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STATE OF PERCEPTION AND KNOWLEDGE OF BIOECONOMY IN SELECTED EUROPEAN UNIVERSITIES

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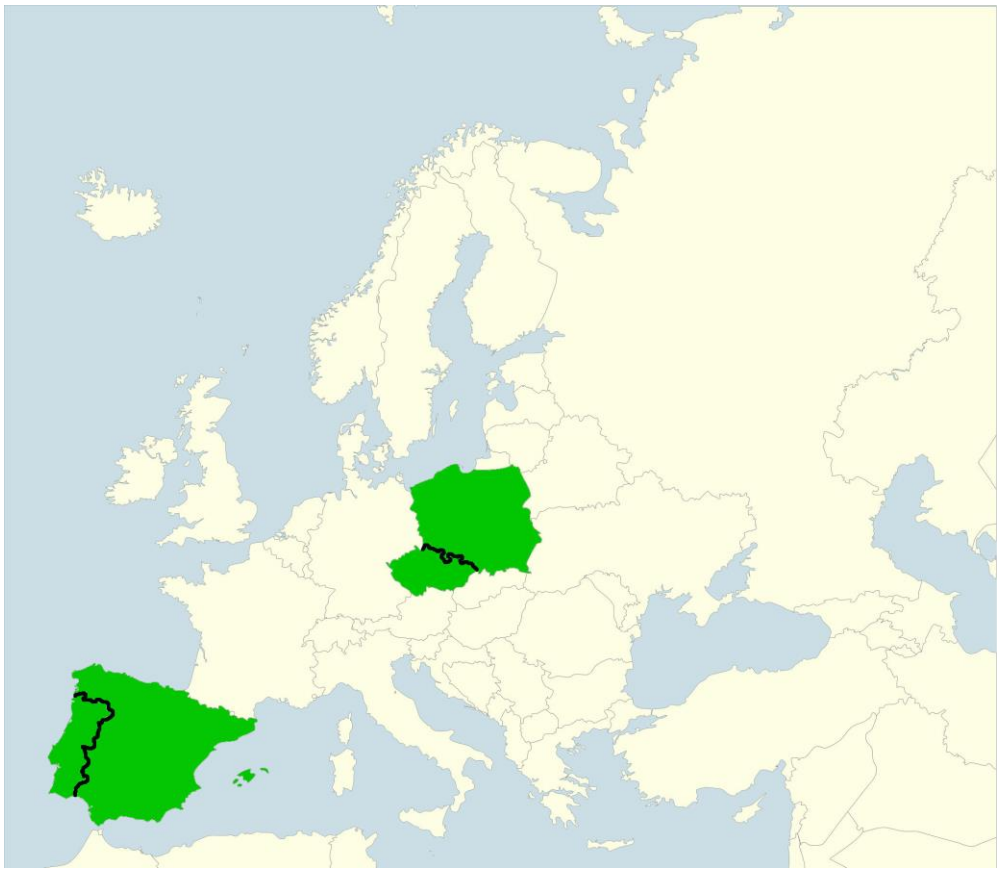

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Abstract: Sustainable bioeconomy is one of the concepts that makes it possible to achieve the European Green Deal. A similar understanding of the term bioeconomy gives the opportunity to simultaneously take proportionate actions leading to the implementation of the Sustainable Development Goals in EU countries. Parallel understanding of the concept of bioeconomy is crucial for achieving a common consensus on actions aimed at introducing optimal plans for the development of green technologies. Therefore, the goal of the paper was to compare knowledge and perception about the bioeconomy in different countries. Realization of the work's objective was possible thanks to the use of the C&RT classification tree method. It was shown that the level of knowledge of respondents working or studying at selected universities was similar, while their perception of the bioeconomy differed significantly.

Key words: bioeconomy perception, bioeconomy knowledge, sustainable economy, circular economy

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Streszczenie: Zrównoważona biogospodarka jest jedną z koncepcji, która umożliwia osiągnięcie Europejskiego Zielonego Ładu. Podobne rozumienie pojęcia Biogospodarka daje możliwość równoczesnego podejmowania proporcjonalnych działań prowadzących do realizacji Celów Zrównoważonego Rozwoju w krajach UE. Równoległe rozumienie pojęcia Biogospodarka jest kluczowe dla osiągnięcia wspólnego konsensusu w sprawie działań zmierzających do wprowadzenia optymalnych planów rozwoju zielonych technologii. Dlatego też celem artykułu jest weryfikacja hipotezy mówiącej, że stan postrzegania i wiedzy na temat biogospodarki wśród respondentów różni się w zależności od kraju pracy i edukacji. Weryfikacja tak postawionej hipotezy badawczej była możliwa dzięki zastosowaniu metody drzew klasyfikacyjnych C&RT. Wykazano, że stan wiedzy respondentów pracujących lub studiujących na wybranych uniwersytetach był podobny natomiast ich percepcja biogospodarki różniła się istotnie.

Słowa kluczowe: postrzeganie biogospodarki, wiedza o biogospodarce, zrównoważona gospodarka, ekonomia cyrkularna

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Highlights

- The state of knowledge of the bioeconomy among respondents in all groups was predominantly similar and high.
- Among university teachers, perceptions varied widely, depending on the degree and the country.
- Among students from Spain and Portugal, the bioeconomy was of medium or high concern.
- Among students from Poland and the Czechia, bioeconomy was of medium or low concern.
- Interest in the bioeconomy depended on the country of employment or education.
- Barriers to further development of the bioeconomy exist.

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1. Introduction

Sustainable bioeconomy is one of the pillars of the Circular Economy (Spatial Foresight, 2017), a method that enables achievement of the Sustainable Development Goals and the Green Deal principles. However, the implementation of the bioeconomy assumptions requires the cooperation of many stakeholders, and above all, the awareness of these stakeholders of the opportunities and threats related to the bioeconomy.

Many countries have been developing biotechnology and biosimilar products strategies, but in the 2000s, it was observed that these strategies integration aimed to create the concept of bioeconomy (Staffas,

Gustavsson, & McCormick, 2013). The bioeconomy focuses on sustainable use of natural resources, but also pays attention to nature protection and ecosystem restoration. However, its basic idea is to shift from the economy based on fossil fuels to the one based on the restoration of natural resources. The development of the bioeconomy may result in more elements driving their socio-economic development in rural areas. On the other hand, the application of circular economy principles supports the efficient use and recycling of natural resources. The bioeconomy also includes the protection of habitats and landscapes that determine the existence of rural tourism, which is an important aspect for the development of rural societies (European Network for Rural Development, 2019).

The European Union website presents the motivation for promoting the Bioeconomy in Europe, and it is as follows: In a world of finite biological resources and ecosystems, an innovation effort is needed to feed people, and provide them with clean water and energy. The bioeconomy can turn algae into fuel, recycle plastic, convert waste into new furniture or clothing or transform industrial by-products into bio-based fertilisers. It has the potential to generate 1 million new green jobs by 2030 (European Commission, 2018). The first official document generated by the European Commission in the field of the Bioeconomy was the report published in 2012 entitled "Bioeconomy Strategy". In this document, the following definition of the bioeconomy is given: The bioeconomy provides a useful basis for this approach, as it encompasses the production of renewable biological resources and the conversion of these resources and waste streams into value-added products, such as food, feed, bio-based products and bioenergy (European Commission, 2018).

The effective implementation of the bioeconomy is related to the implementation of socio-ecological and economic strategies, which should be executed with the participation of qualified experts. Only such an approach will ensure effective performance of tasks within the process of transformation of economies. Therefore, an important element in this regard is education, which, if implemented at the appropriate level, will provide the necessary workforce capable of implementing plans related to the bioeconomy. A similar understanding of the concept of bioeconomy and the high state of knowledge about bioeconomy gives the opportunity to simultaneously take proportionate actions to achieve the Sustainable Development Goals in EU countries. Parallel understanding of the concept of bioeconomy is crucial for achieving a common consensus on activities aimed at introducing optimal plans for the development of green technologies. Hence, the goal of the paper was to compare knowledge and perception about the bioeconomy in different countries.

2. The state of bioeconomy education in selected countries

As Turlakova (2021) emphasizes, the development of bioeconomy generates solutions supporting the implementation of social challenges in rural areas, such as: ensuring food security; reducing dependence on non-renewable resources; reducing climate change; protection of biodiversity or stimulating economic growth with the participation of the agricultural sector. Bioeconomy is a means to achieve sustainable development of rural areas, opens new market niches and improves the organization of production processes (Turlakova, 2021). The development of bioeconomy sectors has a significant impact on the creation of innovation and jobs in rural areas (Vivien; Nieddu; Befort; Debref, & Giampietro, 2019). Enterprises engaged in agricultural processing are most often located in cities. This creates a problem in terms of labor mobility in rural areas. The consequence of this process is the decrease in the attractiveness of rural areas for young people and the loss of their economic functions (Atkociuniene, & Balkibayeva, 2019). There are threats of depopulation of some regions. That is why the development of bioeconomy gives an opportunity to create jobs and strengthen the competitiveness of rural regions.

Currently, the global population is growing, and the phenomenon of urbanization is intensifying. This leads to an increase in carbon dioxide emissions and climate change. As indicated by Bugge at al., the bioeconomy consists of different visions of the economy (biotechnology, bioresources and bioecology) (Bugge, Hansen, & Klitkou, 2016; Devaney, & Henchion, 2018). An example of implementing the vision of bioresources can be the replacement of fossil fuels with biogenic alternatives, which makes it possible to mitigate the global warming process (Stewart, Niero, 2018). This is only one of the possibilities of using the bioeconomy concept, however, it shows that there is a chance to minimize

an important problem in the economic aspect. The bioeconomy can also be seen as a way to meet societal challenges – among its potential benefits, one can mention the stimulation of rural development (Congressional Research Service, 2022). Simultaneously, it should be emphasized that the bioeconomy, apart from its positive impact on rural areas, is also an opportunity for economic growth revival throughout the country, thanks to the development of new technologies (Purkus, Hagemann, Bedtke & Gawel, 2018).

As highlighted in the previous two paragraphs, the popularisation of bioeconomic knowledge is important for the improvement of the environment. Moreover, it is crucial not only for the development of rural areas, but also for the economy as a whole. The fundamental question remains:can we conclude that bioeconomic education is promoted better or worse in a given country? A review of the state of education and implemented strategies of bioeconomic development in the countries surveyed proved to be a helpful tool in this aspect.

Accordingly, a cross-country comparison based on study programs of bioeconomy in selected countries was created in tabular form (table 1). The choice of universities was determined by their participation in the BioEra+ project. This program focuses primarily on the development of new teaching methods in the field of Bioeconomy. Consequently, there was a need to investigate existence of differences in the level of knowledge and perception of the bioeconomy at different universities. The work aims to support the decision-making process in developing better tools to promote bioeconomic knowledge in selected countries.

Tab 1. Bioeconomy study programs in selected countries. Source: own study of 2023

Poland	
Programmes	**Universities**
Science and technology programmes	Lodz University of Technology; Warsaw University of Technology; Wroclaw University of Life Sciences; University of Agriculture in Krakow; Military University of Technology in Warsaw; Calisia University of President Stanisław Wojciechowski
Master programmes	Warsaw University of Technology; University of Agriculture in Krakow
Czechia	
Programmes	**Universities**
Specialist courses	University of South Bohemia in České Budějovice; Forestry Bioeconomics course at the Czech University of Life Sciences in Prague
Portugal	
Programmes	**Universities**
Bachelor programmes	Lusófona University of Humanities and Technologies in Lisbon
Master programmes	Polytechnic Institute of Leiria; Superior Institute Manuel Teixeira Gomes/Ensino Lusófona; University of Porto
Specialist courses	University of Lisbon
Spain	
Programmes	**Universities**
Bachelor programmes	Polytechnic University of Madrid
Master programmes	University of Cordoba; University of Zaragoza; University of Almería

2.1 Poland

Bioeconomy is an important sector for Poland, giving a job to nearly 15% of the habitants of the country, mostly in agriculture (European Commission, 2022). Therefore, it is interesting that Poland still has no strategy on bioeconomy at the national level. There is, however, a roadmap for implementing bioeconomy as part of the circular economy strategy. The goals that are mentioned in the roadmap are:

- New business models.
- Bioeconomy: I) providing framework conditions for bioeconomy development; II) building local value chains and a resource base; III) energy; IV) actions in the field of industry; V) identification of R&D&I priorities.
- Sustainable consumption: I) municipal waste; II) food waste; III) education.
- Sustainable industrial production: I) industrial waste; II) extended producer responsibility; III) environmental footprint.

The following sectors are included into the future strategic vision of the bioeconomy: agriculture; bio-based materials and chemicals; bioenergy; food; forestry. Responsibility for a consistent national strategy is widely spread among multiple Ministries: Ministry of Investment and Economic Development; Ministry of Science and Higher Education; Ministry of Agriculture and Rural Development; Ministry of Entrepreneurship and Technology. With further support of: Ministry of Environment; Ministry of Energy; Ministry of Maritime and Inland Waterway Transport (European Commission, 2022).

The university selected for the study in Poland is an entity related to the bioeconomy. All faculties deal with specific aspects of bioeconomy. However, the 'Bioeconomy' field of study (BA, MSc) is carried out at only Faculty of Agriculture and Economics of University of Agriculture in Cracow.

2.2 Czechia

Czechia has not yet published a separate conceptual document that would deal with bioeconomy at the national level, but the ideas and principles of bioeconomy have been appearing in a number of national strategies across departments for a long time. The most significant reference can be seen in the Strategy of the Department of the Ministry of Agriculture. Another important national conceptual document that reflects the ideas of bioeconomy is the Strategic Framework of the Czechia 2030 (BIO HUB CZ, 2022). The European Commission states that in 2019, only 2% of the Czech population has a job linked to bioeconomy, specifically to biomass, therefore, bioeconomy is not perceived as a key area of development (European Commission, 2022b).

The establishment of the Common Agricultural Policy (CAP) for the period 2021–2027 mentions the area of bioeconomy, renewable energy sources and environmental protection as one of the objectives to be fulfilled by the member states. The concept of research, development and innovation of the Ministry of Agriculture of the Czechia for the years 2016–2022 also mentions bioeconomy as a progressive interdisciplinary research area. There are numerous other conceptual and strategic materials related to bioeconomy[5].

The concept of bioeconomy in the Czechia from the perspective of the department of the Ministry of Agriculture for the years 2019–2024 is thus based on the above-mentioned conceptual materials and emphasizes or supplements ideas in the context of current problems and challenges. Sectors included in

[5] **Example materials related to bioeconomy in Czechia:** Action Plan for Biomass in the Czechia 2012 – 2020; State Energy Concept of the Czechia; National Plan of the Czechia in the Field of Energy and Climate; Food Safety and Nutrition Strategy 2014–2020; Climate Protection Policy in the Czechia; Concept of protection against the consequences of drought for the territory of the Czechia; National action plan for adaptation to climate change; National forestry program until 2013; Principles of state forestry policy; Concept of the Ministry of Agriculture for the economic policy of Lesy ČR, s.p.; Multi-year national strategic plan of the Czechia for aquaculture; Biodiversity Protection Strategy of the Czechia 2016–2025; National Action Plan to Reduce the Use of Pesticides in the Czechia; Territorial Development Policy of the Czechia; Waste Management Plan of the Czechia for the Period 2015–2024; Waste Prevention Program of the Czechia and Czech Beekeeping Program 2017–2019.

the future bioeconomy strategy are: agriculture, aquaculture, biotechnology, ecosystem services, food and forestry (European Commission, 2022).

Selected university for the research in Czechia is a public institution with a long tradition of excellence in teaching and research that is by definition an entity related to bioeconomy. In all faculties, teaching addresses specific aspects of the bioeconomy. Nevertheless, two university departments are the most relevant to bioeconomy issues. Bachelor's and master's studies focused on sustainable horticultural production are created under the guidance of one faculty. Chosen university (Mendelova univerzita v Brně – Mendel University in Brno) cooperates closely with various state and private/commercial research institutions as well as with interest groups and associations all over the world.

2.3 Portugal

Bioeconomy in Portugal provides jobs for around 4% of the population and creates 12 billion euro of value added from sectors producing and converting biomass (Euroepan Commission, 2022). On its way towards establishing a bioeconomy strategy at the national level, Portugal has developed several initiatives that can be highlighted in bioeconomy context[6].

The promotion of bioeconomy was outlined in the Program of the XXII Portuguese Constitutional Government within the framework of the strategic challenge for climate change. It is an economic model which, through replacing the use of fossil resources with biologically based resources, allows a continuous economic and social development that respects the natural limits of terrestrial and marine ecosystems.

The in-depth assessment of the Portuguese agri-food, forestry and marine (algae, aquaculture, and fisheries) sectors, as well as the food and beverage, pulp and paper industries and the rest of the forestry sector, revealed the great potential that Portugal has to assert itself as one of the European front-runners of the Green Deal. The emerging bioeconomy sector in Portugal already contributes almost 20 billion euros to the national economy and a Bio-based Industries Consortium study shows that there are new opportunities to accelerate green economic growth in the country (BIOREF, 2023).

The resolution of the Council of Ministers number 183/2021 approves the Action Plan for Sustainable Bioeconomy – Horizon 2025 embodied in various plans and strategies as a framework of reference (Presidência do Conselho de Ministros, 2021). This action plan, if we consider it, as referred to by the European Commission, as a strategy at a national level, provides for investment in new approaches and technologies to create new processes, products, and services of greater added value, as well as for the creation of employment and wealth, territorial cohesion together with the preservation of natural resources.

The university that was selected to conduct the study (Instituto Politécnico de Beja – Polytechnic Institute of Beja) educates students at the BA, MSc, post graduate and short cycle levels. Students can get a degree in numerous areas related to bioeconomy: agronomy, bioanalytic technologies, environmental

[6] **Initiatives in bioeconomy context in Portugal:** Action Plan for the Circular Economy in Portugal (PAEC) approved by the Resolution of the Council of Ministers 190-A/2017, of December 11; Roadmap to Carbon Neutrality (RCN) 2050 published through Council of Ministers Resolution No. 107/2019, of 1 July; National Energy and Climate Plan 2021–2030 (PNEC 2030) approved in December 2019; National Strategy for the Conservation of Nature and Biodiversity 2030 (ENCNB 2030) approved by the Resolution of the Council of Ministers No. 55/2018, of 5 July; National Strategy for Forests (ENF) approved by the Council of Ministers Resolution No. 6-B/2015, of February 4th; National Program for Spatial Planning Policy (PNPOT) revised and approved by Law No. 99/2019 of September 5th; National Research and Innovation Strategy for Intelligent Specialization (ENEI) succeeding the previous ENEI (2014) and approved in June 2022; Innovation Agenda for Agriculture 2020–2030 approved by the Council of Ministers Resolution No. 86/2020 of October 13; National Strategy for Green Public Procurement 2020 (ENCPE 2020), approved by the Resolution of the Council of Ministers No. 38/2016, of 29 July; National Strategy for the Sea (ENM 2021–2030) approved by the the Council of Ministers on May 6 2021; National Plan for the Promotion of Biorefineries (PNPB Horizonte 2030) approved by the Council Resolution of Ministers No. 163/2017 of 31 October; National Strategy and Plan to Combat Food Waste approved by the Resolution of the Council of Ministers No. 46/2018 of 27 April; National Action Program to Combat Desertification (PANCD) approved by the Resolution of the Council of Ministers No. 78/2014 of 24 December (Plano de Ação Para a Bioeconomia Sustentável Horizonte 2025, p. 11).

engineering, food science and technology. Bioeconomy can also be incorporated in study fields related to medicine and social sciences.

2.4 Spain

In Spain, the first document regarding the management of the bioeconomy was Estrategia española de Bioeconomía: Horizonte 2030 (Spanish Bioeconomy Strategy: Horizon 2030), published in 2015 (Ministerio de Economía, Industria y Competitividad, 2015). In general terms, the Joint Research Centre of the European Union provides the data showing that in 2019, only 8% of the Spanish population had a job linked to bioeconomy, in this case specifically to biomass (European Commission, 2022).

Another important strategy in the context of issues related to bioeconomy is the document España Circular 2030, which assumes the promotion of new models of production and consumption. The concepts contained in it concern, i.a. minimizing the production of waste and its reuse. This strategy aims to achieve a sustainable, low-emission use of the economy's resources through the implementation of a number of quantitative goals, such as: reducing the consumption of materials by 30%; minimizing the amount of generated waste by 15%; reducing the generation of food waste; increasing the level of reuse of municipal waste to 10%; improving water use efficiency by 10% and reducing greenhouse gas emissions below 10 million tonnes of CO_2 equivalent (Gobierno de España, 2020). All the points mentioned are to be evaluated in relation to the corresponding values in 2010.

References to the topic of the Spanish bioeconomy were included in documents such as: National Program for Innovation and Research in the Agri-Food and Forestry Sectors (2015) and in the National Rural Development Program 2014–2020. Spain has developed many modern strategies and initiatives that are relevant to the development of the bioeconomy and circular economy[7].

The university selected for the research (Universidad de La Laguna – University of La Laguna) does not offer bioeconomy as a formal education degree. Nevertheless, there are some alternative options like economics of natural resources or economics applied to the environment, which are incorporated in the Environmental Science degree and Economics degree.

2.5 Data collection

To learn about the university community's perception of the bioeconomy concept, a survey was developed and disseminated among faculty and students at the selected universities. The goal of the research was to determine the level of awareness and knowledge among the staff and students of the universities surveyed and to understand the ideas that university staff and students associate with the bioeconomy. To achieve these goals, a questionnaire was prepared and made available to students and lecturers at 4 chosen universities. The survey was addressed to all lecturers and students who have a connection with aspects of bioeconomy in a productive and socio-economic context.

The survey consisted of 58 questions including questions on demographic profile. Some of the questions were dichotomous, most were categorized on a Likert scale. One question was open. On the other hand, 13 questions with a Likert scale (scale from 1–10) were selected for the research conducted using the decision tree method. They concerned the state of perception and knowledge about the bioeconomy (Table 2).

[7] **Initiatives in bioeconomy context in Spain:** Act 3/2020 of March 11 on the prevention of food loss and waste in Catalonia; Act 7/2019, of November 29, on the circular economy of Castilla-La Mancha; Circular economy strategy 2020–2030 of the Galicia region; Murcia Region Circular Economy Strategy 2030; Catalonia – Catalan Ecodesign Strategy; Integrated waste management plan for Andalusia towards a circular economy by 2030 (PIRec 2030); Castilla La Mancha Circular Economy Strategy 2020–2030; Basque Country Circular Economy Strategy 2030; Andalusian Sustainable Development Strategy 2030; Andalusian Circular Bioeconomy Strategy [EABC]; Madrid Community Waste Strategy; Valencian Climate Change and Energy Strategy 2030. Generalitat Valenciana; Sustainable Development Strategy of the Principality of Asturias; Castilla y León Circular Economy Strategy; Aragon's Climate Change Strategy (EACC); Extremadura's Integrated Energy and Climate Plan 2021–2030; Extremadura Ecological and Circular Economy Strategy.

Tab 2. The content of the questions used in the study using the decision tree method study. Source: own study of 2023

ID	Question	Response on a scale of 1 (strongly disagree) to 10 (strongly agree)	
VAR1	The development of the bioeconomy is important to guarantee access to good quality food and food security for society.	I strongly disagree	I definitely agree
VAR2	The bioeconomy enables to replace the products of a conventional refinery (chemicals, plastics, fuels and energy) with analogous products of a biorefinery, obtained exclusively from renewable raw materials of biological origin.	I strongly disagree	I definitely agree
VAR3	The bioeconomy enables the implementation of a circular economy and is in line with its assumptions.	I strongly disagree	I definitely agree
VAR4	The bioeconomy helps to reduce greenhouse gas emissions.	I strongly disagree	I definitely agree
VAR5	The implementation of bioeconomy supports the process of biodiversity protection, water recovery and CO2 sequestration.	I strongly disagree	I definitely agree
VAR6	The bioeconomy is a realistic and rational solution from the economic point of view.	I strongly disagree	I definitely agree
VAR7	The bioeconomy has great potential to create work places in the European Union.	I strongly disagree	I definitely agree
VAR8	The bioeconomy can be or is of great economic importance for the country I come from.	I strongly disagree	I definitely agree
VAR9	The bioeconomy enables the implementation of the Sustainable Development Goals.	I strongly disagree	I definitely agree
VAR10	Overall, I have positive views and feelings about the bioeconomy.	I strongly disagree	I definitely agree
VAR11	I believe that the bioeconomy should be promoted and investments in this area should be rewarded and/or supported by the administration.	I strongly disagree	I definitely agree
VAR12	I am interested in the subject of bioeconomy and, if possible, I engage in activities and projects related to it.	I strongly disagree	I definitely agree
VAR13	The development of the bioeconomy raises my concerns.	I strongly disagree	I definitely agree

3. Method

The empirical material obtained from the study made it possible to distinguish groups of people with different perceptions and knowledge about the bioeconomy. The segmentation of respondents in this study was carried out using the method of classification and regression trees (C&RT – Classification and Regression Trees). This procedure first appeared in the literature in 1963 in the context of sociological research through an article by Morgan and Sonquist (Morgan & Sonquist, 1963). However, decision trees were not popularized until 1984 (Breiman et. al., 2017).

The decision tree method leads to the creation of a graph in which vertices are referred to as nodes, edges as branches, and vertices without descendants as leaves (Kozak & Juszczuk, 2016). The advantage of the method used is the simple and intuitive construction of trees, which makes them interpretable in a direct way. The classification resulting from the application of the procedure can be easily written in the form of decision rules, and more importantly, the decision tree method allows data analysis based on quantitative and qualitative variables (Dudek, 2014). For classification trees, the dependent variable is measured on a nominal or ordinal (weak) scale, while for regression trees, the dependent variable is measured on a strong (e.g., range) scale (Salamaga, 2015).

In order to obtain a classification tree using the C&RT method, the algorithm repeatedly performs the steps at each node, as follows:

1. Finding the split point for each predictor.
2. Finding the best node splitting criterion.
3. Spliting the node using the best split from the previous step (unless the stop split rule is met).

The algorithm used to construct the decision tree solves the maximization problem. It searches all attributes and finds the best division, i.e., the largest value of the impurity measure (Timofeev, 2004).

At node t, the probabilities p(j,t) , p(t) and p(j|t) are estimated by:

$$p(j,t) = \frac{\pi(j)N_{w,j}(t)}{N_{w,j}} \quad (1)$$

$$p(t) = \sum_{j} p(j,t) \quad (2)$$

$$p(j|t) = \frac{p(j,t)}{\sum_{j} p(j,t)} \quad (3)$$

where: p(j,t) , j = 1, …, j – probability of occurrence of a case in class j and node t; p(t) – probability of a case occurrence in node t; p(j|t) , j = 1, …, j – probability of a case in class j given that it is assigned to node t; π(j), j = 1, …, j – initial probability Y = j;

where:

$$N_{w.j} = \sum_{n \in h} w_n f_n I(y_n = j) \quad (4)$$

$$N_{w.j}(t) = \sum_{n \in h(t)} w_n f_n I(y_n = j) \quad (5)$$

where: I (a = b) the pointer function adopts the value 1 when a = b , otherwise 0; n – case; wn – case weight related to case n; fn – frequency weight associated with case n; h – whole training sample; t – node; j – class; Y – dependent variable, if it is categorical with J classes then it takes values wC = {1, ..., J}.

The best division maximizes the division criterion Δi(s, t). If the dependent variable Y is categorical, the division criterion is the decrease in the impurity of the Gini measure.

$$i(t) = \sum_{i,j} C(i|j)\, p\,(i|t)\, p(j|t) \quad (6)$$

$$\Delta i(s,t) = i(t) - p_L i(t_L) - p_R i(t_R) \quad (7)$$

where: C(i|j) – cost of misclassification of a case class j as a case of class i; pL and pR are the assignment probabilities of the case to the left node tL and to the right node tP, respectively. They are estimated as: pL = p(tL) / p(t) and pR = p(tR) / p(t); s – split; s* – best split.

The completion of the classification tree development occurs when at least one of the stopping rules is applied, such as:

1. all cases in the node will have the same values of the dependent variable;
2. all cases in the node have identical values for each predictor;
3. the depth of the tree reaches the maximum limit value (set by the researcher);
4. as a result of node fragmentation, a child node will be created of the size smaller than its minimum size;
5. for the best split s* of node t, the determinant of the split ΔI(s*,t) = p(t)Δi(s*,t) is smaller than the minimum criterion defined by the researcher.

Classification trees created for the purpose of this study were made using the Statistica software. For the categories related to the understanding of the state of perception and knowledge about the bioeconomy (obtained from 13 closed questions), the dependent variable was the place of employment or education of the respondents strictly defined in the research tool (survey).

The level and nature of perception and knowledge about the bioeconomy is the result of many variables, the synthesis effect of which may be reflected in the affiliation of the respondents to university communities in selected countries. The subsets resulting from the C&RT division can be treated as segments of respondents who are characterized by a similar level of knowledge about the bioeconomy and the way it is perceived. During the interpretation of the results of the C&RT analysis, the focus was on the characteristics of selected segments of respondents designated by the end nodes of the classification tree.

4. Results

The survey sample ultimately amounted to 448 people (42% of respondents from Poland, 28% from the Czechia, 20% from Portugal and 11% from Spain). Furthermore, the student-teacher participation has different ratios (in Poland 101:50; in Czechia 75:18; in Spain 32:15; in Portugal 56:30). Poland, Portugal and Spain have a high participation of teachers while the Czechia is the only one out of the four regions that has a higher student participation. The remaining group of 71 participants included university employees who were not academic staff (17 respondents) and students who did not specify their course of study (54 respondents).

For the analysis of statistical data, three comparative ranges have been established in accordance with the results obtained in the survey. Responses could range from 1, which equaled zero, to 10, which represented expert knowledge. To facilitate the analysis, the answers were grouped in ranges from 1 to 5; >5 to <6.5; and > 6.5 to 10, corresponding to low, medium and high values, respectively. Using the method of classification trees, the observations obtained at 4 universities were divided into nodes – 27 terminal nodes were obtained (Table 3).

Based on the obtained research results, it was found that in nodes 4 and 14 (114 observations – with dominance of the Czechia), the respondents answered that the development of the bioeconomy did not raise their concerns to a high degree (node 4) or caused concern among the respondents at an average level (node 14). At the same time, the surveyed respondents in this group did not show interest in the subject of bioeconomy and did not engage in activities and projects related to it.

As for the respondent from Spain (Node 6–15 observations), he/she is likely to disagree with the statement that the development of the bioeconomy is important to guarantee the society access to good quality food and food security. At the same time, the respondents from this group were moderately interested in the topic of bioeconomy and were moderately involved in activities and projects related to it. Furthermore, in the analyzed community, the development of bioeconomy did not raise any concerns.

In node 9 (107 observations), respondents from Poland dominated. They recognized that the bioeconomy enables the implementation of the Sustainable Development Goals. Respondents also confirmed that the development of the bioeconomy is important to guarantee the society access to good quality food and food security. It was found that the respondents grouped in node 9 were moderately interested in the topic of bioeconomy and engaged in activities and projects related to it at an average level. Similarly, the development of the bioeconomy did not raise concerns among the respondents.

Node 26 (44 observations) comprised mainly of respondents from Portugal. They assessed that the bioeconomy has a medium potential for creating employment in the European Union. At the same time, the surveyed respondents were of the opinion that the development of the bioeconomy is of medium importance for guaranteeing the society access to good quality food and food security. The respondents grouped in node 26 stated that the bioeconomy enables the implementation of the Sustainable Development Goals at an average level and that they are moderately interested in the topic of bioeconomy. In addition, the surveyed respondents indicated that the implementation of bioeconomy supports the process of biodiversity protection, water recovery, and CO2 sequestration on average level. At the same time, the development of the bioeconomy raised medium concerns among the respondents from this group.

Tab 3. Numerical construction of the classification tree for concepts related to the term bioeconomy for data obtained as part of research at 4 selected European universities. Source: own study of 2023 in the Statistica program

Node number	Left branch (number)	Right branch (number)	Node size	Place of work or education, location of the university	Splitting variable	Split (constant)
1	2	3	448	Poland	VAR13	3.5
2	4	5	168	Poland	VAR12	2.5
4			42	Czechia		
5	6	7	126	Poland	VAR1	5.5
6			15	Spain		
7	8	9	111	Poland	VAR9	5.5
8			4	Portugal		
9			107	Poland		
3	12	13	280	Czechia	VAR12	4.5
12	14	15	82	Czechia	VAR13	7.5
14			72	Czechia		
15			10	Poland		
13	18	19	198	Poland	VAR5	4.5
18			9	Poland		
19	20	21	189	Portugal	VAR12	9.5
20	22	23	171	Portugal	VAR9	8.5
22	24	25	90	Poland	VAR1	8.5
24	26	27	61	Portugal	VAR7	7.5
26			44	Portugal		
27			17	Poland		
25			29	Poland		
23	28	29	81	Portugal	VAR3	5.5
28			4	Czechia		
29	30	31	77	Portugal	VAR4	7.5
30			10	Czechia		
31			67	Portugal		
21			18	Poland		

To better illustrate the numerical construction of the classification tree, a graphical version is shown below (Figure 1).

The study of the strength of individual predictors in differentiating segments of respondents as part of the answers obtained at four European universities, showed that the variable VAR12 had the greatest impact on the affiliation of the respondents to university communities in selected countries (I am interested in the topic of bioeconomy and, if possible, I engage in activities and projects related to it). Variable VAR10 had a high predictive property (generally, I have positive opinions and feelings about the bioeconomy). Variable VAR4 (bioeconomy helps to reduce greenhouse gas emissions) had a lower rank (Table 3).

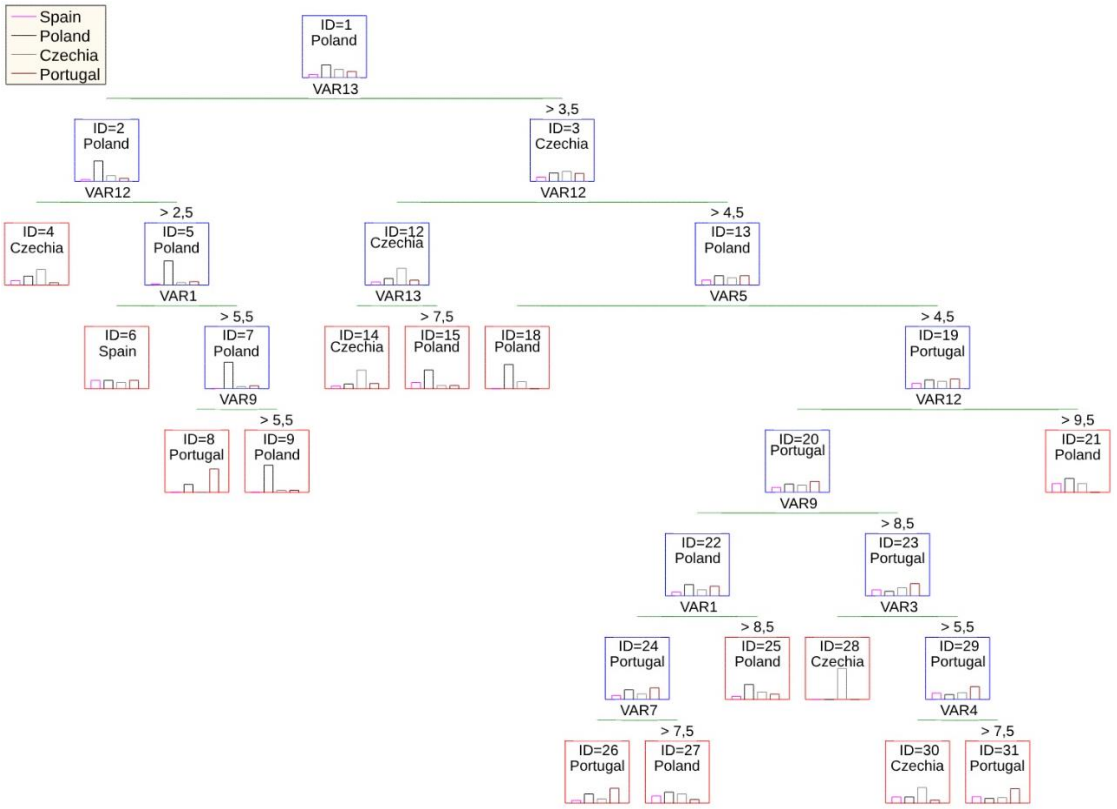

Fig 1. Graphic version of classification tree for concepts related to the term bioeconomy for data obtained as part of research at 4 selected European universities. Source: own study of 2023 in the Statistica program

Tab 4. Importance of discriminant variables at the stage of creating a classification tree for perception and knowledge about bioeconomy. Source: own study of 2023 in the Statistica program

ID	Variable	Importance
VAR12	I am interested in the subject of bioeconomy and, if possible, I engage in activities and projects related to it.	100
VAR10	Overall, I have positive views and feelings about the bioeconomy.	97
VAR4	The bioeconomy helps to reduce greenhouse gas emissions.	86
VAR1	The development of the bioeconomy is important to guarantee access to good quality food and food security for society.	85
VAR11	I believe that the bioeconomy should be promoted and investments in this area should be rewarded and/or supported by the administration.	83
VAR9	The bioeconomy enables the implementation of the Sustainable Development Goals.	82
VAR13	The development of the bioeconomy raises my concerns.	80
VAR7	The bioeconomy has great potential to create work places in the European Union.	78
VAR2	The bioeconomy enables to replace the products of a conventional refinery (chemicals, plastics, fuels and energy) with analogous products of a biorefinery, obtained exclusively from renewable raw materials of biological origin.	74
VAR6	The bioeconomy is a realistic and rational solution from the economic point of view.	74
VAR3	The bioeconomy enables the implementation of a circular economy and is in line with its assumptions.	73
VAR5	The implementation of bioeconomy supports the process of biodiversity protection, water recovery and CO2 sequestration.	71
VAR8	The bioeconomy can be or is of great economic importance for the country I come from.	45

Splitting the nodes showed that there are differences in the perception and knowledge of the bioeconomy. Therefore, it was decided to segment the respondents' answers according to their country of employment and education and academic degree/title. For this purpose, the average answers in individual university communities for all the analyzed questions were compared. From all observations, an academic group (students who specified their field of study and academics) was selected to approximate the state of perception and knowledge of the bioeconomy only in the academic community in the countries studied. Therefore, for further analysis, non-academic university staff, students who did not specify their course of study, and students in master's programs (due to too few observations – 33 observations for all countries) were excluded from all study groups (448 observations). On this basis, a group of 344 respondents divided into five clusters was formed (Table 5).

Tab 5. Average answers of the respondents in terms of their employment or education and academic degree/title. Source: own study of 2023 in the Statistica program

Doctoral (student)	**VAR1**	**VAR2**	**VAR3**	**VAR4**	**VAR5**	**VAR6**	**VAR7**	**VAR8**	**VAR9**	**VAR10**	**VAR11**	**VAR12**	**VAR13**
Czechia	7.50	6.00	7.50	6.50	8.33	6.17	6.83	6.50	7.83	8.00	8.17	5.83	5.83
Spain	8.13	8.25	8.75	8.63	8.88	7.38	8.75	9.00	8.75	8.38	8.88	7.50	6.63
Poland	9.00	7.67	8.33	9.00	8.67	8.33	8.00	7.67	9.33	9.00	9.33	7.33	1.33
Portugal	9.50	10.00	10.00	9.00	10.00	9.50	10.00	10.00	9.50	10.00	10.00	9.00	8.50
PhD (employed)	**VAR1**	**VAR2**	**VAR3**	**VAR4**	**VAR5**	**VAR6**	**VAR7**	**VAR8**	**VAR9**	**VAR10**	**VAR11**	**VAR12**	**VAR13**
Czechia	7.60	7.47	8.07	7.40	7.93	6.53	7.67	7.27	8.53	7.73	7.80	5.53	6.40
Spain	7.38	7.00	7.88	8.25	7.75	7.00	7.50	7.75	7.88	7.63	7.88	6.25	6.88
Poland	8.91	7.86	9.05	8.18	8.41	8.18	7.45	8.45	8.68	8.82	8.55	7.41	3.41
Portugal	8.07	7.07	8.29	7.86	8.21	6.57	7.00	7.14	7.71	7.57	7.43	5.14	4.71
Habilitation / Profesorship (employed)	**VAR1**	**VAR2**	**VAR3**	**VAR4**	**VAR5**	**VAR6**	**VAR7**	**VAR8**	**VAR9**	**VAR10**	**VAR11**	**VAR12**	**VAR13**
Czechia	8.67	8.00	8.33	9.33	9.00	7.67	8.33	8.33	8.67	8.33	9.00	7.33	7.00
Spain	6.86	6.57	8.00	7.57	7.57	7.86	6.86	8.14	8.14	7.29	7.00	4.43	4.71
Poland	8.50	7.82	8.46	7.79	8.18	7.18	7.11	8.00	8.36	8.32	8.07	6.89	4.11
Portugal	7.94	6.81	8.75	8.06	8.31	8.25	7.88	8.06	8.88	8.38	7.56	6.19	5.63
Science and technology (student)	**VAR1**	**VAR2**	**VAR3**	**VAR4**	**VAR5**	**VAR6**	**VAR7**	**VAR8**	**VAR9**	**VAR10**	**VAR11**	**VAR12**	**VAR13**
Czechia	7.67	5.67	7.07	7.00	7.53	5.27	5.93	6.73	7.53	6.87	7.33	4.07	4.47
Spain	7.67	7.00	7.75	8.00	7.92	5.83	7.33	7.75	8.25	8.08	8.17	5.00	6.42
Poland	8.79	8.38	8.41	8.28	8.72	7.90	7.93	7.45	8.03	8.79	8.69	6.66	3.31
Portugal	7.00	8.50	7.75	9.00	8.50	7.25	8.75	8.25	8.75	9.00	9.00	7.50	8.00
Bachelor (student)	**VAR1**	**VAR2**	**VAR3**	**VAR4**	**VAR5**	**VAR6**	**VAR7**	**VAR8**	**VAR9**	**VAR10**	**VAR11**	**VAR12**	**VAR13**
Czechia	7.80	7.44	6.78	7.16	7.38	6.66	6.80	7.30	7.52	7.22	7.58	3.76	4.76
Spain	9.00	7.71	9.14	8.57	8.86	8.43	8.86	9.57	9.43	9.00	9.14	4.86	7.00
Poland	7.89	7.56	6.81	7.39	7.41	6.74	7.28	6.98	7.72	7.48	7.56	4.98	3.85
Portugal	7.32	6.76	6.93	7.20	7.37	6.54	7.15	7.02	7.34	7.17	7.63	5.29	5.88

The analysis showed that the variables with the greatest discrepancies among selected groups of respondents were: VAR2, VAR6, VAR7, VAR12 and VAR13.

Students of doctoral programs in the Czechia claimed that the bioeconomy makes it possible to replace conventional refinery products (chemicals, plastics, fuels and energy) with analogous biorefinery products, obtained from renewable bio-based raw materials at an average level. The surveyed respondents in this group indicated that the bioeconomy is a moderately realistic and rational solution from the economic point of view. At the same time, the respondents from the group of students – doctoral students in the Czechia decided that they were moderately interested in the subject of bioeconomy and

that the development of the bioeconomy was of moderate concern to them. Respondents from the surveyed group of doctoral students from Spain and Portugal expressed concern about the expansion of the bioeconomy. On the other hand, respondents from Poland declared that they were not afraid of the development of the bioeconomy.

In the group of academic employees researchers with a doctoral degree in the Czechia, Spain and Portugal, it was observed that the interest in the topic of bioeconomy and projects related to it was at an average level. At the same time, a high interest in bioeconomy was noted in the Polish group of respondents. In addition, respondents from the Czechia considered the development of the bioeconomy to be of medium concern, and concern about the expansion of the bioeconomy was high among respondents from Spain. The development of the bioeconomy did not raise concerns among the respondents from Poland and Portugal in the study group.

The study of academic employees holding the degree of professor or habilitated doctor showed that interest and involvement in activities and projects related to bioeconomy was high among respondents from the Czechia and Poland, while average or low for respondents from Spain and Portugal. The development of the bioeconomy was a cause for concern among respondents from the Czechia, while in Spain, Poland and Portugal, concerns about the expansion of the bioeconomy were at a medium or low level.

Respondents who studied science and technology programs in Czechia stated that the bioeconomy makes it possible to replace the products of a conventional refinery with biorefinery products obtained from renewable raw materials of biological origin at an average level. At the same time, the respondents in this group on average agreed with the statements that the bioeconomy is a realistic and rational solution from the economic point of view and that the bioeconomy has great potential for creating jobs in the European Union. Respondents from Spain in the study group also stated that the bioeconomy has medium potential for job creation in the European Union. In addition, among students of science and technology in the Czechia and Spain, low interest in the subject of bioeconomy and low involvement in activities and projects related to it were observed. In Poland and Portugal, however, this phenomenon was completely opposite – the respondents confirmed their interest in the topic of bioeconomy. A survey of a group of science and technology students in Portugal showed that they were concerned about the development of the bioeconomy. At the same time, among respondents in Poland, Spain and the Czechia, concern about this phenomenon was low or medium.

Respondents in the community of undergraduate students in the Czechia, Spain and Poland stated that the topic of bioeconomy was not interesting for them. At the same time, interest in the researched issues was at an average level in Portugal. Undergraduate students in Spain indicated that they were concerned about the development of the bioeconomy, while respondents from the Czechia and Poland indicated no concern in this regard. On the other hand, among the respondents from Portugal, it was observed that the development of the bioeconomy raises their concerns to a medium degree.

The research results of this study confirmed that the respondents in academic group are diverse in terms of two important characteristics. It was observed that the respondents differed mainly in the way they perceived the development of the bioeconomy. It was found that around 35% of 344 respondents were highly or moderately concerned about the expansion of the bioeconomy. In addition, it was estimated that about 71% of the 344 respondents were interested in the topic of bioeconomy and engaged in activities and projects related to it at an average level. The other answers given in the survey were relatively similar and showed that the academic community has knowledge about the bioeconomy and perceives it as a positive phenomenon. Only slight discrepancies appeared among the answers concerning the VAR2, VAR6 and VAR7 variables in the groups from the Czechia and Spain.

The groups with the smallest discrepancies in the knowledge and perception of bioeconomy were the following: academic employees of universities with a doctoral degree; professors or habilitated doctors and undergraduate students (about 77% of 344 observations). However, the greatest discrepancies in the perception of bioeconomy and knowledge about it were noted in the group of students of doctoral and science and technology programs (about 23% of 344 observations).

A study conducted using the C&RT classification and regression tree method, which was carried out on a group of 448 respondents, showed that within the presented characteristics of individual nodes (nodes: 4, 14, 6, 9 and 26 – about 62% of observations), the development of bioeconomy did not raise concerns of respondents in high or medium degree. About 49% of respondents decided that the bioeconomy is at the best an average interesting field a medium or not very interesting field of science. Nearly 27% of respondents (nodes 6 and 9 – 122 observations) from groups dominated by records from Spain and Poland stated that the development of the bioeconomy is important to guarantee access to good quality food and food security for the society. On the other hand, among the respondents grouped in node 26 (44 observations), where observations from Portugal dominated, it was observed that the expansion of the bioeconomy was of medium importance for the respondents to ensure access to good quality food for the society.

5. Conclusions

Thanks to the study, it was possible to combine the aspects of the labor market and education as well as the respondents' education with hard-to-measure categories responsible for the level of knowledge and perception of the bioeconomy.

The presented research results may support the identification of problems related to the popularization of bioeconomy and knowledge about it. Both studies showed that regardless of the place of employment or education or obtained academic degree, a large group of respondents were concerned about the development of the bioeconomy. At the same time, the large group of respondents did not express interest in the subject of bioeconomy. The obtained research results in the context of the researched field indicate the existence of serious barriers to the further development of bioeconomy.

Despite the fact that the general knowledge of the respondents about the bioeconomy was satisfactory, the results of the research may help in optimizing study programs – so that they generate greater interest among students. Bioeconomy is a relatively new field of science that results from new regulations in economies, bioeconomy strategies are being implemented on all continents. Therefore, the increased interest in this subject should be an important element of education at the academic level. Meanwhile, a survey among academic employees holding a doctorate, professor or habilitation degree showed that interest in bioeconomy is uneven and depends on the place of employment, despite the fact that all the surveyed universities implement elements of bioeconomy in their curricula.

University education possibilities in the field of bioeconomy varied from country to country. In particular, Poland has the largest number of bioeconomy study programs of all the countries studied. At the same time, this country was characterized by a low level of regulation for bioeconomic development regarding the legislative aspect. Spain and Portugal were characterized by a smaller number of bioeconomic study programmes than Poland. On the other hand, legal regulations and plans for the bioeconomy implementation were more extensive in these countries. The situation was quite different in the Czechia, where although the universities did not have separate bioeconomy programs of studies, the bioeconomy is included in many national development plans.

As previously indicated, the level of knowledge in the field of bioeconomy in the academic community was satisfactory. However, it is worth noting that it was also slightly higher in Poland, Portugal and Spain compared to the Czechia. More importantly, Poland, Portugal and Spain had the highest percentage of people employed in industries related to the bioeconomy. In addition, Poland, Portugal and Spain have universities that offer bioeconomy majors – so they are capable of creating a larger workforce for bioeconomy-related industries and services. This suggests that university bioeconomic education plays an important role in the countries surveyed, which becomes apparent in the creation of new jobs and increased awareness of bioeconomy and changed attitudes towards it.

Unfortunately, the results of the study do not make it clear which country has a higher level of bioeconomic education and whether greater regulation of bioeconomic development affects the level of bioeconomic knowledge. When drawing far-fetched conclusions, a caution should be applied as it is possible that with an expanded study group, the survey results would be different. The degree of

perception within the survey of academic communities varied. The bioeconomy was of no concern to the Polish and Czech groups while it was of medium concern to the Spanish and Portuguese groups. The following trend shows that the existence of educational opportunities in the bioeconomy does not necessarily affect its positive perception.

A study published in 2016 showed that the majority of surveyed respondents (Polish students) had not encountered the term bioeconomy in everyday life or at the university (Drejerska, 2017). In contrast, based on the results of the present article, it was assessed that the level of knowledge among the surveyed respondents was satisfactory. Another paper published in 2022 emphasizes that in the group of surveyed respondents, more than two-thirds had heard of bioeconomy (Výbošťok et al., 2022). This may confirm that the concept is becoming more popular over time, and the level of knowledge about the bioeconomy is increasing. Research published in 2020, which investigated the perception of the bioeconomy among forestry students in selected countries, found that it differs from one region of Europe to another, which may have implications for various developmental paths toward the transition to bioeconomy (Masiero et al., 2020). The difference in perceptions of bioeconomy in this aspect is also highlighted in this article.

On the basis of a study conducted with a group of German students, it was pointed out that the age of the person, the chosen model of study or educational program has an impact on the assessment of the bioeconomy (Golowko et al., 2019). This indicates that in order to effectively implement the bioeconomy, at least a basic element of it should be introduced in more study programs. In addition, an important role can be performed by the media, which would positively influence the perception of the bioeconomy through the implementation of appropriate social campaigns.

The conducted study demonstrated that the state of perception and knowledge about bioeconomy among the respondents varies depending on the surveyed country in which the respondents work or are educated. The level of knowledge of respondents working or studying at selected universities was similar, while the perception of bioeconomy differed depending on the place of work, education and academic degree or title.

The presented analysis confirmed the usefulness of classification trees for segmentation of respondents due to the perception of bioeconomy and the state of knowledge about it. Undoubtedly, the advantage of the method used was the easy interpretation of the obtained model. However, the procedure used has some limitations that make the classification tree model unstable because small changes in the data set can lead to different splits. The limitation of the research is also the fact that it was conducted on respondents working or studying at selected universities – this means that the generalizations included in the content of the article may be limited. Certainly, it would be interesting to compare the perception and knowledge about bioeconomy among employees of other sectors in individual countries.

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