LOCATION AND STRUCTURE OF THE BIOECONOMY IN THE 13 NEW EU MEMBER STATES

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Abstract
The bioeconomy constitutes a significant part of the economies of many EU countries. Its structure is very diverse in the NMS-13 countries. The study aims to determine the importance of the bioeconomy sector in the new EU member states and to determine countries' specialization in the bioeconomy industries, considering the GVA (Gross value added) creation and employment. The share of the bioeconomy in employment is as much as 14.6% and in GVA—7.5%. This is two times more than the average for the EU. Agriculture recorded the largest employment within the bioeconomy – 63% jobs, while its share in GVA was only 35%. The bioeconomy in NMS-13 was characterized by significant spatial concentration. The forestry and wood processing industry are dominant in the north of the region. In contrast, the countries in the south had a high concentration of agriculture and food processing. Labour productivity in the bioeconomy remained low and amounted to only about 51% of the productivity in the entire economy in 2021. The future development of the bioeconomy should be based on increasing the importance of sectors producing high-value-added products, which now constitute only 8.9% of the bioeconomy's GVA in NMS-13. Depending on the country, this is food or wood processing, as well as biochemicals, biopharmaceuticals, or bioenergy. Economic policy should be directed towards the sustainable use of locally available biomass resources. This will also allow for maintaining rural areas' economic and social vitality. The bioeconomy is still an essential sector in NMS-13 for creating jobs and income in rural areas.
Keywords: bioeconomy, location quotient, spatial concentration, gross value added, employment.

Introduction

Bioeconomy encompasses the production and processing of biomass to supply food, feed, non-food materials, and energy. A portion of the materials and energy currently derived from non-renewable sources in the economy can be replaced by their counterparts, which are partially or entirely produced from biomass (e.g., plants and microorganisms). In the European Union (EU) bioeconomy strategies, substituting fossilbased materials and energy with biomass-based solutions has been identified as a key strategic development direction (European Commission, 2012, 2018). This transition is expected to reduce environmental pressure, increase employment, and enhance the added value of the EU's 'green' economic sectors while also contributing to climate change mitigation (Pascoli et al., 2022). The development of the bioeconomy aligns with efforts to expand the scope of the circular economy, fostering industrial circularity and promoting growth and job creation in rural areas. Implementing the Bioeconomy Action Plan is a crucial component of the Circular Economy Action Plan European Comission, 2020). In EU member states, national bioeconomy development strategies have been formulated to reflect the potential and aspirations of individual countries and regions in advancing the bioeconomy sector.

Measuring the share of bioeconomy in the economy

Different approaches are used to quantify the importance of the bioeconomy. This has led to varying estimates of the importance of this sector (Vandermeulen et al., 2011). They were based on the share in the creation of gross margin or on calculations based on input-output tables (Heijman, 2016). Further activities resulted in a model developed in the EU based on biomass flow between sectors and its share in the final product (Gurría et al., 2020). It was assumed that the importance of the bioeconomy in the sectors is the same as the biomass share in relation to fossil, mineralbased or synthetic feedstock (Ronzon et al., 2020).

The quantification method based on 'bio-shares' allows for the calculation of the share in production, gross value added, and employment and makes it possible to compare the obtained values to gross value added (GVA) and employment in the entire economy. The calculation technique used to assess the bioeconomy in EU countries is based on an integrated 'baseline' approach, i.e., the share of biomass in finished production is taken into account (Lasarte-López et al., 2023).

The importance of the bioeconomy sector in the economy

The basic idea of developing the bioeconomy beyond the traditional sectors, i.e., agriculture, forestry, and fisheries, is to replace non-renewable fossil resources used in industry and the energy sector with renewable biological resources.

Many efforts are being made within the development strategies in the EU and beyond to increase the share of bio-raw materials in final production (Thomchick et al., 2024). However, traditional sectors still dominate in employment and production although more and more attention is now being paid not to resource substitution, but to biotechnological innovations, which enable the use of bio-raw materials to produce products with high added value. This is achieved by supporting investment and research in the bioeconomy, including in traditional sectors. Research funds serve both to improve efficiency and to protect the environment and biodiversity (Muska et al., 2022; Popluga et al., 2015; Zeverte-Rivza & Bulderberga, 2015).

The development of the bioeconomy is also seen as an opportunity to enhance food security (Gawel et al., 2019) and reduce greenhouse gas emissions (Pascoli et al., 2022). On the other hand, it is noted that many technologies have not yet been scaled up to industrial levels (Parajuli et al., 2021), and increasing demand for biomass for energy purposes and the production of advanced bioproducts may lead to competition with traditional biomass applications, such as food production or the manufacturing of paper and wood-based products (Parajuli et al., 2021; Wicki, 2017). Additionally, it should be emphasized that the development of the bioeconomy is often driven by subsidies rather than economic feasibility (Salma et al., 2024). Many proposed solutions lack proven economic efficiency and are therefore associated with a high risk of failure (Czernyszewicz, 2016). It was also confirmed that achieving environmental goals in the bioeconomy through agriculture alone is difficult because of its almost constant emissivity per unit (Bennetzen et al., 2016; Rawa & Pietrzykowski, 2024).

Expectations related to bioeconomy development

In the EU, in accordance with the adopted bioeconomy development strategy, the reaching of both traditional and new objectives is expected. These include:

- Ensuring food security through more environmentally sustainable methods.
- Sustainable use of natural resources to prevent excessive competition for biomass and biodiversity loss.
- Reducing dependence on non-renewable resources, including fossil fuels.
- Efficient processing of organic waste within the circular economy framework.
- Mitigating climate change by reducing fossil energy demand and lowering emissions.
- Creating jobs and maintaining economic competitiveness, including through technological development and innovation.

It should be noted that, depending on their available natural biomass resources, these ambitious goals may be achieved to varying degrees and in different ways across individual countries.

The above premises became the basis for setting the aim of this work. Its aim is to determine the role of the bioeconomy in the economies of new EU member states, identify structural differences, and compare labour productivity in the bioeconomy sector and the economy.

In the EU, the bioeconomy sector employed 17.2 million people in 2021, representing 8.2% of total employment. In NMS-13, the share of jobs in the bioeconomy was higher, amounting to 14.6% in 2021, representing 6.97 million jobs. In the countries surveyed, the importance of the bioeconomy sector is almost twice as high as in the EU as a whole (8.2%), which justifies a more detailed assessment of the changes taking place.

As economies develop, the share of employment in the bioeconomy decreases, and increasingly higher labour productivity is achieved (Faber & Jarosz, 2023). It is also clear that this sector may be strongly localized, and the location depends on the availability of natural resources in individual countries. In some countries, high biomass availability results from good conditions for the development of agriculture; in others, e.g. in Sweden, Finland, and Latvia, from large forest biomass resources. In larger countries, but not only, there is a differentiation of the potential of the bioeconomy in individual regions (Komor, 2018; Muska et al., 2022; Nowak & Kobiałka, 2017).

The use of the wealth of resources in a given region can contribute to economic growth (Refsgaard et al., 2018). The easiest is to observe changes in the internal structure of the bioeconomy, e.g. the increase in the role of food or wood processing at the expense of the importance of agriculture or forestry (Popluga et al., 2024; Wicka & Wicki, 2024). However, innovative sectors of the bioeconomy with high-added value products are expected to develop rapidly, e.g., the production of biopharmaceuticals and biochemicals.

The study aims to determine the difference in the importance of bioeconomy in the new EU member states and to determine changes in the importance of bioeconomy in the creation of GVA and employment. The study covered 13 countries that joined the EU in 2004 and later. These are Bulgaria, Croatia, Cyprus, Czechia, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Romania, Slovakia and Slovenia (NMS-13). The research period covers the years 2008–2021.

Materials and Methods

The source data was obtained from the bioeconomy database: *Jobs and wealth in the EU bioeconomy / Joint Research Centre – Bioeconomics* (Lasarte López et al., 2022). Following the applied methodology there, the output-based approach is used.

Data on employment, output, and GVA were collected for each of the bioeconomy sectors distinguished in the database. Based on the gathered data, the significance of the bioeconomy in national economies was determined by assessing its share in the total economy. The dynamics of changes in the bioeconomy's importance within national economies from 2008 to 2021 were analyzed regarding employment, turnover, and GVA.

Labour productivity in the bioeconomy was also determined and compared. It was defined as the value-added divided by the number of people employed. The specialization of countries in the bioeconomy and bioeconomy spatial concentration were determined using the location quotient (LQ) (Billings & Johnson, 2012; Carroll et al., 2008). The following formula for LQ was used:

$$LQ_{b,c,y} = \frac{\frac{B_{b,c,y}}{E_{c,y}}}{\frac{B_{b,y}}{E_y}} \quad (1)$$

where:
$B_{b,c,y}$ – size of sector *b* in country *c* and year *y* according to a specific variable (e.g. employment, GVA),
$E_{c,y}$ – total value of the variable in country *c* and year *y*,
$B_{b,y}$ – total size of sector *b* in year *y* in all the countries studied according to a specific variable,
E_{y} – total value of the variable in year *y* in all the countries studied.
LQ values above 0.9-1.1 indicate average or higher than average concentration/specialization of a given country in a specific production (Miller et al., 1991).

Results and Discussion

In the NMS-13, the significance of the bioeconomy varies across countries. Figure 1 illustrates the contribution of individual sectors to employment and GVA within the bioeconomy in studied countries. Agriculture is the largest sector in terms of employment and GVA, followed by food processing. Sectors related to forestry and wood processing also play an essential role. Notably, processing industries have a higher share of GVA than employment.
Agriculture accounted for as much as 63% of total employment in the bioeconomy. The second-largest sector, food processing, employed 17%, while wood processing accounted for approximately 9%. The contribution of agriculture to GVA was nearly half of its share in employment (35%), whereas food processing accounted for 29%, and wood processing and paper production contributed 14% to GVA. High-value-added sectors accounted for 4.6% of the bioeconomy employment share and generated 8.9% of its total gross value added. This means that labour productivity in these sectors was 1.93 times higher than the bioeconomy average.
In the NMS-13, the importance of the bioeconomy in the economy declined between 2008 and 2021. Employment fell by 2.4 million people (26%) while remaining at a similar level in the total economy. Turn over and GVA increased at just over 3% per year (Table 1), but this was about 0.5 percentage points lower than that observed in the entire economy. It can be stated with some approximation that the bioeconomy, as a whole, maintains a similar share in the turnover and creation of GVA, but its share in employment is declining.

Figure 1
Share of bioeconomy sectors in employment and gross value added of total bioeconomy in NMS-13 countries in 2021

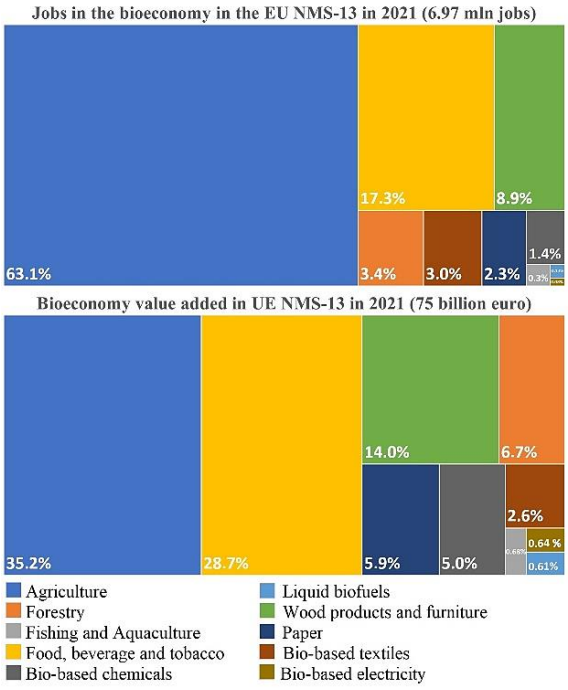


Table 1
The importance and dynamics of bioeconomy on the background of total economy in NMS-13 in 2008–2021

Year	Bioeconomy			Total economy		
	jobs (million)	GVA (billion euro)	turnover (billion euro)	jobs (million)	GVA (billion euro)	turnover (billion euro)
2008	9.37	75.0	265.8	46.83	943.9	2221.3
2009	8.96	64.7	223.4	45.94	847.8	1908.1
2010	8.75	67.8	241.2	44.74	901.6	2085.4
2011	8.46	75.2	266.3	44.52	945.7	2235.8
2012	8.39	71.7	270.7	44.61	956.8	2244.1
2013	8.16	75.6	278.5	44.53	963.1	2252.2
2014	8.07	77.1	281.3	45.19	995.4	2312.9
2015	7.84	76.6	284.5	45.63	1050.4	2419.3
2016	7.42	79.3	286.9	46.06	1074.6	2457.7
2017	7.41	87.7	308.7	46.86	1170.1	2685.8
2018	7.32	91.8	330.2	47.33	1260.4	2907.7
2019	7.11	96.9	342.1	47.54	1352.3	3088.9
2020	7.02	98.5	336.7	47.02	1324.0	2951.3
2021	6.97	108.8	381.5	47.62	1455.6	3362.5
CAGR in 2008–2021, in percent	–2.27	3.34	3.21	0.40	3.86	3.69

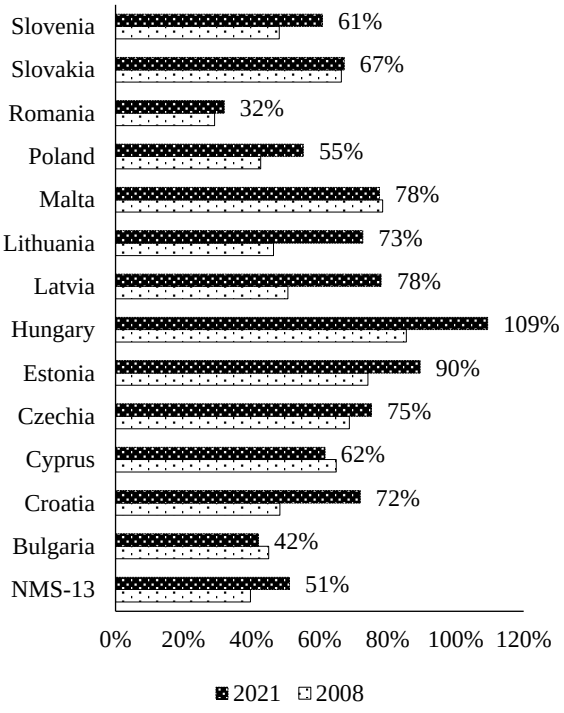
The decline in employment levels within the bioeconomy should be considered a positive trend. Given the significant share of traditional sectors, particularly agriculture, this indicates an increase in labour productivity in agriculture, which is a necessary condition for improving competitiveness. In 2008, the average labour productivity in the bioeconomy within NMS-13 was relatively low, amounting to only 39.7% of the overall economy's productivity. By 2021, labour productivity had increased by 11 percentage points, reaching 51.1% of the economy-wide productivity level (Figure 2).

The highest increases in labour productivity were observed in Croatia, Estonia, Hungary, Latvia, and Lithuania, where productivity rose by more than 20 percentage points. In contrast, countries such as Bulgaria and Romania did not experience any growth in bioeconomy labour productivity, and their productivity levels remained low.

Figure 3 illustrates the spatial concentration of the bioeconomy's significance in the economies of NMS-13 countries. Based on GVA generation, it was found that, in spatial terms, the bioeconomy is most concentrated in Latvia, Lithuania, Croatia, and Bulgaria. In contrast, its importance was relatively low in more industrialized countries such as the Czech Republic, Slovakia, and Slovenia, as well as in Cyprus and Malta, where the location quotient (LQ) was significantly below 1.

Figure 2

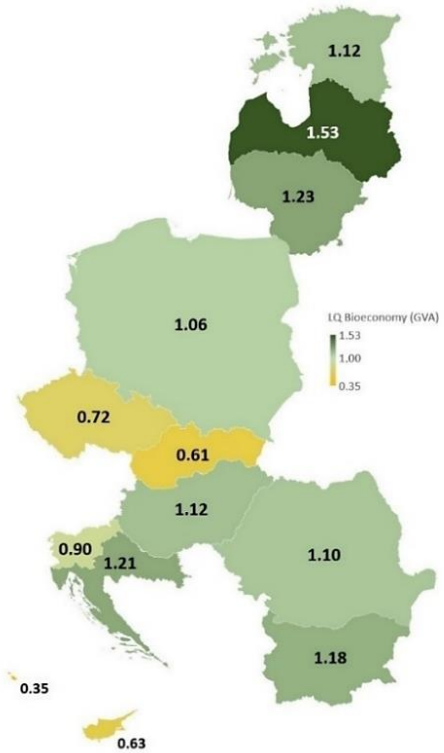
Changes in the level of labour productivity in the bioeconomy sector in NMS-13 in 2008–2021 (economy=100%)



The spatial concentration of the bioeconomy differs when analyzed in terms of employment. The highest importance of the bioeconomy in employment was observed in Romania, Bulgaria, Poland, and Latvia, where the share of jobs in this sector reached 15% (Table 2).

Figure 3

Geographical distribution of bioeconomy location quotient in NMS-13 states in 2021 (based on GVA)



On the other end of the spectrum, countries such as Cyprus, the Czech Republic, Hungary, Malta, and Slovakia had only about 7% of their workforce employed in the bioeconomy, which is half the level observed in the leading countries.

The significance of the bioeconomy, measured by total turnover, also varied. The highest shares were recorded in Latvia, Estonia, and Poland, while the lowest was observed in the more industrialized countries mentioned above.

The share of the bioeconomy measured by GVA was lower than the share in turnover in all the countries studied. This means that this sector is characterized by a lower-than-average capacity for creating added value in economies. This is primarily due to the large share of raw material sectors—agriculture and forestry. The importance of sectors with high added value (e.g., biobased chemicals) amounted to no more than 5% on average. Different type biorefineries are important in creating high-value-added products and waste recycling. It allows to reach cascading use of biomass (McCormick & Kautto, 2013; Sirkin & Houten, 1994).

Only in four countries namely Hungary, Latvia, Lithuania, and Slovenia was an increase in the significance of the bioeconomy within the economy

observed, considering its share in generated GVA. This indicates that the sector has undergone modernization and plays an important role in the development of these countries.
In contrast, in several countries, such as Bulgaria, Romania, and Estonia, the opposite trend was observed, with a significant decline in the share of GVA from the bioeconomy in the overall economy.
Overall, the bioeconomy is losing significance in most of the studied countries. Its share in employment is particularly decreasing, along with its contribution to turnover and GVA generation.

Table 2
Share of bioeconomy in NMS-13 countries in 2008-2021 and observed dynamics of change

Country	2008			2021			CAGR#		
	employ-ment	GVA	turnover	employ-ment	GVA	turnover	employ-ment	GVA	turnover
NMS-13	20.0%	7.9%	12.0%	14.6%	7.5%	11.3%	-1.34	-1.12	-1.35
Bulgaria	25.4%	11.4%	15.1%	21.0%	8.8%	12.6%	-1.34	-1.12	-1.35
Croatia	19.9%	9.6%	13.5%	12.6%	9.0%	12.5%	-5.01	-0.65	-0.79
Cyprus	9.0%	5.8%	8.1%	7.6%	4.7%	6.1%	-1.43	-1.16	-1.75
Czechia	8.4%	5.8%	8.6%	7.2%	5.4%	8.1%	-1.23	-0.36	-0.81
Estonia	11.6%	8.6%	13.6%	9.4%	8.4%	15.1%	-1.31	-0.81	0.24
Hungary	9.1%	7.8%	11.8%	7.6%	8.4%	11.5%	-1.02	**0.44**	-0.39
Latvia	14.4%	7.3%	11.4%	14.7%	11.5%	17.1%	-0.54	**1.91**	**1.90**
Lithuania	15.9%	7.4%	13.8%	12.6%	9.2%	14.6%	-1.85	**1.43**	-0.08
Malta	5.5%	4.3%	4.7%	3.4%	2.6%	3.3%	-4.45	-5.14	-4.08
Poland	19.3%	8.2%	13.6%	14.3%	7.9%	13.4%	-2.35	-0.28	**0.03**
Romania	36.4%	10.6%	14.5%	25.8%	8.2%	11.2%	-3.21	-2.64	-2.08
Slovakia	7.6%	5.1%	7.5%	6.8%	4.6%	6.6%	-1.19	-0.75	-1.24
Slovenia	13.9%	6.7%	9.5%	11.0%	6.7%	8.9%	-1.67	**0.58**	-0.18

Note: # - the annual rate of change was determined based on the exponential function for the entire time series, i.e. 2008–2021.

Individual countries exhibit varying significance of specific bioeconomy sectors within the overall structure. On average, in NMS-13, as much as 63% of those employed in the bioeconomy work in agriculture. In some countries, employment is dominated by agriculture and food processing, while in others, forestry and wood-processing sectors play a more significant role. The highest share of employment in agriculture within the bioeconomy was observed in Romania (80%), Bulgaria (74%), and Poland (61%). The forestry sector employed up to 15% of the workforce, with the highest shares in Slovakia and Latvia. Employment in high-value-added sectors reached up to 8%, with the highest shares in the Czechia, Slovenia, Hungary, Estonia, and Lithuania, compared to an NMS-13 average of 4.6%.
The structure of GVA by bioeconomy sectors exhibited different patterns compared to employment. In seven countries, the share of food processing in GVA was higher than in agriculture, indicating a shift toward a more modern structure, where raw food materials are processed on a larger scale (Table 3). The highest share of food processing in bioeconomy GVA was observed in the Czech Republic, Poland, and Croatia, as well as in the Cyprus and Malta. A similar trend was noted for forestry and wood processing. In countries such as Latvia, Lithuania, Estonia, and, to some extent, Slovakia and Slovenia, wood processing was even more significant than food processing. This reflects the specialization of these countries in wood production and processing, driven by the availability of natural resources. The basis of the bioeconomy in any of the countries analysed is food security, which is based on the role of food production (Aguilar et al., 2019).
The share of high value-added sectors in bioeconomy GVA in NMS-13 averaged around 9% in 2021, with Slovenia having the highest share (25%). Such a low proportion of the innovative sector in the bioeconomy indicates that in the studied countries, the bioeconomy still maintains a traditional structure based on agriculture and forestry.

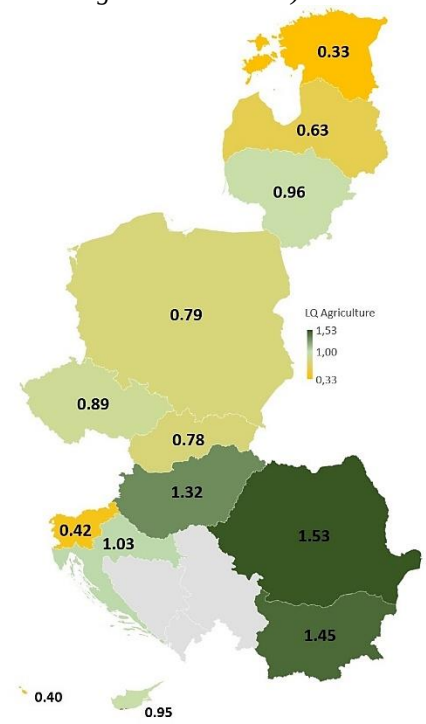
Table 3
The structure of GVA creation in bioeconomy sectors in NMS–13 in 2021

Country	***Agri-culture***	***Forestry***	***Food proces–sing***	***Wood proces-sing***	***HVA bioeco-nomy***
	in percent				
NMS-13	**35**	7	29	20	9
Bulgaria	**51**	5	25	7	11
Croatia	**36**	5	33	15	8
Cyprus	34	3	**43**	10	8
Czechia	**31**	6	**31**	22	9
Estonia	12	14	**20**	47	6
Hungary	**46**	3	27	11	13
Latvia	22	17	14	**40**	5
Lithuania	**34**	7	22	26	11
Malta	14	0	**42**	7	13
Poland	28	5	**36**	24	8
Romania	**54**	9	17	12	7
Slovakia	27	16	**28**	21	7
Slovenia	15	14	24	23	**25**

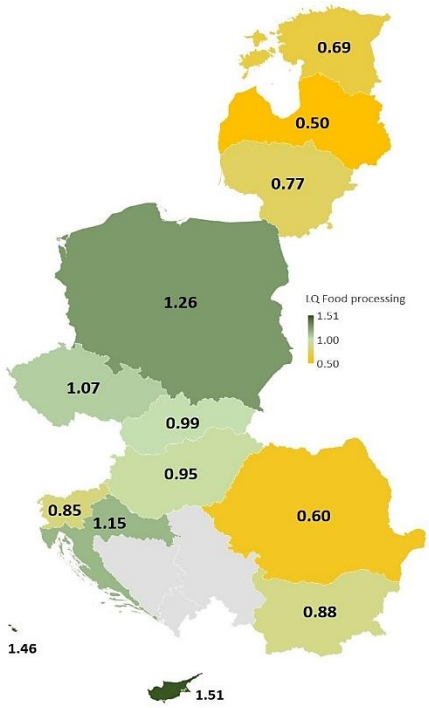
The geographical distribution of the bioeconomy's sectoral location quotient based on GVA is illustrated in Figure 4. A concentration of GVA generation from agriculture is evident in southern countries such as

Romania, Bulgaria, Hungary, and Croatia, whereas GVA from food processing is predominantly concentrated in Poland and the Czech Republic.
This pattern may be influenced, among other factors, by differences in agricultural production. In southern countries, there is a higher production of ready-to-eat food products, vegetables, and fruits, while in countries where food processing dominates, livestock production and crop production intended for processing play a more significant role.

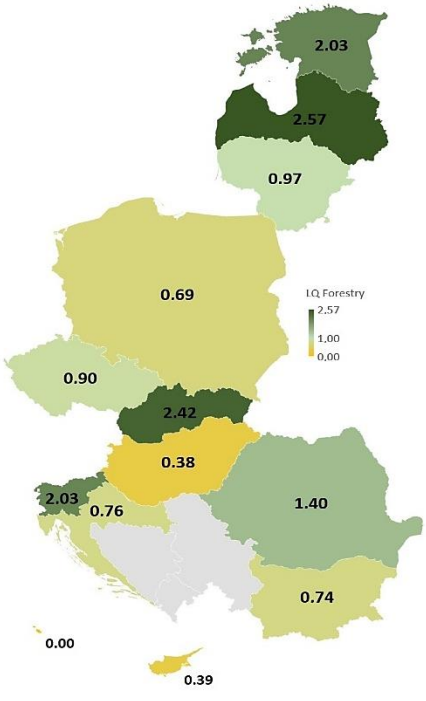
Figure 4
Geographic distribution of the bioeconomy location quotient by main bioeconomy sectors in NMS-13 in 2021 (based on gross value added)



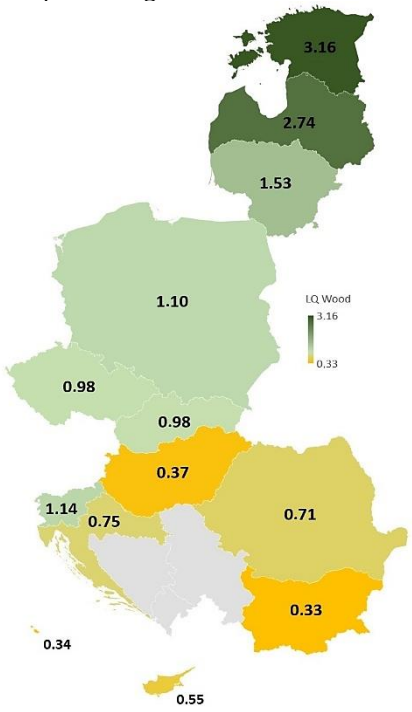
Agriculture



Food processing



Forestry



Wood industry

Forestry and wood products are sectors with strong spatial concentration. The location quotient for forestry reaches over 2 for Estonia, Latvia, Slovakia and Slovenia. Wood processing and paper production are similarly

strongly concentrated. In this case, there is also a concentration in Estonia, Latvia, and Lithuania. Poland also has a high indicator due to the relatively strongly developed production of paper, furniture and other wood products. In NMS-13, there is a great diversity in the development of bioeconomy sectors, which results from the natural resources available. Forestry and wood processing dominate in countries in the north, along with those with a large share of mountainous areas with large forest cover and wood resources for use. Agricultural production is concentrated in countries located in the south, with better soils and climate. Food processing plays a most considerable role in countries with strong agriculture, where the structure of agribusiness has also been modernized towards the production of food with higher consumer and export suitability. This concerns the countries in the centre of the study area, mainly the Czech Republic and Poland.

Conclusions

Based on the research and analyses conducted, it is possible to present several key conclusions.

1. The bioeconomy is an essential sector in the economies of NMS-13 countries. It generates about 7.5% of its GVA. Employment amounted to as many as 6.97 million people, which constituted 14.6% of total employment. For comparison, in the entire EU-27, it was 5.6% and 8.2%, respectively.
2. The importance of the bioeconomy in economies decreased. On average, the share in employment decreased from 20 to 14.6%, and the share in creating GVA decreased from 7.9 to 7.5%. Only in four countries, Latvia, Lithuania, Slovenia, and Hungary, did the share of GVA from the bioeconomy increase. In Latvia, it increased the most, from 7.5 to 11.3%. This means that these countries still have great potential in the development of the biomass-based industry.
3. The location of the bioeconomy is strongly concentrated in the countries studied. Bioeconomy was highly represented in countries such as Latvia, Croatia, Lithuania, Bulgaria, and Estonia. Bioeconomy was of relatively low importance in Slovakia, the Czech Republic, and Slovenia.
4. There is a significant differentiation between countries in sectoral specialization. Agriculture and food processing are strongly localized in Poland, the Czech Republic, Bulgaria, and Romania. Poland had the highest localization coefficient of food processing. Forestry and wood products production are concentrated in Latvia, Lithuania, Estonia, Slovakia, and Slovenia. Latvia and Estonia had the highest localization coefficient of bioeconomy sectors based on forest resources (above 2).
5. Labour productivity in the bioeconomy sector remained low, due to the high importance of traditional sectors, such as agriculture. The level of labour productivity reached only 51% of the productivity in the entire economy. Only in modern sectors of the bioeconomy, producing products with high added value, labour productivity was higher and close to the average for the entire economy.
6. The bioeconomy remains important to most national economies in NMS-13. Appropriate use of biomass resources can lead to increased prosperity in these countries and contribute to maintaining rural areas' vitality and environmental protection.

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