologies	Electricity consumption, GWh	Renewable energy, as % of primary energy supply	Air pollution exposure (PM2.5 (µg/m³))	CO ₂ emission per capita, Tonnes/capita	Number of passenger cars, Cars/1000 capita	Households with Internet access, %
Australia	0,00	0,00	0,00	0,00	0,02	0,00	0,06	0,00	0,07	0,00	0,12	0,02	0,01
Austria	0,00	0,00	0,00	0,00	0,03	0,00	0,07	0,00	0,00	0,00	0,00	0,02	0,00
Belgium	0,00	0,00	0,00	0,00	0,00	0,00	0,08	0,00	0,06	0,00	0,01	0,01	0,00
Canada	0,00	0,00	0,00	0,00	0,00	0,01	0,04	0,07	0,01	0,00	0,10	0,04	0,00
Czech Republic	0,00	0,00	0,00	0,00	0,00	0,00	0,10	0,00	0,04	0,03	0,02	0,01	0,00
Denmark	0,00	0,00	0,00	0,00	0,09	0,00	0,08	0,00	0,00	0,00	0,00	0,00	0,00
Finland	0,00	0,00	0,00	0,00	0,01	0,00	0,07	0,00	0,00	0,00	0,00	0,01	0,00
France	0,00	0,01	0,00	0,00	0,02	0,00	0,00	0,05	0,04	0,00	0,00	0,01	0,00
Germany	0,00	0,00	0,00	0,00	0,05	0,00	0,00	0,07	0,02	0,00	0,00	0,02	0,00
Greece	0,01	0,04	0,01	0,01	0,01	0,04	0,10	0,00	0,03	0,01	0,00	0,01	0,01
Hungary	0,01	0,00	0,00	0,01	0,00	0,02	0,10	0,00	0,05	0,03	0,00	0,00	0,00
Ireland	0,00	0,00	0,00	0,00	0,03	0,03	0,09	0,00	0,04	0,00	0,00	0,00	0,00
Italy	0,00	0,01	0,01	0,00	0,01	0,02	0,03	0,00	0,00	0,02	0,00	0,04	0,00
Japan	0,00	0,00	0,01	0,00	0,00	0,00	0,00	0,16	0,07	0,00	0,01	0,01	0,00
South Korea	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,06	0,10	0,12	0,06	0,00	0,00
Luxembourg	0,00	0,00	0,00	0,00	0,03	0,02	0,10	0,00	0,06	0,00	0,11	0,04	0,00
Mexico	0,01	0,00	0,13	0,02	0,00	0,06	0,09	0,00	0,06	0,06	0,00	0,00	0,04
Netherlands	0,00	0,00	0,00	0,00	0,01	0,00	0,03	0,00	0,07	0,00	0,01	0,01	0,00
Norway	0,00	0,00	0,00	0,00	0,04	0,00	0,09	0,00	0,00	0,00	0,01	0,01	0,00
Poland	0,01	0,00	0,00	0,01	0,00	0,04	0,09	0,00	0,05	0,08	0,00	0,03	0,00
Portugal	0,00	0,00	0,00	0,00	0,00	0,02	0,10	0,00	0,00	0,00	0,00	0,00	0,01
Slovakia	0,01	0,00	0,00	0,01	0,00	0,04	0,10	0,00	0,05	0,05	0,00	0,00	0,01
Spain	0,00	0,03	0,01	0,00	0,00	0,03	0,07	0,00	0,02	0,00	0,00	0,01	0,00
Sweden	0,00	0,00	0,00	0,00	0,00	0,00	0,04	0,00	0,00	0,00	0,00	0,00	0,00
Turkey	0,01	0,03	0,02	0,01	0,00	0,04	0,08	0,00	0,01	0,12	0,00	0,00	0,00
United Kingdom	0,00	0,00	0,00	0,00	0,00	0,01	0,00	0,00	0,03	0,00	0,00	0,01	0,00

United States	0,00	0,00	0,02	0,00	0,08	0,00	0,00	0,95	0,06	0,00	0,10	0,00	0,01
Chile	0,01	0,00	0,02	0,02	0,00	0,06	0,10	0,00	0,00	0,09	0,00	0,00	0,02
Estonia	0,00	0,00	0,01	0,01	0,00	0,02	0,10	0,00	0,00	0,00	0,08	0,02	0,00
Slovenia	0,00	0,00	0,00	0,01	0,00	0,00	0,10	0,00	0,01	0,03	0,00	0,02	0,00
Latvia	0,01	0,00	0,02	0,02	0,00	0,05	0,10	0,00	0,00	0,00	0,00	0,00	0,00
Lithuania	0,00	0,00	0,02	0,01	0,00	0,04	0,10	0,00	0,00	0,00	0,00	0,00	0,01

Source: based on author.

Appendix 39. Normalized values of SP_i and SN_i and final results (AS_i), 2018

Country	SP _i	SN _i	NSP _i	NSN _i	AS _i	RANK
Australia	0,09	0,29	0,09	0,76	0,42	30
Austria	0,24	0,13	0,23	0,90	0,56	8
Belgium	0,14	0,15	0,13	0,87	0,50	15
Canada	0,19	0,27	0,18	0,78	0,48	21
Czech Republic	0,14	0,21	0,13	0,83	0,48	22
Denmark	0,34	0,16	0,31	0,87	0,59	5
Finland	0,30	0,11	0,28	0,91	0,59	3
France	0,14	0,13	0,13	0,89	0,51	12
Germany	0,34	0,16	0,32	0,87	0,59	4
Greece	0,10	0,26	0,09	0,78	0,44	27
Hungary	0,19	0,20	0,18	0,83	0,51	14
Ireland	0,16	0,19	0,15	0,84	0,49	19
Italy	0,05	0,15	0,05	0,88	0,46	24
Japan	0,80	0,27	0,75	0,78	0,76	1
South Korea	0,37	0,34	0,35	0,72	0,53	9
Luxembourg	0,18	0,37	0,17	0,69	0,43	28
Mexico	0,17	0,46	0,16	0,62	0,39	32
Netherlands	0,12	0,14	0,11	0,89	0,50	17
Norway	0,36	0,19	0,33	0,85	0,59	6
Poland	0,10	0,31	0,09	0,75	0,42	31
Portugal	0,20	0,15	0,18	0,88	0,53	10
Slovakia	0,14	0,26	0,13	0,78	0,46	26
Spain	0,07	0,17	0,07	0,86	0,47	23
Sweden	0,38	0,04	0,35	0,97	0,66	2
Turkey	0,14	0,33	0,13	0,73	0,43	29
United Kingdom	0,10	0,06	0,10	0,95	0,52	11
United States	1,07	1,22	1,00	0,00	0,50	16
Chile	0,27	0,31	0,25	0,75	0,50	18
Estonia	0,16	0,28	0,15	0,77	0,46	25
Slovenia	0,11	0,17	0,10	0,86	0,48	20
Latvia	0,33	0,20	0,31	0,84	0,58	7
Lithuania	0,17	0,17	0,16	0,86	0,51	13

Source: based on author.

Appendix 40. Normalized values of SP_i and SN_i and results (AS_i), 2019

Country	SP_i	SN_i	NSP_i	NSN_i	AS_i	RANK
Australia	0,09	0,31	0,08	0,75	0,42	31
Austria	0,23	0,12	0,22	0,90	0,56	8
Belgium	0,13	0,16	0,12	0,87	0,50	18
Canada	0,11	0,27	0,11	0,78	0,44	26
Czech Republic	0,14	0,21	0,13	0,83	0,48	21
Denmark	0,35	0,17	0,34	0,86	0,60	5
Finland	0,31	0,10	0,29	0,92	0,61	4
France	0,15	0,13	0,14	0,89	0,52	12
Germany	0,34	0,16	0,32	0,87	0,60	6
Greece	0,10	0,27	0,09	0,78	0,44	28
Hungary	0,19	0,21	0,18	0,82	0,50	15
Ireland	0,16	0,19	0,15	0,85	0,50	14
Italy	0,05	0,15	0,05	0,88	0,46	25
Japan	0,81	0,27	0,77	0,78	0,77	1
South Korea	0,35	0,34	0,34	0,72	0,53	9
Luxembourg	0,17	0,37	0,16	0,69	0,43	29
Mexico	0,16	0,47	0,16	0,62	0,39	32
Netherlands	0,12	0,14	0,11	0,89	0,50	17
Norway	0,38	0,15	0,36	0,88	0,62	3
Poland	0,11	0,31	0,10	0,74	0,42	30
Portugal	0,18	0,14	0,17	0,88	0,53	10
Slovakia	0,16	0,25	0,15	0,79	0,47	23
Spain	0,08	0,17	0,07	0,86	0,47	24
Sweden	0,39	0,04	0,37	0,96	0,67	2
Turkey	0,14	0,31	0,13	0,74	0,44	27
United Kingdom	0,10	0,05	0,10	0,96	0,53	11
United States	1,06	1,22	1,00	0,00	0,50	16
Chile	0,23	0,31	0,22	0,74	0,48	22
Estonia	0,19	0,25	0,18	0,80	0,49	19
Slovenia	0,12	0,17	0,11	0,86	0,49	20
Latvia	0,32	0,20	0,31	0,84	0,57	7
Lithuania	0,17	0,18	0,16	0,86	0,51	13

Source: based on author.

Appendix 41. Collected data and calculated average solution (Av), 2018

Country	Gross domestic product, USD/capita	Unemployment rate, as % of labour force	Poverty rate, %	Household disposable income Gross adjusted, USD/capita	Municipal waste generated, Tonnes/1000 capita	Gross domestic expenditure on R&D, as % of GDP	Patents in environment-related technologies	Electricity consumption, GWh	Renewable energy, as % of primary energy supply	Air pollution exposure (PM2.5 (µg/m³))	CO ₂ emission per capita, Tonnes/capita	Number of passenger cars, Cars/1000 capita	Households with Internet access, %
Asia	37439,26	5,76	14,37	25262,96	375,20	2,99	19101,21	650,89	7,03	22,84	9,19	320,65	91,52
Australia	53700,68	5,29	12,40	40236,66	550,82	2,12	1859,21	261,00	7,08	6,74	16,79	558,76	83,02
Europe	48816,33	6,57	10,32	30629,17	499,24	1,85	2193,98	137,25	18,87	12,00	7,76	486,89	87,86
North America	44562,31	4,35	24,08	35335,28	349,42	1,57	19397,41	1815,14	11,15	11,74	11,96	402,02	71,26
South America	24710,82	7,38	16,47	17291,21	391,90	0,37	165,13	82,31	28,77	23,64	5,03	181,32	73,30
Avj	41845,88	5,87	15,53	29751,06	433,32	1,78	8543,39	589,32	14,58	15,39	10,15	389,93	81,39

Source: based on author.

Appendix 42. Collected data and calculated average solution (Av), 2019

Country	Gross domestic product, USD/capita	Unemployment rate, as % of labour force	Poverty rate, %	Household disposable income Gross adjusted, USD/capita	Municipal waste generated, Tonnes/1000 capita	Gross domestic expenditure on R&D, as % of GDP	Patents in environment-related technologies	Electricity consumption, GWh	Renewable energy, as % of primary energy supply	Air pollution exposure (PM2.5 (µg/m³))	CO ₂ emission per capita, Tonnes/capita	Number of passenger cars, Cars/1000 capita	Households with Internet access, %
Asia	38247,28	6,61	15,17	25716,26	367,66	2,86	19297,85	628,49	8,19	22,65	8,93	323,74	93,13
Australia	55961,86	5,16	12,43	38653,45	543,05	2,07	1871,35	264,03	7,10	6,75	17,27	556,19	83,84
Europe	50913,98	6,05	10,38	29557,35	479,76	1,81	2198,41	135,38	19,94	11,89	7,44	488,21	89,73
North America	45729,51	4,28	24,74	34136,29	435,99	1,61	19113,37	1783,75	11,05	11,62	11,62	400,78	74,45
South America	25040,97	7,23	16,47	16472,50	387,29	0,37	168,99	81,20	24,27	23,68	4,90	184,22	75,64
Avj	43178,72	5,87	15,84	28907,17	442,75	1,74	8529,99	578,57	14,11	15,32	10,03	390,63	83,36

Source: based on author.

Appendix 43. Positive distance from Average (PDA), 2018

Country	Gross domestic product, USD/capita	Unemployment rate, as % of labour force	Poverty rate, %	Household disposable income Gross adjusted, USD/capita	Municipal waste generated, Tonnes/1000 capita	Gross domestic expenditure on R&D, as % of GDP	Patents in environment-related technologies	Electricity consumption, GWh	Renewable energy, as % of primary energy supply	Air pollution exposure (PM2.5 (µg/m³))	CO ₂ emission per capita, Tonnes/capita	Number of passenger cars, Cars/1000 capita	Households with Internet access, %
Asia	0,02	0,02	0,06	0,04	0,14	0,08	0,10	0,08	0,11	0,09	0,11	0,10	0,06
Australia	0,00	0,02	0,07	0,00	0,13	0,68	1,24	0,00	0,00	0,00	0,09	0,18	0,12
Europe	0,28	0,10	0,20	0,35	0,00	0,19	0,00	0,56	0,00	0,56	0,00	0,00	0,02
North America	0,17	0,00	0,34	0,03	0,00	0,04	0,00	0,77	0,29	0,22	0,24	0,00	0,08
South America	0,06	0,26	0,00	0,19	0,19	0,00	1,27	0,00	0,00	0,24	0,00	0,00	0,00

Source: based on author.

Appendix 44. Positive distance from Average (PDA), 2019

Country	Gross domestic product, USD/capita	Unemployment rate, as % of labour force	Poverty rate, %	Household disposable income Gross adjusted, USD/capita	Municipal waste generated, Tonnes/1000 capita	Gross domestic expenditure on R&D, as % of GDP	Patents in environment-related technologies	Electricity consumption, GWh	Renewable energy, as % of primary energy supply	Air pollution exposure (PM2.5 (µg/m³))	CO ₂ emission per capita, Tonnes/capita	Number of passenger cars, Cars/1000 capita	Households with Internet access, %
Asia	0,02	0,02	0,06	0,04	0,14	0,08	0,10	0,08	0,11	0,09	0,11	0,10	0,06
Australia	0,00	0,00	0,04	0,00	0,17	0,64	1,26	0,00	0,00	0,00	0,11	0,17	0,12
Europe	0,30	0,12	0,22	0,34	0,00	0,19	0,00	0,54	0,00	0,56	0,00	0,00	0,01
North America	0,18	0,00	0,34	0,02	0,00	0,04	0,00	0,77	0,41	0,22	0,26	0,00	0,08
South America	0,06	0,27	0,00	0,18	0,02	0,00	1,24	0,00	0,00	0,24	0,00	0,00	0,00

Source: based on author.

Appendix 45. Negative distance from Average (NDA), 2018

Country	Gross domestic product, USD/capita	Unemployment rate, as % of labour force	Poverty rate, %	Household disposable income Gross adjusted, USD/capita	Municipal waste generated, Tonnes/1000 capita	Gross domestic expenditure on R&D, as % of GDP	Patents in environment-related technologies	Electricity consumption, GWh	Renewable energy, as % of primary energy supply	Air pollution exposure (PM2.5 (µg/m³))	CO ₂ emission per capita, Tonnes/capita	Number of passenger cars, Cars/1000 capita	Households with Internet access, %
Asia	0,02	0,02	0,06	0,04	0,14	0,08	0,10	0,08	0,11	0,09	0,11	0,10	0,06
Australia	0,11	0,00	0,00	0,15	0,00	0,00	0,00	0,10	0,52	0,48	0,00	0,00	0,00
Europe	0,00	0,00	0,00	0,00	0,27	0,00	0,78	0,00	0,51	0,00	0,66	0,43	0,00
North America	0,00	0,12	0,00	0,00	0,15	0,00	0,74	0,00	0,00	0,00	0,00	0,25	0,00
South America	0,00	0,00	0,55	0,00	0,00	0,12	0,00	2,08	0,24	0,00	0,18	0,03	0,12

Source: based on author.

Appendix 46. Negative distance from Average (NDA), 2019

Country	Gross domestic product, USD/capita	Unemployment rate, as % of labour force	Poverty rate, %	Household disposable income Gross adjusted, USD/capita	Municipal waste generated, Tonnes/1000 capita	Gross domestic expenditure on R&D, as % of GDP	Patents in environment-related technologies	Electricity consumption, GWh	Renewable energy, as % of primary energy supply	Air pollution exposure (PM2.5 (µg/m³))	CO ₂ emission per capita, Tonnes/capita	Number of passenger cars, Cars/1000 capita	Households with Internet access, %
Asia	0,02	0,02	0,06	0,04	0,14	0,08	0,10	0,08	0,11	0,09	0,11	0,10	0,06
Australia	0,11	0,13	0,00	0,11	0,00	0,00	0,00	0,09	0,42	0,48	0,00	0,00	0,00
Europe	0,00	0,00	0,00	0,00	0,23	0,00	0,78	0,00	0,50	0,00	0,72	0,42	0,00
North America	0,00	0,03	0,00	0,00	0,08	0,00	0,74	0,00	0,00	0,00	0,00	0,25	0,00
South America	0,00	0,00	0,56	0,00	0,00	0,08	0,00	2,08	0,22	0,00	0,16	0,03	0,11

Source: based on author.

Appendix 47. Weighted sum of PDA, 2018

Country	Gross domestic product, USD/capita	Unemployment rate, as % of labour force	Poverty rate, %	Household disposable income Gross adjusted, USD/capita	Municipal waste generated, Tonnes/1000 capita	Gross domestic expenditure on R&D, as % of GDP	Patents in environment-related technologies	Electricity consumption, GWh	Renewable energy, as % of primary energy supply	Air pollution exposure (PM2.5 (µg/m³))	CO ₂ emission per capita, Tonnes/capita	Number of passenger cars, Cars/1000 capita	Households with Internet access, %
Asia	0,02	0,02	0,06	0,04	0,14	0,08	0,10	0,08	0,11	0,09	0,11	0,10	0,06
Australia	0,00	0,00	0,00	0,00	0,02	0,06	0,12	0,00	0,00	0,00	0,01	0,02	0,01
Europe	0,01	0,00	0,01	0,01	0,00	0,02	0,00	0,05	0,00	0,05	0,00	0,00	0,00
North America	0,00	0,00	0,02	0,00	0,00	0,00	0,00	0,06	0,03	0,02	0,03	0,00	0,00
South America	0,00	0,00	0,00	0,01	0,03	0,00	0,13	0,00	0,00	0,02	0,00	0,00	0,00

Source: based on author.

Appendix 48. Weighted sum of PDA, 2019

Country	Gross domestic product, USD/capita	Unemployment rate, as % of labour force	Poverty rate, %	Household disposable income Gross adjusted, USD/capita	Municipal waste generated, Tonnes/1000 capita	Gross domestic expenditure on R&D, as % of GDP	Patents in environment-related technologies	Electricity consumption, GWh	Renewable energy, as % of primary energy supply	Air pollution exposure (PM2.5 (µg/m³))	CO ₂ emission per capita, Tonnes/capita	Number of passenger cars, Cars/1000 capita	Households with Internet access, %
Asia	0,00	0,00	0,00	0,00	0,02	0,05	0,13	0,00	0,00	0,00	0,01	0,02	0,01
Australia	0,01	0,00	0,01	0,01	0,00	0,02	0,00	0,04	0,00	0,05	0,00	0,00	0,00
Europe	0,00	0,00	0,02	0,00	0,00	0,00	0,00	0,06	0,05	0,02	0,03	0,00	0,00
North America	0,00	0,00	0,00	0,01	0,00	0,00	0,12	0,00	0,00	0,02	0,00	0,00	0,00
South America	0,00	0,00	0,00	0,00	0,02	0,00	0,00	0,07	0,08	0,00	0,06	0,05	0,00

Source: based on author.

Appendix 49. Weighted sum of NDA, 2018

Country	Gross domestic product, USD/capita	Unemployment rate, as % of labour force	Poverty rate, %	Household disposable income Gross adjusted, USD/capita	Municipal waste generated, Tonnes/1000 capita	Gross domestic expenditure on R&D, as % of GDP	Patents in environment-related technologies	Electricity consumption, GWh	Renewable energy, as % of primary energy supply	Air pollution exposure (PM2.5 (µg/m³))	CO ₂ emission per capita, Tonnes/capita	Number of passenger cars, Cars/1000 capita	Households with Internet access, %
Asia	0,02	0,02	0,06	0,04	0,14	0,08	0,10	0,08	0,11	0,09	0,11	0,10	0,06
Australia	0,00	0,00	0,00	0,01	0,00	0,00	0,00	0,01	0,06	0,06	0,00	0,00	0,00
Europe	0,00	0,00	0,00	0,00	0,04	0,00	0,08	0,00	0,06	0,00	0,07	0,05	0,00
North America	0,00	0,00	0,00	0,00	0,02	0,00	0,07	0,00	0,00	0,00	0,00	0,03	0,00
South America	0,00	0,00	0,03	0,00	0,00	0,01	0,00	0,17	0,03	0,00	0,02	0,00	0,01

Source: based on author.

Appendix 50. Weighted sum of NDA, 2019

Country	Gross domestic product, USD/capita	Unemployment rate, as % of labour force	Poverty rate, %	Household disposable income Gross adjusted, USD/capita	Municipal waste generated, Tonnes/1000 capita	Gross domestic expenditure on R&D, as % of GDP	Patents in environment-related technologies	Electricity consumption, GWh	Renewable energy, as % of primary energy supply	Air pollution exposure (PM2.5 (µg/m³))	CO ₂ emission per capita, Tonnes/capita	Number of passenger cars, Cars/1000 capita	Households with Internet access, %
Asia	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,01	0,05	0,05	0,00	0,00	0,00
Australia	0,00	0,00	0,00	0,00	0,03	0,00	0,08	0,00	0,06	0,00	0,08	0,05	0,00
Europe	0,00	0,00	0,00	0,00	0,01	0,00	0,07	0,00	0,00	0,00	0,00	0,03	0,00
North America	0,00	0,00	0,03	0,00	0,00	0,01	0,00	0,17	0,02	0,00	0,02	0,00	0,01
South America	0,01	0,00	0,00	0,02	0,00	0,06	0,10	0,00	0,00	0,06	0,00	0,00	0,01

Source: based on author.

Appendix 51. Normalized values of SP_i and SN_i and final results (AS_i), 2018

Country	SP_i	SN_i	NSP_i	NSN_i	AS_i	RANK
Asia	0,24	0,13	0,78	0,56	0,67	1
Australia	0,15	0,30	0,48	0,00	0,24	5
Europe	0,17	0,13	0,57	0,58	0,58	2
North America	0,19	0,28	0,62	0,07	0,34	4
South America	0,30	0,27	1,00	0,11	0,55	3

Source: based on author.

Appendix 52. Normalized values of SP_i and SN_i and final results (AS_i), 2019

Country	SP_i	SN_i	NSP_i	NSN_i	AS_i	RANK
Asia	0,24	0,12	0,86	0,60	0,73	1
Australia	0,14	0,30	0,51	0,00	0,26	5
Europe	0,19	0,11	0,68	0,61	0,65	3
North America	0,16	0,27	0,57	0,09	0,33	2
South America	0,28	0,27	1,00	0,10	0,55	4

Source: based on author.

Appendix 53. Test of normality

Parameter	Kolmogorov-Smirnov ^a		
	Statistic	df	Sig.
LN_GDP	0,066	127	,200*
LN_Unemployment	0,074	127	0,088
LN_Poverty	0,106	127	0,001
LN_Dispos_income	0,108	127	0,001
LN_Waste	0,211	127	0,000
LN_RD	0,078	127	0,055
LN_Patents	0,067	127	,200*
LN_Electricity	0,085	127	0,026
LN_Renew_energy	0,073	127	0,093
LN_Air_quality	0,069	127	,200*
LN_CO ₂	0,115	127	0,000
LN_No_cars	0,203	127	0,000
LN_Internet	0,111	127	0,001

Source: based on author according the SPSS calculations.

Appendix 54. Spearmans's corelation

		LN_ SDI	LN_ GDP	LN_Unem ployment	LN_ Poverty	LN_Displ income	LN_ Waste	LN_ RD	LN_ Patents	LN_ Electricity	LN_Renew_ energy	LN_Air_ quality	LN_ CO ₂	LN_No_ cars	LN_ Internet
LN_SDI	Correlation Coefficient	1,000	,601**	-,269**	-,689**	,517**	-0,064	,680**	,305**	-0,001	,268**	-,421**	,191*	,319**	,713**
	Sig. (2- tailed)		0,000	0,002	0,000	0,000	0,476	0,000	0,000	0,990	0,002	0,000	0,031	0,000	0,000
	N	128	128	128	128	128	127	128	128	128	128	128	128	128	128
LN_GDP	Correlation Coefficient	,601**	1,000	-,269**	-,434**	,907**	0,027	,652**	,485**	0,126	-0,080	-,616**	,518**	,433**	,648**
	Sig. (2- tailed)	0,000		0,002	0,000	0,000	0,765	0,000	0,000	0,156	0,368	0,000	0,000	0,000	0,000
	N	128	128	128	128	128	127	128	128	128	128	128	128	128	128
LN_Unempl oyment	Correlation Coefficient	-,269**	-,269**	1,000	0,117	-,216*	0,135	-,371**	-,260**	-,271**	,369**	-0,095	-,405**	-0,114	-,362**
	Sig. (2- tailed)	0,002	0,002		0,190	0,014	0,131	0,000	0,003	0,002	0,000	0,287	0,000	0,199	0,000
	N	128	128	128	128	128	127	128	128	128	128	128	128	128	128
LN_Poverty	Correlation Coefficient	-,689**	-,434**	0,117	1,000	-,331**	0,014	-,372**	-0,016	,266**	-0,087	,188*	-0,153	-,266**	-,462**
	Sig. (2- tailed)	0,000	0,000	0,190		0,000	0,876	0,000	0,854	0,002	0,330	0,033	0,084	0,002	0,000
	N	128	128	128	128	128	127	128	128	128	128	128	128	128	128
LN_Displ income	Correlation Coefficient	,517**	,907**	-,216*	-,331**	1,000	0,117	,688**	,589**	,306**	-0,102	-,608**	,545**	,543**	,520**
	Sig. (2- tailed)	0,000	0,000	0,014	0,000		0,191	0,000	0,000	0,000	0,250	0,000	0,000	0,000	0,000
	N	128	128	128	128	128	127	128	128	128	128	128	128	128	128
LN_ Waste	Correlation Coefficient	-0,064	0,027	0,135	0,014	0,117	1,000	0,137	,268**	,192*	-0,073	-0,030	-0,028	-0,076	-0,095
	Sig. (2- tailed)	0,476	0,765	0,131	0,876	0,191		0,125	0,002	0,030	0,412	0,738	0,759	0,394	0,289
	N	127	127	127	127	127	127	127	127	127	127	127	127	127	127
LN_RD	Correlation Coefficient	,680**	,652**	-,371**	-,372**	,688**	0,137	1,000	,705**	,387**	-0,085	-,334**	,428**	,285**	,626**
	Sig. (2- tailed)	0,000	0,000	0,000	0,000	0,000	0,125		0,000	0,000	0,339	0,000	0,000	0,001	0,000

	N	128	128	128	128	128	127	128	128	128	128	128	128	128	128
LN_Patents	Correlation Coefficient	,305**	,485**	-,260**	-0,016	,589**	,268**	,705**	1,000	,852**	-,302**	-0,171	,270**	0,168	,412**
	Sig. (2-tailed)	0,000	0,000	0,003	0,854	0,000	0,002	0,000		0,000	0,001	0,054	0,002	0,058	0,000
	N	128	128	128	128	128	127	128	128	128	128	128	128	128	128
LN_Renew_energy	Correlation Coefficient	-0,001	0,126	-,271**	,266**	,306**	,192*	,387**	,852**	1,000	-,339**	0,057	,180*	0,067	0,110
	Sig. (2-tailed)	0,990	0,156	0,002	0,002	0,000	0,030	0,000	0,000		0,000	0,520	0,042	0,454	0,217
	N	128	128	128	128	128	127	128	128	128	128	128	128	128	128
LN_Air quality	Correlation Coefficient	,268**	-0,080	,369**	-0,087	-0,102	-0,073	-0,085	-,302**	-,339**	1,000	-,321**	-,460**	-0,060	-0,036
	Sig. (2-tailed)	0,002	0,368	0,000	0,330	0,250	0,412	0,339	0,001	0,000		0,000	0,000	0,502	0,686
	N	128	128	128	128	128	127	128	128	128	128	128	128	128	128
LN_CO ₂	Correlation Coefficient	-,421**	-,616**	-0,095	,188*	-,608**	-0,030	-,334**	-0,171	0,057	-,321**	1,000	-,251**	-,300**	-,310**
	Sig. (2-tailed)	0,000	0,000	0,287	0,033	0,000	0,738	0,000	0,054	0,520	0,000		0,004	0,001	0,000
	N	128	128	128	128	128	127	128	128	128	128	128	128	128	128
LN_No_cars	Correlation Coefficient	,191*	,518**	-,405**	-0,153	,545**	-0,028	,428**	,270**	,180*	-,460**	-,251**	1,000	,550**	,367**
	Sig. (2-tailed)	0,031	0,000	0,000	0,084	0,000	0,759	0,000	0,002	0,042	0,000	0,004		0,000	0,000
	N	128	128	128	128	128	127	128	128	128	128	128	128	128	128
LN_Internet	Correlation Coefficient	,319**	,433**	-0,114	-,266**	,543**	-0,076	,285**	0,168	0,067	-0,060	-,300**	,550**	1,000	,299**
	Sig. (2-tailed)	0,000	0,000	0,199	0,002	0,000	0,394	0,001	0,058	0,454	0,502	0,001	0,000		0,001
	N	128	128	128	128	128	127	128	128	128	128	128	128	128	128

Source: based on author according the SPSS calculations.

Appendix 55. Estimates of Fixed Effects regression

Parameter	Estimate	Std. Error	df	t	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Intercept	4,043275	0,221858	89,296	18,225	0,000	3,602468	4,484081
LN_GDP	0,017721	0,017221	69,208	1,029	0,307	-0,016633	0,052074
LN_Unempl.	-0,031385	0,005005	82,227	-6,271	0,000	-0,041341	-0,021428
LN_Poverty	-0,040712	0,008535	98,781	-4,770	0,000	-0,057649	-0,023775
LN_Dispos.income	-0,043786	0,025955	60,471	-1,687	0,097	-0,095695	0,008124
LN_RD	0,028657	0,007705	80,428	3,719	0,000	0,013324	0,043990
LN_Patents	0,002157	0,002299	71,412	0,938	0,351	-0,002426	0,006740
LN_Re.energy	0,016853	0,005109	85,443	3,299	0,001	0,006696	0,027010
LN_Air.quality	-0,026667	0,008076	68,233	-3,302	0,002	-0,042782	-0,010553
LN_CO ₂	-0,029458	0,007923	88,330	-3,718	0,000	-0,045202	-0,013714
LN_No.cars	0,035782	0,009192	99,544	3,893	0,000	0,017544	0,054020
LN_Internet	0,123182	0,031509	97,355	3,909	0,000	0,060648	0,185715

Source: based on author according the SPSS calculations.

Article

Assessment of Sustainable Socioeconomic Development in European Union Countries

Viktorija Skvarciany * , Daiva Jurevičienė and Gintarė Volskytė

Department of Economics Engineering, Faculty of Business Management, Vilnius Gediminas Technical University, Vilnius 10221, Lithuania; daiva.jureviciene@vgtu.lt (D.J.); gintare.volskyte@stud.vgtu.lt (G.V.)

* Correspondence: viktorija.skvarciany@vgtu.lt

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Abstract: There are still debates in the scientific literature about the factors influencing countries' sustainable socioeconomic development. Therefore, the current article aims at determining the factors of sustainable socioeconomic development and assessing its level in the EU countries. The following methods were employed for the research: an evaluation based on distance from average solution (EDAS) and hierarchical cluster analysis (HCA). EDAS was used to reveal which countries have the highest level of sustainable socioeconomic development, and which have the lowest. The ranking was done based on the appraisal score, which is an outcome of EDAS. Hierarchical cluster analysis (HCA) was used for clustering the countries based on the appraisal scores in order to distinguish groups of countries having a similar level of sustainable socioeconomic development. The results revealed that the highest level of sustainable socioeconomic development is in Germany, and the lowest in Portugal. Based on HCA, the countries were divided into three groups. The first cluster's countries have the weakest sustainable socioeconomic development, and countries assigned to the third cluster have the best. In the current research, the third cluster consists of one country, Germany, which supports the results obtained with the EDAS method, i.e., Germany is the country with the highest level of sustainable socioeconomic development in the EU.

Keywords: sustainable development; socioeconomic development; multicriteria decision-making approach (MCDA); evaluation based on distance from average solution (EDAS); hierarchical cluster analysis (HCA)

1. Introduction

Sustainable development is being analysed by a large number of scientists. Many scholars study sustainable development in the context of the sustainable development goals (SDG) announced by the United Nations [1]. The 17 announced goals cover three sustainability pillars: environmental, social, and economical. However, many researchers state that the social and economic pillars should be analysed in relationship. Hence, we examine those two pillars together to explore sustainable socioeconomic development.

A wide range of scientists have researched sustainable social and economic development. Some scholars have investigated the link between social and economic development and water. For instance, Liu, Zhang, and Zhang (2019) [2] claim that there is a relationship between socioeconomic development and industrial and domestic water pollution, i.e., the availability of clean water is crucial [3]. There are also scholars analysing sustainable development from an organisational perspective [4,5].

However, there are few articles investigating socioeconomic development from the economic perspective. It is worth mentioning that in the Economics category in the Clarivate Analytics Database only 17 articles cover sustainable socioeconomic development, which means that the topic is vital for the overall development of a country, but there are only a few pieces of research examining

that issue. Some articles are devoted to methodology development [6–8]; others analyse the role of business in socioeconomic development [7,9]. However, there is a lack of research investigating the factors of socioeconomic development. Hence, the research problem is how sustainable socioeconomic development can be assessed from an economic perspective. This study aims to determine the factors of socioeconomic development and assess the level of the development of EU countries in 2015–2017. After analysing and summarising previous research, the most critical factors of socioeconomic development are identified. Moreover, the indicators that can be used for the measurement of the distinguished factors are identified.

2. Literature Review

Before determining the factors of socioeconomic sustainable development assessment, it is necessary to define the concept of socioeconomic sustainability. The term “sustainability” could be described as the ability to maintain a decent standard of living without causing damage to the environment. Sustainability could thus be understood as the qualities of human well-being, social equity, and environmental integrity [10]. In other words, it could be viewed as the goal of human-ecosystem equilibrium. Socioeconomic sustainability includes two sustainability pillars—social and economical; hence, first of all, it is crucial to understand them. Social sustainability refers to the improvement of living conditions for both current and future generations [11]. Economic sustainability could be defined as the ability of the economy to support and maintain economic growth, but at the same time, it requires that natural resources be used efficiently [12]. Hence, socioeconomic sustainability could be understood as the ability to ensure economic growth without undermining humans’ interests and to meet their needs without harming nature.

In order to evaluate sustainable socioeconomic development, scientists use different factors. For instance, Gonzalez-Garcia, Manteiga, Moreira, and Feijoo (2018) [13] used net disposable income, the number of operating companies, the number of inhabitants with higher education, house prices, and unemployment rates. Pietrzak and Balcerzak [14] distinguished five diagnostic variables proposed by Eurostat relating to socioeconomic sustainability. Diagnostic variables used for the assessment of socioeconomic sustainability are GDP per capita, which measures socioeconomic development, resource productivity, which measures sustainable production and consumption, people at risk of poverty or social exclusion, the unemployment rate of workers aged 55–65, and healthy life years and life expectancy [14]. Ssebunya et al. (2019) [15] distinguished three elements of socioeconomic sustainability: social wellbeing, economic resilience, and good governance. The economic resilience element consists of profitability, the stability of production, the stability of supply, the stability of the market, risk management, private investment, and value creation. According to the author, all these indexes could be used to assess the country’s socioeconomic sustainability [15].

Rugani, Marvuglia, and Pulselli (2018) [16] used the Index of Sustainable Economic Welfare (ISEW) for socioeconomic sustainability research, which is a complementary macroeconomic measure to describe the performance of the country realistically. The Index of Sustainable Economic Welfare is a monetary measure of sustainability and economic welfare that aims to overcome some of the limitations of the Gross Domestic Product (GDP) [17]. They use 20 different variables in the research. From the point of view of socioeconomic sustainability, they use personal consumption expenditures and net capital growth. According to the scientists, personal consumption and expenditure directly affect the economic welfare in a country, while net capital growth estimates the amount of annual capital that must be maintained over time to ensure socioeconomic sustainability [16]. Gigliarano, Balducci, Ciommi, and Chelli (2014) [17] also analysed the Index of Sustainable Economic Welfare. They used the adjusted private consumption expenditures, net capital growth, and net balance payment. The authors adjusted private consumption expenditures to take into account income inequality and the poverty rate. They calculated the net balance of payment by subtracting imports from exports [17].

Moreover, Menegaki and Tugcu (2018) [18], as well as previous scientists, analysed the Index of Sustainable Economic Welfare. The authors used eight variables. From a socioeconomic perspective,

the authors used the adjusted personal consumption of durables, education expenditures, and net capital growth. They also adjusted personal consumption of durables by multiplying by the Gini coefficient and poverty index. Education expenditures include wages and salaries and exclude capital investment in buildings and equipment, while net capital growth represents the fixed capital accumulation [18].

Song et al. (2018) [19] pinpointed both qualitative and quantitative factors influencing sustainability. From the socioeconomic sustainability perspective, they identified five leading indicators: land ownership, living conditions, food insecurity, personal wealth, and subjective change in wealth. According to scientists, direct economic benefits include land value increase, and indirect economic benefits include employment and local business vitality [19]. All these factors have an impact on socioeconomic sustainability [19]. Economic issues such as poverty and land scarcity are the primary factors that influence socioeconomic sustainability [20]. Chelan et al. (2018) [21] extracted eight sustainability components as follows: activity and employment, utilisation, productivity, economic welfare, efficiency, economic justice, and governmental services. They state that business and work, productivity and economic well-being are the most essential and significant components for economic sustainability compared with the eight elements listed above [21]. Cadil, Mirošnik, Petkovova, and Mirvald (2018) [22] evaluated the effect of public R&D on private companies in the context of socioeconomic sustainability. Performance indicators, such as value-added, sales, or productivity, reflect the competitiveness of companies and their socioeconomic sustainability. For this reason, they used the following indicators in the research: value-added, patents, and value-added per labour cost. According to scholars, one of the main engines of economic growth is R&D, and a higher amount of R&D means more innovations, which leads to higher competitiveness and sustainable economic growth [22]. However, according to the calculations, scientists conclude that the public R&D support for private companies is probably ineffective from an economic sustainability point of view. These results might arise due to the limitations on research and the data availability of selected indicators [22].

Madudova, Čorejova, and Valica (2018) [23] analysed socioeconomic sustainability in a broader context based on the method of the Composite Sustainable Development Index. They used the Location Index (LI), the Hoover Coefficient of Concentration (CC), and the Sustainability subindex. The Location Index (LI) consists of two variables: national and regional employment, and national and regional population. The Hoover Coefficient of Concentration (CC) consists of six indicators: sectoral employment, national and regional employment, value-added costs, production value, and gross operating surplus. The sustainability subindex includes total profit, value-added factors cost, gross operating surplus, production value and sales revenue, an average monthly wage, average monthly employees, and R&D. According to scientists, it is impossible to assess sector sustainability only by the evaluation of economic data related to economic sustainability [23].

To sum up, the assessment of socioeconomic development relies on both social and economic factors. Based on the analysis of the scientific literature that aimed to assess the factors of sustainable socioeconomic development and the availability of statistical data of indicators (factor measurement), 11 factors measured by 12 indicators were used in the current research (see Table 1).

Table 1. Factors and indicators assessed in the research.

Factors	Indicators (Factor Measurement)	Authors
Education	Total general government expenditures on education (% of GDP)	Gonzalez-Garcia et al. (2018) [13]; Kolukisa & Uğurlu (2016) [24]; Menegaki and Tugcu (2018) [18]; United Nations (2015) [1]
	Population with tertiary education, 25–34 years old (% in the same age group)	Gonzalez-Garcia et al. (2018) [13]
Innovation and technology	Patent application to the European Patent Office (EPO) (thousand)	Cadil et al. (2018) [19]; Knoerzer (2016) [25]
Economic performance and living standards	GDP per capita (thousand EUR)	Pietrzak and Balcerzak (2016) [14]
Unemployment	Unemployment rate (% of active population)	Gonzalez-Garcia et al. (2018) [13]; Madudova et al. (2018) [23]; Mofidi Chelan et al. (2018) [21]; Pietrzak and Balcerzak (2016) [14]
Disposable income	Adjusted gross disposable income of households per capita (thousand EUR)	Gonzalez-Garcia et al. (2018) [13]
Research and Development (R&D)	Intramural R&D expenditure (GERD) by sectors of performance and fields of science (EUR per inhabitant)	Cadil et al. (2018) [22]
General government gross debt	General government gross debt (% of GDP)	Madudova et al. (2018) [23]
Cost of labour force	Average wage per hour (EUR)	Madudova et al. (2018) [23]
Government services	Corruption Perception Index	Mofidi Chelan et al. (2018) [21]
Consumption	Final consumption expenditure (% of GDP)	Gigliarano et al. (2014) [17]; Menegaki and Tugcu (2018); Pietrzak and Balcerzak (2016) [14]; Rugani et al. (2018) [16]
Value added	Manufacturing gross value added (% of GDP)	Cadil et al. (2018) [22]; Madudova et al. (2018) [23]; Ssebunya et al. (2019) [15]
House price index	House price index (%)	Gonzalez-Garcia et al. (2018) [13]
Poverty rate	People at risk of poverty or social exclusion (%)	Pietrzak and Balcerzak (2016) [14]

Source: developed by authors based on the literature review.

The indicators summarised in Table 1 were used to assess the socioeconomic development of European Union countries.

3. Methodology

The methodology aggregates the joint performance of the country by ranking, assuming that a country with better sustainable socioeconomic development should be close to the top rank and far from the worst. Conversely, a country with the lowest sustainable socioeconomic development should be close to the lowest position and distant from the highest one. For a comprehensive assessment, MCDA and HCA were used in the research.

Due to the research limitation (a lack of statistical information), not all European Union countries are included in the research. Countries involved in the study are Belgium, the Czech Republic, Denmark, Germany, Estonia, Spain, Italy, Latvia, Lithuania, Luxembourg, Hungary, the Netherlands, Austria, Poland, Portugal, Slovenia, the Slovak Republic, Finland, Sweden, and the United Kingdom.

The present study uses data that cover 2015–2017. The data were collected from the World Bank, Eurostat, OECD, and Transparency International Organization databases.

Multicriteria Decision-Making Approach. MCDA refers to choosing the best alternative from among a finite set of decision alternatives [26]. The MCDA method is characterised by the ability to handle multiple and conflicting data, as well as the ability to integrate values and perceptions, identify risks, and process vast amounts of information. MCDA can involve both quantitative and qualitative factors [27]. This method is based on the assumption that a country that has a better sustainable economic development is closer to the best scores on indexes and far from the worst ratings and vice versa. The MCDA approach is based on the distance to two reference points—one is desirable and the other undesirable [28].

MCDA consists of three application stages: decision context and structuring, analysis, and decision. In the first stage, it is necessary to determine goals, identify criteria and alternatives, and select the MCDA technique. The main objective of the use of MCDA is to rank European Union countries in the context of sustainable socioeconomic development.

For the countries assessment, the Evaluation Based on Distance from Average Solution (EDAS) method was chosen. The EDAS method is based on the average solution for appraising the alternatives. Because of that, EDAS is very useful when there are some different criteria [29]. The method is relatively new compared with other multicriteria decision-making methods. It was developed by Keshavarz Ghorabae, Zavadskas, Olfat, and Turskis (2015) [30] and is based on searching for the best solutions by finding the distance from the average one. This is the main difference to the TOPSIS method, which seeks to find the best solution by calculating the distance from the ideal solutions (both positive and negative) [31]. The motivation for selecting the EDAS method as a tool for the current research is that the obtained results are based on the average solution that represents normalised data that significantly limit the chances of deviation from the best solution; this allows this technique to generate more accurate solutions in solving real-life problems [32]. The methodology of the EDAS is provided below [30].

First, the decision-making matrix is constructed:

$$X = [X_{ij}]_{m \times n} = \begin{bmatrix} X_{11} & \cdots & X_{1m} \\ \vdots & \ddots & \vdots \\ X_{n1} & \cdots & X_{nm} \end{bmatrix}, \quad (1)$$

where:

X_{ij} —value of i -th alternative on j -th criterion

n —number of alternatives

m —number of criteria

Second, the average solution is determined:

$$AV_j = \frac{\sum_{i=1}^n X_{ij}}{n}, \quad (2)$$

where AV_j is the average solution

Third, the positive distance from average (PDA) and the negative distance from average (NDA) matrixes according to the type of criteria (benefit and cost) are calculated:

if j -th criterion is beneficial:

$$PDA_{ij} = \frac{\max(0, (X_{ij} - AV_j))}{AV_j} \quad (3)$$

$$NDA_{ij} = \frac{\max(0, (AV_j - X_{ij}))}{AV_j}; \quad (4)$$

if j -th criterion is cost:

$$PDA_{ij} = \frac{\max(0, (AV_j - X_{ij}))}{AV_j} \quad (5)$$

$$NDA_{ij} = \frac{\max(0, (X_{ij} - AV_j))}{AV_j}, \quad (6)$$

where:

PDA_{ij} —positive distance from average

NDA_{ij} —negative distance from average.

Fourth, the weighted sums of PDA_{ij} and NDA_{ij} for all alternatives are determined:

$$SP_i = \sum_{j=1}^m w_j PDA_{ij} \quad (7)$$

$$SN_i = \sum_{j=1}^m w_j NDA_{ij}, \quad (8)$$

where:

SP_i —weighted sum of PDA_{ij}

SN_i —weighted sum of NDA_{ij} .

Fifth, the values of SP_i and NP_i for all alternative are normalised:

$$NSP_i = \frac{SP_i}{\max_i(SP_i)} \quad (9)$$

$$NSN_i = 1 - \frac{SN_i}{\max_i(SN_i)}, \quad (10)$$

where:

NSP_i —normalised value of SP_i

NSN_i —normalised value of SN_i .

Sixth, the appraisal score (AS_i) for all alternatives is calculated:

$$AS_i = \frac{1}{2}(NSP_i + NSN_i), \quad (11)$$

where AS_i is the appraisal score (AS) for all alternatives, $0 \leq AS_i \leq 1$.

Lastly, the alternatives are ranked according to the decreasing values of AS_i , i.e., the alternative with the highest AS is the best choice among the candidate alternatives.

Hierarchical Cluster Analysis. HCA is a technique used to classify data by similar factors into groups, called clusters. HCA is a way of grouping sets of available data based on the measurement of similarities or distance. The results of HCA are usually presented in a dendrogram. The horizontal axis of the dendrogram represents the objects and clusters (in this case, European Union countries), while the vertical axis of the dendrogram represents the distance or dissimilarity between clusters. Hierarchical Cluster Analysis is based on the range that combines the most similar objects (in the current study, countries) into one group/cluster. Each cluster has well-defined centroids, meaning

the average across all the points in the cluster. Therefore, each cluster is represented by the centroids. According to the centroids' values, countries are assigned to a cluster [33].

The HCA method is applied via the following steps [33,34]:

Step 1. Let the distance between clusters i and j be represented as d_{ij} and let cluster i contain n_i objects. Let D denote the set of all remaining d_{ij} . Suppose there are N objects to the cluster.

Step 2. Find the smallest element d_{ij} remaining in D .

Step 3. Merge cluster i and j into a single new cluster, k .

Step 4. Calculate a new set of distances d_{km} using the following formula:

$$d_{km} = \alpha_i d_{im} + \alpha_j d_{jm} + \beta d_{ij} + \gamma |d_{im} - d_{jm}|, \quad (12)$$

where m represents any cluster different from k .

These new distances replace d_{im} , and d_{jm} in D . Also, let $n_k = n_i + n_j$. The coefficients of the distance equation are:

$$\alpha_i = \frac{n_i}{n_k}, \alpha_j = \frac{n_j}{n_k}, \beta = -\alpha_i \alpha_j, \gamma = 0. \quad (13)$$

Step 5. Repeat steps 1–3 until D contains a single group made up of all objects.

Based on the steps above, the method of HCA will be used for grouping the researched countries.

4. Results

The first step of the research aimed at prioritising the EU countries, where the criteria were the socioeconomic development factors, measured by indicators (see Table 1). The EDAS method was used to rank the countries. The prioritising procedure was completed for 2015–2017 in order to see the changes between the years (initial data is presented in Appendix A). After the prioritising was done, the hierarchical cluster analysis was employed using the appraisal score. The cluster analysis was used in order to group the countries with similar levels of socioeconomic development. The cluster analysis covered 2015–2017. This was done not only in order to divide EU countries into groups, but also to analyse how the groups have been changing.

Before obtaining the main results of the study, descriptive statistics were gathered (see Appendix B). The mean values of the unemployment rate varied from 6.90 to 8.61 (with a standard deviation varying from 3.164 to 3.924). It is worth mentioning that the lowest values were in 2017. The mean values of Intramural R&D expenditure (GERD) by sectors of performance and fields of science varied from 56.1 to 1615 (with standard deviation varying from 492.4 to 526.84). Based on that, it could be stated that these expenditures were very different in different countries in different years. That is supported by a high value of standard deviation as well. The mean of patent applications to the EPO was almost the same all three years and varied from 2.226 to 2.350 (with a standard deviation varying from 4.219 to 4.688). The mean value of the total general government expenditures on education varied from 5.085 to 5.275 percentage of GDP (with a standard deviation varying from 0.733 to 0.799, percentage of GDP). It could be stated that government expenditure on education was quite stable.

The mean value of GDP per capita, in thousands of euros, varied from 29.990 to 31.435 (with a standard deviation varying from 19.207 to 19.278, thousands of euros). The mean of the house price index varied from 99.998 to 111.823, in percentage (standard deviation differs from 0.006 to 5.414, %). Corruption perception index, i.e., its mean value, varied from 68.250 to 69.300 (with standard deviation varying from 13.661 to 14.833). Based on these figures, it could be concluded that the index was stable and sufficiently predictable. The situation is different from the average wage per hour. The mean values (in euros) varied from 22.715 to 23.430; on the other hand, the standard deviation was high, i.e., from 12.488 to 12.639. The mean values of people at risk of poverty or social exclusion changed from 20.960 to 22.120 and the standard deviations were not high, i.e., from 4.879 to 5.095. A very similar situation is seen with adjusted gross disposable income of households per capita. The mean values vary from (in thousands of euros) 20.881 to 21.145 (the standard deviation is from 5.165 to 5.517).

Final consumption expenditure, as a percentage of GDP, could be treated as stable and predictable as the mean values varied from 73.267 to 73.798 with a standard deviation varying from 7.946 to 8.009. The mean values of general government gross debt, as a percentage of GDP, varied from 63.850 to 66.810. The standard deviation was adequately high (varying from 32.744 to 33.392), which shows that it could not be treated as a standard for the EU average. The mean values of manufacturing gross value-added percentage of GDP varied from 14.937 to 15.035, with a standard deviation from 4.627 to 4.670. The last variable analysed was the population with tertiary education and 25–34 years old, a percentage in the same age group. Its mean value changed from 40.519 to 41.655, with the standard deviation varying from 7.700 to 7.986.

The main findings are presented in the following subsections.

4.1. Sustainable Economic Development Assessment Using the EDAS Technique

The first stage of the current study is to rank the countries by applying a multicriteria decision-making approach, EDAS. The results are presented in Table 2.

Table 2. Countries' ranking procedure results obtained using the EDAS technique.

Country	2015		2016		2017	
	AS_i	Rank	AS_i	Rank	AS_i	Rank
Belgium	0.464	9	0.489	9	0.487	9
Czech Republic	0.291	10	0.260	11	0.282	10
Denmark	0.603	3	0.662	3	0.657	3
Germany	0.926	1	0.948	1	0.952	1
Estonia	0.235	13	0.226	12	0.230	12
Spain	0.089	18	0.077	18	0.064	18
Italy	0.262	12	0.200	13	0.173	14
Latvia	0.066	19	0.037	19	0.024	19
Lithuania	0.156	15	0.131	15	0.120	15
Luxembourg	0.561	6	0.587	6	0.577	5
Hungary	0.126	17	0.081	17	0.076	17
Netherlands	0.563	5	0.599	4	0.605	4
Austria	0.572	4	0.589	5	0.577	6
Poland	0.196	14	0.193	14	0.196	13
Portugal	0.004	20	0.000	20	0.010	20
Slovenia	0.275	11	0.269	10	0.275	11
Slovak Republic	0.147	16	0.114	16	0.115	16
Finland	0.506	8	0.546	7	0.529	7
Sweden	0.652	2	0.695	2	0.692	2
United Kingdom	0.516	7	0.526	8	0.499	8

Source: authors' calculations.

Table 2 displays the AS_i (appraisal score) values according to which the countries are ranked. Germany had the highest appraisal score, while Portugal had the lowest in 2015–2017. This means that Germany had the most significant sustainable socioeconomic development, while Portugal had the worst in comparison with the 20 European Union countries. A similar situation was seen in Sweden and Latvia, which took second and nineteenth place in all three research years, respectively. This means that Germany and Sweden could be treated as a benchmark of sustainable socioeconomic development. It is worth mentioning that environmental development was not the objective of the current study; hence, the results of the environmental sustainability level could differ from the current research outcomes.

What is more, all the countries analysed reached more significant sustainable socioeconomic development in 2017, while in some countries, we noticed a decrease in sustainable socioeconomic development in 2016. This might arise due to the slight reduction in total general government expenditures on education, corruption perception index, adjusted gross disposable income of

households per capita, patent applications to the EPO, manufacturing gross value added, Intramural R&D expenditure (GERD) by sectors of performance and fields of science compared to 2015.

In order to see the whole picture more thoroughly, the results are depicted in Figure 1.

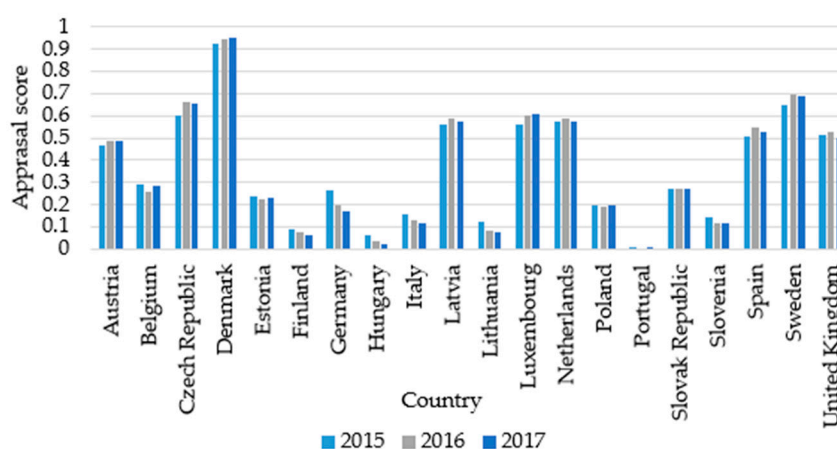


Figure 1. Appraisal scores obtained using EDAS in 2015–2017. Source: created by authors.

Figure 1 summarises the appraisal scores of sustainable socioeconomic development during 2015–2017. There are no significant differences within this period. However, it is worth mentioning that sustainable socioeconomic development increased in the following countries in 2017, compared to 2015: Austria, the Czech Republic, Denmark, Latvia, Luxembourg, Spain, and Sweden. However, there are only a few countries in which the level of socioeconomic development increased in 2017 compared to 2016: Belgium, Estonia, Luxembourg, and the Slovak Republic.

The results revealed that the countries that gained the lowest rank had the highest unemployment rates, while Germany had one of the lowest. This means that the unemployment rate is crucial for ensuring sustainable socioeconomic development. The highest number of patent applications and R&D expenditures were in the leading countries as well. This means that the government should invest in education, research activities, and innovation support (start-ups) to reach the highest level of socioeconomic development. In order to ensure these activities, people should receive a decent salary in order to be motivated to conduct research and develop a new product. The research results support this as well, as the wage is the variable that could encourage sustainable socioeconomic development.

4.2. Hierarchical Cluster Analysis

Hierarchical Cluster Analysis (HCA) was carried out to group the European Union countries into separate clusters according to similar criteria in 2015, 2016, and 2017 to show the tendencies in sustainable economic development.

Information about clusters distinguished by HCA is presented in Table 3.

Table 3. Cluster analysis results.

Cluster	Countries, 2015–2017
1	Czech Republic, Estonia, Spain, Italy, Latvia, Lithuania, Hungary, Poland, Portugal, Slovenia, Slovak Republic
2	Belgium, Denmark, Luxembourg, Netherlands, Austria, Finland, Sweden United Kingdom
3	Germany

Source: authors' calculation.

As can be seen from Table 3, the clusters are the same for the whole period. The first cluster consists of the Czech Republic, Estonia, Spain, Italy, Latvia, Lithuania, Hungary, Poland, Portugal, Slovenia, and the Slovak Republic; the second cluster consists of Belgium, Denmark, Luxembourg, the Netherlands, Austria, Finland, Sweden, and the United Kingdom; and the third cluster consists of Germany. In this case, Germany is interpreted as the best country in terms of sustainable socioeconomic development, because it has a zero value as the minimum distance to the centroid, average distance to the centroid, and maximum distance to the centroid. Countries that are assigned to the first cluster have the weakest sustainable economic development compared to the other European Union countries as they have the highest values for the minimum distance to the centroid, the average distance to the centroid, and the maximum distance to the centroid. The results of the EDAS method confirm that countries assigned to the first cluster have the weakest sustainable socioeconomic development, while Germany, assigned to the third cluster, has the most sustainable socioeconomic development.

5. Discussion

The study aimed at assessing the sustainable socioeconomic development of the EU countries. For that purpose, socioeconomic development was defined as the ability to ensure economic growth without undermining humans' interests and to meet their needs without harming nature. To evaluate the level of socioeconomic development, the following factors were distinguished from the scientific literature: education, innovation and technology, economic performance and living standards, unemployment, disposable income, R&D, cost of the labour force, government services, consumption, value-added, changes in prices, and poverty rate.

Two indicators measured education: total general government expenditures on education, and the population with tertiary education 25–34 years old. The research results revealed that in almost all the analysed countries, the higher the government's expenditures on education, the higher the number of young people who graduated from higher education institutions. This could be explained by the fact that expenditure on education increases the affordability of higher education. In turn, tertiary education could have a positive impact on a country's economy [35]. Governments should take this into account while planning the budget.

Innovation and technology were measured by patent applications to the EPO. The results revealed that this variable is one of the most powerful forces of sustainable socioeconomic development. The highest value was found for Germany, which has the highest level of socioeconomic development according to the results obtained by the EDAS technique. In fact, many studies support this outcome [36–39]. It is worth noting that innovation is one of the sustainable development goals [40].

Traditional indicators such as GDP per capita and the unemployment rate were also employed for the evaluation of sustainable socioeconomic development. The results were entirely predictable, i.e., the GDP of countries with a higher level of sustainable socioeconomic development is higher. As for the unemployment rate, it is different in every country and it is challenging to find a general tendency.

Disposable income, the cost of the labour force, and consumption could be analysed together. It is worth mentioning that the countries that are more socioeconomically developed have higher levels of disposable income and a higher cost of the labour force, which seems logical. In other words, those variables are directly proportional quantities. Regarding consumption, it is noted that the figures are almost the same in all the countries (Luxembourg is an exception); hence, it can be said that expenditure on final consumption is not a variable that has a relationship with the final results. However, it is worth noting that in other countries, final consumption could play a significant role in the rankings.

The countries that are more socioeconomically developed have higher R&D expenditure. The difference between the lowest and the highest value is more than 15,000 euros per inhabitant. Based on those results, it is highly recommended that local/regional governments encourage scientists to conduct high-quality research in order to develop their research skills and capabilities, which, in turn, will promote the sustainable socioeconomic development of a country/region.

Government service is the variable that could not be treated as having a close link with the level of a country's sustainable socioeconomic development in the analysed countries, i.e., it cannot be claimed that the level of sustainable socioeconomic development and government debt move in the same direction. The same situation is seen with manufacturing gross value added (% of GDP), which is used for measuring a country's value-added.

The house price index and poverty rate are similar in the investigated countries; hence, these variables could be treated as significant when assessing the level of socioeconomic development in other countries or regions.

6. Conclusions and Future Research Directions

In the current paper, sustainable socioeconomic development was examined. The aim of the study was to determine the factors and evaluate the level of sustainable socioeconomic development of the EU countries from 2015 to 2017. The identified factors were assigned indicators that were used for the quantitative representation. The results obtained by the EDAS method revealed that the most sustainably socioeconomically developed country is Germany, with the least being Portugal.

Moreover, the results highlighted that the countries that were assigned to the lowest sustainable socioeconomic development level had the highest level of unemployment. Hence, unemployment is the social area that should be given the most government attention. The significance of that factor was supported by the outcome that Germany, which has the highest level of sustainable socioeconomic development, had one of the lowest unemployment rates. What is more, the findings emphasised that Germany had the highest R&D expenditure, which significantly contributed to its sustainable socioeconomic development. This means that the German government paid great attention to such areas as education, scientific development, and innovation. In fact, R&D could speed up the development of other areas, such as technology, which, in turn, could create new job opportunities. In other words, there is a connection between all the sustainable socioeconomic development factors. Hence, future studies should focus on establishing the relationships between the factors and determining their strength.

Additionally, a cluster analysis was performed. According to the HCA results, clusters and clusters' structure in 2015–2017 were the same. It is noteworthy that the third cluster contained only one country—Germany, which means that it has the most sustainable socioeconomic development, while the countries assigned to the second cluster were the weakest in terms of sustainable socioeconomic development. The clusters will be used in further research to create models for each cluster to speed up the process of reaching a higher level of sustainable socioeconomic development.

What is more, it is crucial to note that there were several limitations of the research. Firstly, not all countries were investigated due to limited statistical data. Secondly, the latest data were from 2017, i.e., not all the necessary statistics had been announced for 2018 and 2019. Consequently, in future research, it is vital to investigate the situation from 2018 and 2019.

Author Contributions: V.S. and G.V. developed the research idea. G.V. and D.J. were responsible for the scientific literature review, visualisation, research results interpretation, and conclusions preparation. V.S. and G.V. were responsible for the research design, methodology, data collection and analysis, and validation of the research results. All authors have read and agreed to the published version of the manuscript.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A. Initial Research Data

Table A1. The 2015 data.

Country	Austria	Belgium	Czech Republic	Denmark	Estonia	Finland	Germany	Hungary	Italy	Latvia	Lithuania	Luxembourg	Netherlands	Poland	Portugal	Slovak Republic	Slovenia	Spain	Sweden	United Kingdom
Unemployment rate (% of active population)	5.70	8.50	5.10	6.20	6.20	9.40	4.60	6.80	11.90	9.90	9.10	6.50	6.90	7.50	12.60	11.50	9.00	22.10	7.40	5.30
Intramural R&D expenditure (GERD) by sectors of performance and fields of science (EUR per inhabitant)	959.5	280.8	1 534.2	1 121.7	205.4	285.5	382	56.1	113.4	1 198.1	139.5	833	1 279.9	108.3	231	393.4	118.1	1 080	1 537	618.3
Patent applications to the EPO (thousands)	2.00	1.57	0.30	1.36	0.04	1.38	21.03	0.21	4.37	0.03	0.02	0.07	3.50	0.58	0.14	0.04	0.12	1.63	2.93	5.69
Total general government expenditures on education (% of GDP)	4.90	6.40	4.90	7.00	6.00	6.20	4.20	5.10	3.90	5.90	5.40	4.70	5.20	5.30	5.10	4.20	5.50	4.10	6.50	5.00
GDP per capita (thousand EUR)	39.90	36.60	16.00	48.00	15.70	38.30	37.30	11.30	27.20	12.30	12.90	90.60	40.70	11.20	17.40	14.60	18.80	23.30	45.80	40.10
House price index (%)	100.00	100.00	100.00	100.00	100.00	100.00	99.98	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Corruption perception index	76.00	77.00	56.00	91.00	70.00	90.00	81.00	51.00	44.00	56.00	59.00	85.00	84.00	63.00	64.00	51.00	60.00	58.00	89.00	81.00
Average wage per hour (EUR)	32.50	39.10	9.80	41.20	10.40	33.00	32.30	7.90	28.10	7.10	6.80	36.30	33.70	8.60	13.40	10.00	15.80	21.20	37.40	29.70
People at risk of poverty or social exclusion (%)	18.30	21.10	14.00	17.70	24.20	16.80	20.00	28.20	28.70	30.90	29.30	18.50	16.40	23.40	26.60	18.40	19.20	28.60	18.60	23.50
Adjusted gross disposable income of households per capita (thousand EUR)	26.97	25.06	17.16	23.76	15.19	24.33	28.08	13.87	21.40	13.06	16.60	33.08	24.96	15.13	17.22	16.39	16.97	19.31	24.75	24.33
Final consumption expenditure (% of GDP)	72.50	75.06	66.05	72.74	72.18	79.70	72.86	69.31	79.76	78.28	79.90	46.65	69.52	76.53	83.59	74.19	72.04	77.34	70.85	84.74
General government gross debt (% of GDP)	84.80	106.50	40.00	39.90	9.90	63.60	70.80	76.60	131.60	36.80	42.60	22.20	64.60	51.30	128.80	52.20	82.60	99.30	44.20	87.90
Manufacturing gross value added (% of GDP)	16.56	12.83	24.13	12.41	13.83	14.80	20.76	20.52	14.39	10.52	17.36	4.86	10.70	17.64	12.16	19.75	19.96	12.90	13.69	8.97
Population with tertiary education, 25–34 years old (% in same age group)	48.47	43.14	31.01	44.48	40.51	40.52	29.59	32.13	25.15	39.87	54.77	49.95	45.09	43.19	33.14	31.31	40.76	40.96	46.41	49.94

Table A2. The 2016 data.

Country	Austria	Belgium	Czech Republic	Denmark	Estonia	Finland	Germany	Hungary	Italy	Latvia	Lithuania	Luxembourg	Netherlands	Poland	Portugal	Slovak Republic	Slovenia	Spain	Sweden	United Kingdom
Unemployment rate (% of active population)	6.00	7.80	4.00	6.20	6.80	8.80	4.10	5.10	11.70	9.60	7.90	6.30	6.00	6.20	11.20	9.70	8.00	19.60	6.90	4.80
Intramural R&D expenditure (GERD) by sectors of performance and fields of science (EUR per inhabitant)	959.5	280.8	1534.2	1121.7	205.4	285.5	382	56.1	113.4	1198.1	139.5	833	1279.9	108.3	231	393.4	118.1	1080	1537	618.3
Patent applications to the EPO (thousands)	2.03	1.59	0.32	1.37	0.03	1.31	20.14	0.20	4.24	0.02	0.02	0.06	3.45	0.63	0.14	0.05	0.11	1.64	2.90	5.54
Total general government expenditures on education (% of GDP)	4.90	6.30	4.50	6.80	5.80	6.10	4.10	4.90	3.80	5.50	5.10	4.60	5.20	5.00	4.80	3.80	5.50	4.00	6.70	4.80
GDP per capita (thousand EUR)	40.80	37.60	16.70	49.20	16.50	39.30	38.40	11.60	27.90	12.80	13.50	91.30	41.60	11.10	18.10	15.00	19.50	24.10	46.70	36.60
House price index (%)	114.26	106.37	119.70	110.00	110.51	102.01	110.78	120.13	99.18	118.01	114.80	111.96	112.93	105.78	117.02	112.99	111.56	111.10	115.58	111.81
Corruption perception index	75.00	77.00	55.00	90.00	70.00	89.00	81.00	48.00	47.00	57.00	59.00	81.00	83.00	62.00	62.00	51.00	61.00	58.00	88.00	81.00
Average wage per hour (EUR)	33.20	39.20	10.10	41.60	10.90	33.20	33.20	8.30	28.00	7.50	7.30	36.70	34.00	8.60	13.70	10.40	16.20	21.10	38.20	26.80
People at risk of poverty or social exclusion (%)	18.00	20.70	13.30	16.80	24.40	16.60	19.70	26.30	30.00	28.50	30.10	19.80	16.70	21.90	25.10	18.10	18.40	27.90	18.30	22.20
Adjusted gross disposable income of households per capita (thousand EUR)	26.70	24.73	17.30	23.68	15.40	24.09	28.00	14.03	21.58	13.49	16.96	31.67	24.39	15.34	17.32	16.28	17.04	19.21	24.26	23.90
Final consumption expenditure (% of GDP)	72.71	74.72	66.18	72.83	73.48	79.14	72.83	70.14	79.65	79.52	81.46	46.95	68.94	76.38	83.40	73.93	72.14	76.49	70.41	84.65
General government gross debt (% of GDP)	83.00	106.10	36.80	37.90	9.20	63.00	67.90	75.90	131.40	40.30	39.90	20.70	61.90	54.20	129.20	51.80	78.70	99.00	42.40	87.90
Manufacturing gross value added (% of GDP)	16.21	12.74	24.35	13.27	13.52	14.54	20.64	19.90	14.65	10.67	16.99	5.06	10.91	18.05	12.15	20.45	20.13	12.88	13.51	9.02
Population with tertiary education, 25–34 years old (% in same age group)	49.31	44.31	32.56	45.88	41.05	41.13	30.53	30.40	25.58	42.10	54.93	51.43	45.22	43.48	34.96	33.37	42.98	40.98	47.22	51.78

Table A3. The 2017 data.

Country	Austria	Belgium	Czech Republic	Denmark	Estonia	Finland	Germany	Hungary	Italy	Latvia	Lithuania	Luxembourg	Netherlands	Poland	Portugal	Slovak Republic	Slovenia	Spain	Sweden	United Kingdom
Unemployment rate (% of active population)	5.50	7.10	2.90	5.70	5.80	8.60	3.80	4.20	11.20	8.70	7.10	5.60	4.90	4.90	9.00	8.10	6.60	17.20	6.70	4.40
Intramural R&D expenditure (GERD) by sectors of performance and fields of science (EUR per inhabitant)	1 045.5	324.5	1 551.4	1 206.4	231.3	302.2	392.7	70.7	133	1 220.1	170.8	857	1 286.9	127.3	250.7	388.4	137.8	1 121.7	1 615	590.8
Patent applications to the EPO (thousands)	2.03	1.66	0.36	1.42	0.04	1.30	18.88	0.20	4.15	0.02	0.02	0.06	3.48	0.69	0.14	0.06	0.11	1.65	2.83	5.44
Total general government expenditures on education (% of GDP)	4.80	6.30	4.60	6.50	5.80	5.70	4.10	5.10	3.80	5.80	4.90	4.70	5.10	4.90	5.00	3.80	5.40	4.00	6.80	4.60
GDP per capita (thousand EUR)	42.10	114.26	18.10	50.80	18.00	40.60	39.60	12.70	28.50	13.90	14.90	92.60	43.00	12.20	18.90	15.60	20.80	25.10	47.20	35.40
House price index (%)	75.00	106.37	119.70	110.00	110.51	102.01	110.78	120.13	99.18	118.01	114.80	111.96	112.93	105.78	117.02	112.99	111.56	111.10	115.58	111.81
Corruption perception index	75.00	75.00	57.00	88.00	71.00	85.00	81.00	45.00	50.00	58.00	59.00	82.00	82.00	60.00	63.00	50.00	61.00	57.00	84.00	82.00
Average wage per hour (EUR)	34.10	39.60	11.30	42.50	11.70	32.70	34.10	9.10	28.90	8.10	8.00	37.60	34.80	9.40	14.10	11.10	17.00	21.20	38.30	25.70
People at risk of poverty or social exclusion (%)	18.10	20.30	12.20	17.20	23.40	15.70	19.00	25.60	28.90	28.20	29.60	21.50	17.00	19.50	23.30	16.30	17.10	26.60	17.70	22.00
Adjusted gross disposable income of households per capita (thousand EUR)	26.73	24.96	17.97	24.40	15.96	24.17	28.47	14.41	21.80	14.04	17.56	32.68	24.70	15.68	17.73	16.65	17.50	19.34	24.54	23.60
Final consumption expenditure (% of GDP)	71.63	74.67	66.45	71.94	71.58	77.64	72.64	69.64	79.67	79.86	80.53	46.65	68.16	76.27	82.65	73.86	71.06	76.19	70.11	84.15
General government gross debt (% of GDP)	78.30	103.40	34.70	36.10	8.70	61.30	63.90	73.30	131.20	40.00	39.40	23.00	57.00	50.60	124.80	50.90	74.10	98.10	40.80	87.40
Manufacturing gross value added (% of GDP)	16.51	12.54	24.28	12.81	13.28	14.93	20.66	19.87	14.69	11.05	17.56	5.15	10.75	17.59	12.37	20.10	20.70	13.06	13.60	9.20
Population with tertiary education. 25–34 years old (% in same age group)	40.32	45.73	33.82	46.57	43.04	41.25	31.31	30.16	26.82	41.61	55.63	51.40	46.59	43.53	34.03	35.07	44.57	42.64	47.39	51.62

Appendix B. Descriptive Statistics

Table A4. Descriptive statistics of 2015 data.

Statistic	Minimum	Maximum	1st Quartile	Median	3rd Quartile	Mean	Variance (n-1)	Standard deviation (n-1)
Unemployment rate (% of active population)	4.600	22.10	6.200	7.45	9.525	8.610	15.4	3.924
Intramural R&D expenditure (GERD) by sectors of performance and fields of science (EUR per inhabitant)	76.6	1504	204.3	389	1097.4	621.3	242474	492.4
Patent applications to the EPO (thousand)	0.025	21.03	0.106	0.97	2.233	2.350	21.98	4.688
Total general government expenditures on education (% of GDP)	3.900	7.000	4.850	5.15	5.925	5.275	0.733	0.856
GDP per capita (thousand EUR)	11.20	90.60	15.43	25.3	39.9	29.90	368.9	19.21
House price index (%)	99.98	100.0	99.99	100	100.0	99.99	0.000	0.006
Corruption perception index	44.00	91.00	57.50	67.0	81.75	69.30	220.0	14.83
Average wage per hour (EUR)	6.800	41.20	9.950	24	33.18	22.72	159.7	12.64
People at risk of poverty or social exclusion (%)	14.00	30.90	18.38	20.6	27.00	22.12	25.96	5.095
Adjusted gross disposable income of households per capita (thousand EUR)	13.06	33.08	16.55	20.4	24.80	20.88	30.44	5.517
Final consumption expenditure (% of GDP)	46.65	84.7	71.74	73.5	78.63	73.69	64.15	8.009
General government gross debt (% of GDP)	9.900	131.6	41.95	64.1	85.58	66.81	1102	33.2
Manufacturing gross value added (% of GDP)	4.855	24.13	12.35	14.1	18.17	14.94	21.81	4.670
Population with tertiary education, 25–34 years old (% in same age group)	25.15	54.77	32.89	40.6	45.42	40.52	62.40	7.899

Table A5. Descriptive statistics of 2016 data.

Statistic	Minimum	Maximum	1st Quartile	Median	3rd Quartile	Mean	Variance (n-1)	Standard deviation (n-1)
Unemployment rate (% of active population)	4.00	19.60	6.00	6.85	9.00	7.84	12.31	4.00
Intramural R&D expenditure (GERD) by sectors of performance and fields of science (EUR per inhabitant)	56.1	1537	188.9	387.7	1090.4	623.8	265651	515.4
Patent applications to the EPO (thousand)	0.02	20.14	0.10	0.97	2.24	2.29	20.17	0.02
Total general government expenditures on education (% of GDP)	3.80	6.80	4.58	4.95	5.58	5.11	0.80	3.80
GDP per capita (thousand EUR)	11.10	91.30	16.13	26.0	39.68	30.42	371.1	11.10
House price index (%)	99.18	120.1	110.4	112	115	111.8	29.32	99.18
Corruption perception index	47.00	90.00	57.75	66.0	81.00	68.75	205.4	47.00
Average wage per hour (EUR)	7.30	41.60	10.33	24	33.40	22.91	158.8	7.30
People at risk of poverty or social exclusion (%)	13.30	30.10	18.08	20.3	25.40	21.64	24.61	13.30
Adjusted gross disposable income of households per capita (thousand EUR)	13.49	31.67	16.79	20.4	24.29	20.77	26.78	13.49
Final consumption expenditure (% of GDP)	46.95	84.65	71.71	73.7	79.24	73.80	63.82	46.95
General government gross debt (% of GDP)	9.20	131.4	40.20	62	84.23	65.86	1115	9.20
Manufacturing gross value added (% of GDP)	5.06	24.35	12.60	14.0	18.52	14.98	21.55	5.06
Population with tertiary education, 25–34 years old (% in same age group)	25.58	54.93	34.57	42.5	46.22	41.46	63.77	25.58

Table A6. Descriptive statistics of 2017 data.

Statistic	Minimum	Maximum	1st Quartile	Median	3rd Quartile	Mean	Variance (n-1)	Standard deviation (n-1)
Unemployment rate (% of active population)	2.90	17.20	4.90	6.20	8.23	6.90	10.01	2.90
Intramural R&D expenditure (GERD) by sectors of performance and fields of science (EUR per inhabitant)	70.7	1615	216.17	390.6	1142.9	651.21	277558	526.84
Patent applications to the EPO (thousand)	0.02	18.88	0.10	0.99	2.23	2.23	17.80	0.02
Total general government expenditures on education (% of GDP)	3.80	6.80	4.60	4.95	5.73	5.09	0.74	3.80
GDP per capita (thousand EUR)	12.20	92.60	17.40	26.8	40.98	31.44	371.7	12.20
House price index (%)	99.18	120.1	110.4	112	115	111.8	29.32	99.18
Corruption perception index	45.00	88.00	57.75	67.0	82.00	68.25	186.6	45.00
Average wage per hour (EUR)	8.00	42.50	11.25	23.5	34.28	23.43	156	8.00
People at risk of poverty or social exclusion (%)	12.20	29.60	17.18	19.9	23.95	20.96	23.81	12.20

Table A6. Cont.

Statistic	Minimum	Maximum	1st Quartile	Median	3rd Quartile	Mean	Variance (n-1)	Standard deviation (n-1)
Adjusted gross disposable income of households per capita (thousand EUR)	14.04	32.68	17.29	20.6	24.58	21.15	26.67	14.04
Final consumption expenditure (% of GDP)	46.65	84.15	70.82	73.3	78.15	73.27	63.13	46.65
General government gross debt (% of GDP)	8.70	131.2	39.85	59.2	80.58	63.85	1072	8.70
Manufacturing gross value added (% of GDP)	5.15	24.28	12.50	14.2	18.16	15.04	21.41	5.15
Population with tertiary education, 25–34 years old (% in same age group)	26.82	55.63	34.81	42.8	46.58	41.65	59.29	26.82

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