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Progress of EU Member States Regarding the Bioeconomy and Biomass Producing and Converting Sectors

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Abstract: The development of the bioeconomy on regional and national levels is heavily reliant on the establishment of precise and efficient governance frameworks. These structures encompass a wide range of components, spanning from financial support to regulatory tools and limitations. These mechanisms play a pivotal role in addressing the challenges that emerge during the bioeconomy’s growth. In this context, the necessity for continuous research to underpin and guide bioeconomy policies, while also bridging existing knowledge gaps, is glaringly evident. The current study brings a new perspective, using hierarchical cluster analysis as an exploratory approach and a technique for generating hypotheses. Its aim is to assess the progress of EU countries concerning the bioeconomy, including sectors involved in biomass production and conversion. The research draws on data published by the European Commission and Eurostat for the years 2015 and 2020, to capture the changes brought about by the adoption of the 2030 Agenda. The research findings furnish valuable insights into advancements in the bioeconomy and the clustering of countries based on their performance levels. Notably, Belgium and Denmark emerge as standout performers, potentially offering exemplary models of best practices.

Keywords: bioeconomy; biomass; sustainable development; 2030 agenda

1. Introduction

The major problems we face today mean that part of the way we carry out activities of all kinds has to be differently planned, differently organized, differently carried out, so that the impact on the planet is positive. A totally different approach to human activities is therefore inevitable, because we are going through a difficult period marked by major problems, particularly the exploitation of largely exhausted natural resources, population growth and accelerated climate warming with all the serious consequences that this entails. Being in balance with nature is no longer a subject that requires different debates and approaches, but rather a global objective that cannot be marginalized, omitted or neglected.

We are thus identifying totally different approaches to the way human activities are carried out, identifying sustainable strategies and long-term actions aimed at mitigating and combating rapidly and even radically the effects of global warming, of the depletion of natural resources, as is also envisaged in the 2030 Agenda and in other long-term strategies and plans at regional and local levels.

In this context, the bioeconomy is currently one of the few solutions that society can target and implement on a large scale, a point that is also highlighted in the strategies, poli-
cies and actions that governments and policy makers are intensively promoting, regardless of the country or region we are referring to.

Reflecting the bioeconomy in the sustainable development of society, and the way it works requires a complex approach, as it is primarily a knowledge-based economy where the resource and energy basics are derived from renewable biological resources such as plant and animal resources. The bioeconomy is also responsible for the transformation of existing environmental wastes into bio-economic products [1–3].

The bioeconomy is thus an accumulation of activities aimed at producing renewable biological resources or “biomass”, such as those from agriculture and forestry, which are then used in various other industries, such as the food industry, the textile industry, construction etc., relying exclusively on waste management.

At EU level, the bioeconomy strategy was launched in 2012, promoting new sustainable policy initiatives at regional, national and pan-European level. In the same vein, in 2019, the EU Green Pact was also initiated with the aim of stimulating the transition of all countries towards a sustainable, low-carbon economy by stepping up actions on food and energy security, biodiversity and natural resource management. The Green Deal includes, as a central element, the bioeconomy, which is solely responsible for structural, often radical changes in production and consumption [4,5].

The growing political interest in stimulating the bioeconomy at EU level is reflected in the actions promoted and implemented in all Member States, as evidenced in particular by the adopted “results-based” management of the bioeconomy transition status performance indicators. At EU level, agriculture and the food industry have played a key role in the transition to the bioeconomy sectors from the outset, although there are still significant differences between countries, with significant developments in Northern and Western Europe and early stages in Central and Eastern Europe [6,7].

Therefore, the prospects for the transition to a sustainable economy remain rather fragmented, as the exact shape of the transition to the bioeconomy remains rather unclear. This is because research in the field [2,8] suggests that investments in the relevant sectors of the bioeconomy are currently the main bottleneck preventing such a transition occurring rapidly.

Given the relative scarcity of aggregated studies at EU level on this important topic, as well as the existing need for studies and research among policy-makers, civil society and academics, our research focuses on the analysis of the progress made by the 27 EU Member States in the bioeconomy and biomass producing and converting sectors in the transition towards a sustainable economy.

This paper is divided into six distinct sections. Following the introduction, Section 2 presents the current literature, Section 3 describes the research methodology, Section 4 discusses the empirical results, Section 5 aggregates the discussions, and the last section summarizes the conclusions of the research.

2. Literature Review

Many countries around the world are now pursuing complex strategies to implement and expand bioeconomies, aware that this is the only way in which the sustainable development goals set by the 2030 Agenda and beyond can be achieved. However, how the bioeconomy evolves at regional and national levels depends overwhelmingly on the creation of specific and effective governance mechanisms, from financial support to the constraints and regulatory tools they can use to address these bioeconomy growth challenges [9].

2.1. Why Bioeconomy?

This is a question that most governments have answered through allocating financial and legislative support for research and innovation in the bioeconomy, as well as for its implementation in national and regional economies. Therefore, by using renewable biological resources (crops, forests, fish, animals, micro-organisms to produce food, materials
and energy), progress towards a low-carbon, circular economy can be rapid with multiple positive effects on society and life on the planet [10].

However, all this generates a set of challenges related to infrastructure, institutional and legislative structures, which are often lacking or underdeveloped in different regions, and which require innovation policy to be considered from the perspective of transformational failures rather than the simple structural failures that persist in the traditional economy [11–13].

From this perspective, at EU level, we are identifying sustainable practices that support the bioeconomy in all Member States, notably through creating and strengthening public–private partnerships to promote and develop bio-based industries. In this way, strong initiatives build bridges between biotechnology and the economy, as well as between science, industry and society. While the challenges and prospects of bioeconomies are immense, from large-scale manufacturing of products such as chemicals, materials, food, pharmaceuticals, biomaterials and bioenergy etc., in a sustainable and cost-effective way for a growing world population, success for different countries varies greatly from high-tech bioeconomies, diversified emerging bioeconomies to advanced bioeconomies [14–16].

2.2. Bioeconomy Strategy

Today we identify multiple governmental approaches in terms of strategies for implementing the bioeconomy. These differ from country to country, from region to region, and often differ according to the financial capacity of each economy, which is particularly evident in developed economies.

At EU level, we identify a number of specific measures and actions but also constant concerns to redefine specific strategies, reflected in the latest strategy updated in 2018, which has sustainability and circularity at its core. However, there is no specific EU legislation on the bioeconomy, it is only present at Member State level and in their regions [17].

On the other hand, the 2018 update of the EU Bioeconomy Strategy as well as the European Green Deal (launched in 2019) have underlined that the bioeconomy is at the top of the political agenda in Europe. This priority is evident in many forms, with a focus on various other areas of activity as the bioeconomy has several related concepts, such as bio-based economy, green economy or circular economy, with clear synergies between these concepts, in particular, between the concepts of bioeconomy and circular economy [18–20].

Equally important to mention is that the bioeconomy can create 400,000 new green jobs by 2035, especially in rural and coastal areas, underpinned by regional and national strategies, with funding of up to €250 million for green projects through the European Circular Bioeconomy Fund. Investments in agriculture, aquaculture, fisheries, forestry sectors, biochemistry, biomaterials, energy efficiency in housing and use of bio-based insulation materials etc., are a great opportunity, but in order to make them a success, they need to be strongly anchored in the constitutional framework of the EU legal order, in particular, in the concepts of solidarity, sustainable development and high level of environmental protection [21–23].

It is worth mentioning that the bioeconomy strategy will accelerate the implementation of a sustainable European bioeconomy, based on five objectives: ensuring food and nutrition security, sustainable management of natural resources, reducing dependence on non-renewable, unsustainable resources, limiting and adapting to climate change, strengthening European competitiveness and creating jobs. The strategy contributes to the European Green Pact, as well as to industrial, circular and clean energy innovation strategies [17].

In order to identify how the bioeconomy is part of European policy from the perspective of fostering sustainable development and achieving sustainable development goals, a number of policy directions and actions are presented below that define their direct and indirect contribution to the growth of the bioeconomy in EU Member States.
2.3. Bioeconomy and Agricultural Policy in the EU

At EU level, we identify a number of programmes and measures that support the development of the bioeconomy. These include the Common Agricultural Policy (CAP), the European Agricultural Guarantee Fund (EAGF) which includes a number of measures related to the environment and agricultural production as well as direct payments to farmers for compliance with basic standards related to the environment, food safety, animal and plant health, animal welfare and maintaining land in good agricultural and environmental condition. Equally important, in terms of the bioeconomy, is the European Agricultural Fund for Rural Development (EAFRD) which includes a set of measures that help to stabilize biomass prices and environmental impacts. In the same sense, from an EU agricultural policy point of view, we also mention that the multi-annual financial framework 2021–2027 identifies national allocations that support the transition to the bioeconomy and the generation of biomass resources [24].

On the other hand, not to be overlooked is the fact that biomass and sustainability are two main recurring concepts, confirming that the bioeconomy currently operates at three different levels: energy demand, land demand and governance. Therefore, in order to stimulate the development of the agricultural bioeconomy, the following aspects need to be assessed: efficient use of resources, understanding of the key factors of the agricultural bioeconomy but also a clear perception of their associations. However, there is not yet a consensus on which key factors will accelerate its accelerated and sustainable development [25].

Moreover, the Agricultural Policy takes into account that the opportunities for global growth in the bioeconomy are mainly driven by the need to expand food supplies for a growing world population without further compromising the environment. Organic agriculture is certainly an innovation-based alternative that claims to be more environmentally friendly than conventional agriculture and is capable of addressing sustainable development goals through the use of green technologies, resulting in economic, social and environmental benefits. However, what is important is the openness and vision of organic farmers in terms of green innovation and biomass production that is absolutely necessary in the expanding bioeconomy [26–28].

2.4. Bioeconomy and Forestry Policy at EU Level

Forestry policy includes a set of general principles for the sustainable production of forest biomass, which is an essential part of the bioeconomy. However, forestry legislation is dealt with at Member State level, while at EU level, the forestry strategy includes only general principles, relating to a number of related issues, e.g., birds, habitats and rural development in forested areas [29].

However, there are conflicts and priorities between different stakeholders that are not openly addressed and that influence sustainable forest policy and bioeconomy development.

This is because the prioritization of production over environmental concerns is, however, challenged by the environmental coalition and in conflict with the views of the general public, who have become more aware of conservation, biodiversity and recreation. A political shift is often identified that promotes a productivist forest policy under the guise of a “forest bioeconomy”. Therefore, stimulating landowners’ willingness to act against climate change is important for an effective climate policy, but also in implementing alternative mitigation strategies related to forests and the use of wood for biomass production [30,31].

Moreover, it is undeniable that the forestry sector, by supplying bio-based products, is expected to be directly involved. However, in Europe, the forestry sector is facing an increase in the number of small private forest holdings, where timber collection is difficult, both due to fragmentation of ownership and lack of interest of the forest owners in existing forest-wood chains. From this point of view, the problem persists for two main reasons: a low uptake of policy instruments by forest owners and a lack of collaboration between stakeholders [32].
2.5. Bioeconomy and Fisheries Policy

From the point of view of bioeconomics and fisheries policy, we identify measures and rules for the management of fishing fleets and the conservation of fish stocks. Thus, the European Fisheries Fund established for the period 2021–2027 aims to promote more sustainable fishing practices but also to support small-scale fishermen. Focusing on protecting marine ecosystems and adapting to climate change are also objectives to boost the planet's sustainability [33].

Nevertheless, the pressure on fish biomass is still high and outside safe biological limits. After 2000, in some eco-regions, the situation is improved, e.g., in the Barents Sea and the Norwegian Sea with the highest percentage (>60%) of sustainably exploited stocks. By contrast, in the Mediterranean Sea, less than 20% of stocks are sustainably exploited. As a result, there is still widespread overfishing in European waters and current management is not able to rebuild depleted stocks. However, actions implemented over the last decade have led to an improvement in the state of many commercially important fish stocks [34,35].

It is important to emphasize that the development of the bioeconomy includes fisheries as a sustainable source of food security and human health worldwide. Moreover, the relationship between environmental and economic sustainability, as well as between economic and social sustainability, continues to be a frequently analyzed and debated topic, as environmental, economic and social objectives are complementary when fisheries are managed sustainably and, effectively, link biomass production to the bioeconomy [36,37].

2.6. Bioeconomy Policy and Food Security

Ensuring food security is one of the most important pillars of bioeconomy development. The bioeconomy must therefore contribute to balancing the pressures coming from the food, feed and biomass industrial sectors.

In this context, the EU has included food security in the strategic priorities for EU development policy and adopted a comprehensive policy framework to promote food security and combat malnutrition. In this respect, the “Farm to Fork” strategy will facilitate the transition to a sustainable food system in the EU. Also, “Food 2030” is a research and innovation policy within the bioeconomy, which includes food and nutrition security priorities. Unfortunately, however, there is currently no EU legislation on food and feed security or legislation on nutrition security [38,39].

Ensuring food security and food safety at a time when society is facing major challenges, boosting the bioeconomy is the only key tool to generate sustainable economic growth. We are therefore witnessing a growing trend of technological research in the bioeconomy, especially in the food industry. New technologies should therefore contribute to food security and safety by providing new innovative solutions in different sectors [40–42].

Like digitalization, the bioeconomy has the huge potential to bring about fundamental change in industry. So bio-based transformation with sustainable economic effects will be directly linked to the creation of innovative technologies. The success of the bioeconomy requires adaptation and the continuous development of national initiatives, as well as effective international cooperation, especially in food security [43,44].

Equally worth mentioning, there are also a number of claims that biomass and biomass production from agricultural land are perceived as major obstacles to increasing biomass supply in the context of food security and environmental conservation. Biomass is responsible for the production of food, feed, natural fibres and fuel but also for ensuring a sustainable supply of biomass in a growing bioeconomy [45,46].

2.7. Bioeconomy Policy, Bio-Based Industries and the Circular Economy

Products made in whole or in part from biomass are at the heart of industrial policies. These include products traditionally made from biomass (paper and textiles) and products increasingly produced from biomass through new value chains such as fermentation and biocatalysis. Currently, there are no specific EU policies and legislation for sectors that traditionally use biomass, but there are initiatives such as the feedstock initiative. However,
bio-based products have been identified in the following initiatives: “A Stronger European Industry for Growth and Economic Recovery”, Communication “Towards a European Industrial Renaissance”, Communication “Investing in smart, innovative and sustainable industry—A renewed strategy for EU industrial policy”, Communication “A new industrial strategy for Europe” and the Action Plan for the Circular Economy. Thus, through the public–private partnership model, we identify a new approach to support research and innovation and to reduce the risks of investments in industrial biotechnology [47–49].

Organic products and organic-based value chains are one of the ways to achieve a resource-efficient circular economy. Such an approach can be extremely useful in identifying the value of bio-based production. This approach will help actors in the chain, especially investors and policy makers, to understand the complexities of such multi-actor systems and make informed decisions [50].

Biomass is also expected to play a key role in achieving global climate targets. However, to date, limited attention has been paid to the end-of-life of bio-based products, i.e., in circular product design, recycling and cascading reuse. Among the product sectors identified as important for the bioeconomy are plastics and building materials with the highest recycling potential [51–53].

2.8. Bioeconomy and Climate Change and Energy Policies

The EU has set out measures to reduce greenhouse gas emissions. In July 2021, the European Commission presented the “Fit for 55” package, which includes a set of proposals setting out how the EU can achieve its sustainable development goals. The package includes new initiatives with specific targets in a wide range of policy areas and economic sectors: climate, energy and fuels, transport, buildings, land use and forestry. A sustainable and circular bioeconomy is thus essential for achieving a climate-neutral future. The transition to the bioeconomy will be based on technological progress in a range of processes, but also on progress in technical performance that will depend on the availability of sustainable biomass [16,54–56].

At the same time, procedures such as CO$_2$ monitoring and CO$_2$ price accounting have become increasingly important and have triggered the search for innovative, low-carbon solutions. [57,58].

2.9. Bioeconomy and Environmental Policy

The bioeconomy depends on well-managed biological resources and healthy ecosystems. Sustainable development is therefore based on improved conservation, recycling, use of renewable resources and development of the bioeconomy, which in turn, relies on biological processes and raw materials to produce renewable products. Designing sustainable development policies and analyzing the bioeconomy thus poses new challenges [9,59,60].

Therefore, multi-stakeholder participation and involvement facilitates the potential for their interventions to identify and mobilize pre-existing resources that, when combined, can influence the green bioeconomy. Therefore, transforming the regional economy into a bioeconomy is the only strategy that can generate long-term change with effects on the sustainability of the planet and society [61–63].

This is because a sustainable and circular bioeconomy is indeed essential to mitigate climate change and biodiversity loss, as well as to strengthen energy and food security. It can also contribute to the development of innovative value chains, with significant benefits for rural communities in terms of job creation.

It is undeniable that we are identifying progress in the EU Bioeconomy Strategy, via mobilizing private investment, start-ups, research and innovation in bio-based industries, and the development of national and regional bioeconomies. Further integration of the bioeconomy into all EU policies will contribute to a substantial reduction in the problems we face today [64].

A concrete assessment of how the bioeconomy is evolving at EU level and from the perspective of each individual Member State is often difficult to measure. However, research
findings in the field, as well as the analysis of the growth directions of the bioeconomy, from the perspective of the EU policies currently being addressed, lead our research in the direction of an in-depth analysis of how the progress in the bioeconomy and biomass producing and converting sectors is reflected in the specific industry sectors in terms of the number of people employed in the biomass industry, the value added by sectors producing and converting biomass, and the turnover of sectors producing and converting biomass.

Through our research, we aim to provide a range of new information to underpin and support evidence-based policy-making at both national and European level in the context of the transition to a sustainable economy, and to narrow the existing knowledge gap regarding the progress of EU Member States in the bioeconomy and biomass producing and converting sectors.

3. Research Methodology
3.1. Sample Selection and Variables

In our research, we have considered the most recent data published by the European Commission’s Joint Research Centre on selected indicators specific to the biomass producing and converting sectors, for a period covering the years 2008–2020 [65]. From the indicators published, we have selected, as relevant for the purpose of this research, the number of people employed in biomass producing and converting sectors, the value added of biomass producing and converting sectors and the turnover added of biomass producing and converting sectors.

According to the methodology proposed by the authors of the dataset [65], the following 10 biomass producing and converting sectors have been selected as relevant for tracking the progress of the bioeconomy at EU level: agriculture; forestry; fishing and aquaculture; food, beverage and tobacco; bio-based textiles; wood products and furniture; paper; bio-based chemicals, plastics and rubber (excluding biofuels); liquid biofuels; and bio-based electricity.

In order to keep the data comparable between the analyzed countries, for each country we have reported the total number of employees in biomass production and converting sectors to the total number of employees in that year, using specific data provided by Eurostat [66], thus obtaining the share of employees in biomass production and converting sectors in total employees ("bioeconomy employees" variable). The variables "value added per employee" and "turnover per employee" are expressed in thousands of euros per employee in the biomass production and processing sectors, being extremely valuable for monitoring the progress made by EU countries in the bioeconomy.

Based on the data published so far, we decided to use the data for the available range, mainly because it includes the year of the adoption of the Paris Agreement (2015), as well the most recent year (2020) for which data are published at EU level. Thus, we have the possibility to capture a number of effects of the adoption of the Paris Agreement on the progress of bioeconomy and biomass producing and converting sectors in EU countries, observing how the values of the analyzed indicators have evolved and how the Member States are grouped in clusters in the two time periods.

The main characteristics of the variables analyzed for the years 2015 and 2020 are presented in Table 1.

### Table 1. Descriptive statistics of the variables analyzed for the years 2015 and 2020.

<table>
<thead>
<tr>
<th>Variable</th>
<th>U.M.</th>
<th>2015</th>
<th>2020</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Min</td>
<td>Mean</td>
</tr>
<tr>
<td>Bioeconomy employees</td>
<td>%</td>
<td>4.08</td>
<td>36.31</td>
</tr>
<tr>
<td>Value added per employee</td>
<td>k€</td>
<td>4.08</td>
<td>94.37</td>
</tr>
<tr>
<td>Turnover per employee</td>
<td>k€</td>
<td>13.47</td>
<td>382.15</td>
</tr>
</tbody>
</table>

Source: own calculations.
By comparing the way in which clusters are formed in the two periods under analysis, we can obtain valuable information about the dynamics of the phenomenon in question, the individual performances of the countries included in the analysis, highlighting the countries with performances significantly above the EU average or, on the contrary, the countries that showed a certain level of underperformance.

3.2. Model and Method

Given the large amount of data available, but also the fact that there is a limited amount of published research on this topic, we proposed to use hierarchical cluster analysis as an exploratory method. This analytical technique assumes an inductive–exploratory character, signifying its capacity to unveil inherent structures within the examined data volume devoid of explicating their underlying rationales. Put differently, it functions as a means of generating hypotheses as opposed to scrutinizing hypotheses.

By using this research methodology, we are able to classify the variables designated for analysis according to their degree of similarity. This approach ensures a higher level of association between variables assigned to a common group, while at the same time, discerning major disparities between variables assigned to distinct groups. The implementation of the cluster analysis introduces a new perspective for exploring and understanding existing variables, thereby generating new trajectories for research exploration and providing insights that guide the application of alternative modelling methodologies [67,68].

In order to identify relevant clusters for the proposed purpose, we will use the squared Euclidean distance [67,69] to determine the proximity Matrix (1):

\[ d(A, B)^2 = \sum_{i=1}^{n} (A_i - B_i)^2, \text{ where } A, B \in \mathbb{R}^n \]  

(1)

The squared Euclidean distance is an etric used to quantify the separation between two points in a multidimensional space, where each dimension incorporates distinct features. The calculation involves squaring the differences between the values of the features corresponding to the two points, summing these squared differences across all dimensions, and then extracting the square root of the summed value. This measure enjoys widespread use in data analysis due to its computational simplicity, intuitive interpretation and adaptability to various types of data. In addition, the squared Euclidean distance possesses valuable mathematical features such as non-negativity, symmetry and respect of the principle of triangular inequality, making it a convenient measure for a multitude of algorithms.

The calculation of the sum of squared errors necessitates the inclusion of the centroid of every cluster, which refers to the average vector of the observations within that cluster. As a result, Ward’s method takes as input an \( n \times p \) matrix \( X \), where \( n \) represents the number of observations and \( p \) represents the number of variables, containing the actual observations. To determine the distance between formed clusters \( (A, B) \), we use Ward’s method [67,69–71], which minimizes the increase in the total within-cluster sum of the squared error, calculated according to Equation (2):

\[ d_{AB}^2 = \frac{2n_A n_B}{n_A + n_B} \| \overline{x}_A - \overline{x}_B \|_2^2, \text{ where } A, B \in \mathbb{R}^n \]  

(2)

where \( \| \overline{x}_A - \overline{x}_B \|_2^2 \) is the squared Euclidean distance between the two cluster centers.

Ward’s method stands as a hierarchical clustering algorithm harnessed within data analysis to amalgamate akin data points into cohesive clusters. Its principal objective resides in the diminution of variance within these clusters, accomplished by minimizing the aggregate of squared deviations between points within each cluster and their respective cluster centroid. The algorithm’s inception entails treating each individual data point as an independent cluster. Subsequently, through an iterative process, it progressively unites the two clusters displaying the most marginal escalation in total variance until a solitary cluster persists.
The hierarchical nesting steps follow a similar procedure as the other methods, involving the merger of the two nearest observations or clusters. However, in this case, the merging is determined by a more intricate distance metric \[67\]. The equation for calculating the (squared) distance between an observation (or cluster) \( P \) and a newly formed cluster \( C \) resulting from the fusion of clusters \( A \) and \( B \) is Equation (3):

\[
d^2_{PC} = \frac{n_A + n_P}{n_C + n_P} d^2_{PA} + \frac{n_B + n_P}{n_C + n_P} d^2_{PB} - \frac{n_P}{n_C + n_P} d^2_{AB}
\] (3)

In quantifying the variance augmentation resultant from merging two clusters, Ward’s method employs the notion of the sum of squares attributed to error. This sum comprises the summation of squared distances spanning from every point to its corresponding cluster centroid. This value is computed for each cluster before and after the amalgamation, and the escalation in the sum of squares due to error directs the decision-making process regarding which clusters should be combined. Ward’s method presents a range of benefits, encompassing its versatility in accommodating diverse data types, its appropriateness for extensive datasets and its capacity to generate distinctly defined clusters.

To check the validity of the assumptions, the first step is to examine selected data for the existence of a normal distribution. The results are summarized in Table 2 (Kolmogorov–Smirnov test) and Table 3 (Shapiro–Wilk test).

Table 2. Tests of Normality (Kolmogorov–Smirnov \( ^a \)).

<table>
<thead>
<tr>
<th>Variable</th>
<th>2015 Statistic</th>
<th>df</th>
<th>Sig.</th>
<th>2020 Statistic</th>
<th>df</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bioeconomy</td>
<td>0.248 27</td>
<td>0.000</td>
<td></td>
<td>0.216 27</td>
<td>0.002</td>
<td></td>
</tr>
<tr>
<td>employees</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Value added</td>
<td>0.190 27</td>
<td>0.013</td>
<td></td>
<td>0.188 27</td>
<td>0.015</td>
<td></td>
</tr>
<tr>
<td>Turnover</td>
<td>0.188 27</td>
<td>0.015</td>
<td></td>
<td>0.181 27</td>
<td>0.024</td>
<td></td>
</tr>
</tbody>
</table>

\( ^a \) Lilliefors Significance Correction. Source: own construction, using SPSS v26.

Table 3. Tests of Normality (Shapiro–Wilk).

<table>
<thead>
<tr>
<th>Variable</th>
<th>2015 Statistic</th>
<th>df</th>
<th>Sig.</th>
<th>2020 Statistic</th>
<th>df</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bioeconomy</td>
<td>0.797 27</td>
<td>0.100</td>
<td></td>
<td>0.837 27</td>
<td>0.051</td>
<td></td>
</tr>
<tr>
<td>employees</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Value added</td>
<td>0.910 27</td>
<td>0.083</td>
<td></td>
<td>0.903 27</td>
<td>0.116</td>
<td></td>
</tr>
<tr>
<td>Turnover</td>
<td>0.896 27</td>
<td>0.071</td>
<td></td>
<td>0.899 27</td>
<td>0.093</td>
<td></td>
</tr>
</tbody>
</table>

Source: own construction, using SPSS v26.

According to the existing literature \(72–74\), findings from the Kolmogorov–Smirnov and Shapiro–Wilk tests signify that the chosen dataset rather likely adheres to a normal distribution, although the potential for deviations from this normality is acknowledged (considering the Kolmogorov–Smirnov test results). Notwithstanding, guided by insights gleaned from the pertinent literature sources \(74,75\), and mindful of factors such as the sample size (27 EU countries) and the constrained influence of distribution on the analysis, the entirety of the dataset can be judiciously employed for the purpose of conducting a hierarchical cluster analysis.

Considering the results of both tests, with the caveat that we have biased the interpretation of normal distribution suggested by the Shapiro–Wilk test results over the Kolmogorov–Smirnov test results, we can reasonably accept a rather normal distribution, especially considering the (relatively) small number of EU countries included in the analysis. Also, the existence of a relatively normal distribution of the data is also the result of the analysis of the normal Q-Q plots, which graphically suggest a normal distribution of data.

In the next phase of the analysis, the optimal number of clusters for each of the selected periods analyzed was established by examining the agglomeration schedules
and dendrograms of the clusters, following the methodology established by the existing literature [67,75].

After a thorough analysis, it was determined that a three-cluster solution provided the best fit for the 2015 data, and a four-cluster solution was optimal for 2020 data. This chosen solution was deemed optimal as it aligned with the established recommendations and findings in the related literature [76,77]. The results of the analysis provide a broader and more accurate picture of the bioeconomy performance across EU countries, highlighting the changes that have occurred between the two time frames (Figures 1 and 2).

**Figure 1.** Dendrogram of bioeconomy clusters, year 2015. Source: own construction, using SPSS v26.
In order to check the validity of the clusters, given the unequal sizes of the clusters and drawing on the existing literature, we have chosen to use the Welch test and the Brown–Forsythe test (with the null hypothesis being $H_{0,1}$: the means of the variables are not significantly different). The tests were performed with a significance level of $\alpha = 0.05$ (Tables 4 and 5).

Figure 2. Dendrogram of bioeconomy clusters, year 2020. Source: own construction, using SPSS v26.
In the next step, the results were tested using the ANOVA methodology (with a significance level of \( p = 0.05 \)) for the clusters that originated. The results are summarized in Tables 6 and 7.

### Table 6. The analysis of variance (ANOVA), clusters for the year 2015.

<table>
<thead>
<tr>
<th></th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bioeconomy employees</td>
<td>Between groups</td>
<td>461.628</td>
<td>2</td>
<td>230.814</td>
<td>5.379</td>
</tr>
<tr>
<td></td>
<td>Within groups</td>
<td>1029.891</td>
<td>24</td>
<td>42.912</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>1491.519</td>
<td>26</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Value added per employee</td>
<td>Between groups</td>
<td>17,035.050</td>
<td>2</td>
<td>8517.525</td>
<td>136.356</td>
</tr>
<tr>
<td></td>
<td>Within groups</td>
<td>1499.163</td>
<td>24</td>
<td>62.465</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>18,534.213</td>
<td>26</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Turnover per employee</td>
<td>Between groups</td>
<td>261,843.768</td>
<td>2</td>
<td>130,921.884</td>
<td>136.986</td>
</tr>
<tr>
<td></td>
<td>Within groups</td>
<td>22,937.541</td>
<td>24</td>
<td>955.731</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>284,781.309</td>
<td>26</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: own construction, using SPSS v26.

### Table 7. The analysis of variance (ANOVA), clusters for the year 2020.

<table>
<thead>
<tr>
<th></th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bioeconomy employees</td>
<td>Between groups</td>
<td>309.428</td>
<td>3</td>
<td>103.143</td>
<td>3.390</td>
</tr>
<tr>
<td></td>
<td>Within groups</td>
<td>699.776</td>
<td>23</td>
<td>30.425</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>1009.204</td>
<td>26</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Value added per employee</td>
<td>Between groups</td>
<td>22,144.946</td>
<td>3</td>
<td>7381.649</td>
<td>132.274</td>
</tr>
<tr>
<td></td>
<td>Within groups</td>
<td>1283.528</td>
<td>23</td>
<td>55.806</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>23,428.474</td>
<td>26</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Turnover per employee</td>
<td>Between groups</td>
<td>300,563.755</td>
<td>3</td>
<td>100187.918</td>
<td>118.487</td>
</tr>
<tr>
<td></td>
<td>Within groups</td>
<td>19,447.864</td>
<td>23</td>
<td>845.599</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>320,011.619</td>
<td>26</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: own construction, using SPSS v26.
4. Empirical Results

By following the described research methodology, distinct clusters with significant differences were identified for each of the analyzed years (three clusters for 2015 and four clusters for 2020) to assess the level of representation of the bioeconomy in the total economic activity among EU countries.

In the year 2015, an analysis of relevant variables enabled the identification of three distinct tariff clusters at EU level. In particular, Cluster_1_2015 comprised six European nations, specifically Austria, Germany, Spain, France, Italy and Luxembourg. Cluster_2_2015 encompassed six additional EU Member States, namely Belgium, Denmark, Finland, Ireland, the Netherlands and Sweden. Cluster_3_2015, observed in the same year, grouped the remaining 15 EU nations, which included Bulgaria, Cyprus, Czech Republic, Estonia, Greece, Croatia, Hungary, Lithuania, Latvia, Malta, Poland, Portugal, Romania, Slovenia and Slovakia. The key characteristics of the three clusters identified for the year 2015 are detailed in Table 8.

Table 8. Characteristics for the 2015 bioeconomy clusters.

<table>
<thead>
<tr>
<th>Cluster</th>
<th>Country</th>
<th>Bioeconomy Employees</th>
<th>Value Added per Employee</th>
<th>Turnover per Employee</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cluster_1_2015</td>
<td>Austria</td>
<td>8.69</td>
<td>46.99</td>
<td>158.88</td>
</tr>
<tr>
<td></td>
<td>Germany</td>
<td>5.31</td>
<td>47.65</td>
<td>199.10</td>
</tr>
<tr>
<td></td>
<td>Spain</td>
<td>7.43</td>
<td>45.65</td>
<td>155.50</td>
</tr>
<tr>
<td></td>
<td>France</td>
<td>6.12</td>
<td>56.42</td>
<td>214.09</td>
</tr>
<tr>
<td></td>
<td>Italy</td>
<td>8.63</td>
<td>46.24</td>
<td>159.52</td>
</tr>
<tr>
<td></td>
<td>Luxembourg</td>
<td>4.08</td>
<td>48.88</td>
<td>166.18</td>
</tr>
<tr>
<td>Cluster_2_2015</td>
<td>Belgium</td>
<td>8.57</td>
<td>66.87</td>
<td>256.17</td>
</tr>
<tr>
<td></td>
<td>Denmark</td>
<td>9.05</td>
<td>94.37</td>
<td>299.03</td>
</tr>
<tr>
<td></td>
<td>Finland</td>
<td>4.93</td>
<td>74.73</td>
<td>319.25</td>
</tr>
<tr>
<td></td>
<td>Ireland</td>
<td>5.72</td>
<td>81.78</td>
<td>271.42</td>
</tr>
<tr>
<td></td>
<td>Netherlands</td>
<td>4.62</td>
<td>83.41</td>
<td>382.15</td>
</tr>
<tr>
<td></td>
<td>Sweden</td>
<td>7.27</td>
<td>73.52</td>
<td>288.00</td>
</tr>
<tr>
<td>Cluster_3_2015</td>
<td>Bulgaria</td>
<td>28.50</td>
<td>4.42</td>
<td>15.91</td>
</tr>
<tr>
<td></td>
<td>Cyprus</td>
<td>8.73</td>
<td>26.32</td>
<td>82.26</td>
</tr>
<tr>
<td></td>
<td>Czech Republic</td>
<td>8.03</td>
<td>22.30</td>
<td>82.85</td>
</tr>
<tr>
<td></td>
<td>Estonia</td>
<td>10.91</td>
<td>24.19</td>
<td>95.27</td>
</tr>
<tr>
<td></td>
<td>Greece</td>
<td>18.56</td>
<td>16.94</td>
<td>49.61</td>
</tr>
<tr>
<td></td>
<td>Croatia</td>
<td>15.83</td>
<td>13.09</td>
<td>43.76</td>
</tr>
<tr>
<td></td>
<td>Hungary</td>
<td>8.27</td>
<td>22.91</td>
<td>78.34</td>
</tr>
<tr>
<td></td>
<td>Lithuania</td>
<td>16.97</td>
<td>13.64</td>
<td>48.20</td>
</tr>
<tr>
<td></td>
<td>Latvia</td>
<td>15.32</td>
<td>14.38</td>
<td>52.23</td>
</tr>
<tr>
<td></td>
<td>Malta</td>
<td>4.46</td>
<td>35.59</td>
<td>106.76</td>
</tr>
<tr>
<td></td>
<td>Poland</td>
<td>17.01</td>
<td>10.92</td>
<td>45.08</td>
</tr>
<tr>
<td></td>
<td>Portugal</td>
<td>16.64</td>
<td>15.31</td>
<td>54.36</td>
</tr>
<tr>
<td></td>
<td>Romania</td>
<td>36.31</td>
<td>4.08</td>
<td>13.47</td>
</tr>
<tr>
<td></td>
<td>Slovenia</td>
<td>13.15</td>
<td>19.81</td>
<td>61.15</td>
</tr>
<tr>
<td></td>
<td>Slovakia</td>
<td>6.64</td>
<td>20.77</td>
<td>73.92</td>
</tr>
</tbody>
</table>

Source: own construction, using SPSS v26.

By implementing the proposed research methodology for the year 2020, it was possible to discern four pertinent clusters. While the composition of the initial three clusters has, for the most part, remained unchanged, a notable departure emerges with two European countries (Belgium and Denmark) displaying significant divergence from the aggregated characteristics of the investigated nations, forming a group independent from the rest of the EU Member States (Cluster_4_2020).

Cluster_1_2020 groups the same six Member States as in 2015: Austria, Germany, Spain, France, Italy and Luxembourg. Cluster_2_2020 brings together four EU countries, namely Finland, Ireland, Netherlands and Sweden. Cluster_3_2020 includes fifteen European
countries, namely Bulgaria, Cyprus, Czech Republic, Estonia, Greece, Croatia, Hungary, Lithuania, Latvia, Malta, Poland, Portugal, Romania, Slovenia and Slovakia. The main characteristics of the 2020 clusters are presented in Table 9.

Table 9. Characteristics for the 2020 bioeconomy clusters.

<table>
<thead>
<tr>
<th>Cluster</th>
<th>Country</th>
<th>Bioeconomy Employees</th>
<th>Value Added per Employee</th>
<th>Turnover per Employee</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cluster_1_2020</td>
<td>Austria</td>
<td>8.09</td>
<td>58.84</td>
<td>202.13</td>
</tr>
<tr>
<td></td>
<td>Germany</td>
<td>5.42</td>
<td>60.00</td>
<td>222.49</td>
</tr>
<tr>
<td></td>
<td>Spain</td>
<td>7.48</td>
<td>48.58</td>
<td>163.05</td>
</tr>
<tr>
<td></td>
<td>France</td>
<td>6.55</td>
<td>58.44</td>
<td>215.66</td>
</tr>
<tr>
<td></td>
<td>Italy</td>
<td>8.64</td>
<td>47.97</td>
<td>162.78</td>
</tr>
<tr>
<td></td>
<td>Luxembourg</td>
<td>3.53</td>
<td>49.41</td>
<td>167.98</td>
</tr>
<tr>
<td>Cluster_2_2020</td>
<td>Finland</td>
<td>7.81</td>
<td>75.71</td>
<td>260.89</td>
</tr>
<tr>
<td></td>
<td>Ireland</td>
<td>8.91</td>
<td>91.39</td>
<td>293.30</td>
</tr>
<tr>
<td></td>
<td>Netherlands</td>
<td>4.97</td>
<td>80.90</td>
<td>327.02</td>
</tr>
<tr>
<td></td>
<td>Sweden</td>
<td>5.53</td>
<td>86.03</td>
<td>296.68</td>
</tr>
<tr>
<td>Cluster_3_2020</td>
<td>Bulgaria</td>
<td>25.61</td>
<td>6.02</td>
<td>19.36</td>
</tr>
<tr>
<td></td>
<td>Cyprus</td>
<td>8.48</td>
<td>29.33</td>
<td>88.00</td>
</tr>
<tr>
<td></td>
<td>Czech Republic</td>
<td>7.63</td>
<td>27.95</td>
<td>96.27</td>
</tr>
<tr>
<td></td>
<td>Estonia</td>
<td>9.92</td>
<td>31.24</td>
<td>124.96</td>
</tr>
<tr>
<td></td>
<td>Greece</td>
<td>18.22</td>
<td>18.02</td>
<td>52.38</td>
</tr>
<tr>
<td></td>
<td>Croatia</td>
<td>12.56</td>
<td>18.21</td>
<td>52.66</td>
</tr>
<tr>
<td></td>
<td>Hungary</td>
<td>8.36</td>
<td>25.83</td>
<td>83.87</td>
</tr>
<tr>
<td></td>
<td>Lithuania</td>
<td>13.50</td>
<td>24.12</td>
<td>74.10</td>
</tr>
<tr>
<td></td>
<td>Latvia</td>
<td>14.73</td>
<td>22.47</td>
<td>67.42</td>
</tr>
<tr>
<td></td>
<td>Malta</td>
<td>3.33</td>
<td>35.80</td>
<td>107.40</td>
</tr>
<tr>
<td></td>
<td>Poland</td>
<td>15.33</td>
<td>15.83</td>
<td>60.95</td>
</tr>
<tr>
<td></td>
<td>Portugal</td>
<td>14.05</td>
<td>18.84</td>
<td>64.91</td>
</tr>
<tr>
<td></td>
<td>Romania</td>
<td>29.02</td>
<td>6.67</td>
<td>18.86</td>
</tr>
<tr>
<td></td>
<td>Slovenia</td>
<td>12.22</td>
<td>25.91</td>
<td>70.81</td>
</tr>
<tr>
<td></td>
<td>Slovakia</td>
<td>6.39</td>
<td>22.05</td>
<td>80.22</td>
</tr>
<tr>
<td>Cluster_4_2020</td>
<td>Belgium</td>
<td>4.73</td>
<td>109.75</td>
<td>419.05</td>
</tr>
<tr>
<td></td>
<td>Denmark</td>
<td>6.35</td>
<td>104.63</td>
<td>358.99</td>
</tr>
</tbody>
</table>

Source: own construction, using SPSS v26.

5. Discussion and Main Implications

Our research findings indicate that EU countries can be categorized based on their bioeconomy and biomass producing and converting sectors performance progression over time. By examining the development of selected data components, we have identified European countries that have consistently demonstrated a commitment to enhancing the bioeconomy related indicators, as well as nations that need to step up their efforts to align with European initiatives.

For improved visual representation, we have consolidated this information in Table 10, mentioning the EU-27 average value for selected variables, making it easier to observe the country clusters each year and track the changes in the defining variables of the identified clusters.

Table 10. Mean values for the 2015 and 2020 EU bioeconomy clusters.

<table>
<thead>
<tr>
<th>Cluster</th>
<th>Bioeconomy Employees</th>
<th>Value Added per Employee</th>
<th>Turnover per Employee</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cluster_1_2015</td>
<td>6.71</td>
<td>48.64</td>
<td>175.54</td>
</tr>
<tr>
<td>Cluster_2_2015</td>
<td>6.69</td>
<td>79.12</td>
<td>302.67</td>
</tr>
<tr>
<td>Cluster_3_2015</td>
<td>15.02</td>
<td>27.95</td>
<td>96.27</td>
</tr>
<tr>
<td>Cluster_4_2015</td>
<td>13.50</td>
<td>24.12</td>
<td>74.10</td>
</tr>
<tr>
<td>EU-27 2015</td>
<td>11.32</td>
<td>22.47</td>
<td>67.42</td>
</tr>
<tr>
<td>Cluster_1_2020</td>
<td>6.62</td>
<td>15.87</td>
<td>60.95</td>
</tr>
<tr>
<td>Cluster_2_2020</td>
<td>6.81</td>
<td>18.84</td>
<td>64.91</td>
</tr>
<tr>
<td>Cluster_3_2020</td>
<td>12.22</td>
<td>25.91</td>
<td>70.81</td>
</tr>
<tr>
<td>Cluster_4_2020</td>
<td>6.39</td>
<td>22.05</td>
<td>80.22</td>
</tr>
</tbody>
</table>

Source: own construction, using SPSS v26.
Also, for a better graphical representation, Figure 3 shows the clusters identified at EU country level in 2020.

![Figure 3. EU clusters—year 2020. Source: own construction.](image)

A first result of the research indicates that, by means of the hierarchical cluster analysis, it is possible to demonstrate the existence of a relatively stable clustering of EU Member States for a medium to long period of time, taking into account selected bioeconomy relevant indicators.

Analyzing the evolution of the indicators analyzed in the period 2015–2020, a significant evolution can be observed at EU country level. Between the two periods analyzed, a reduction can be observed, on average, in the share of the number of employees from 11.32% in 2015 to 10.27% in 2020 (representing a decrease of −9.3%), an increase in the average value added per employee from 38.19 k€ in 2015 to 44.44 k€ in 2020 (corresponding to an increase of 16.4%), as well as an increase in the average turnover per employee from 139.72 k€ in 2015 to 153.79 k€ in 2020 (representing an increase of 10.1%).

Examining the evolution of the identified clusters, between 2015 and 2020, it can be seen that their country cluster composition has been consistently maintained over time. The results obtained confirm the progress made by all EU countries in the period under analysis, but a difference in pace can be noted between the countries grouped in the three clusters. Thus, between 2015 and 2020, the countries grouped in Cluster_3 recorded an average decrease in the share of employees in the bioeconomy sectors of 11.5%, compared to an average decrease of 1.3% recorded by the countries grouped in Cluster_1. It should be mentioned that the EU countries belonging to Cluster_2 recorded a slight average increase (+1.8%) in the share of employees in the economic sectors analyzed, most probably due to the fact that the primary sectors are at a high level of development anyway (which implies that they did not record significant reductions in the number of employees), but the secondary or tertiary sectors have been hiring, which led to an increase in the number...
of employees. These observations are also supported by research published by Nowak et al. [78].

The decrease in overall employment within the bioeconomy primarily results from the contraction of the agricultural sector. This contraction is driven by the growing implementation of optimization, automation and digitalization within this sector. These results are supported by the observations published by Hájek et al. [79], Woźniak and Twardowski [80] or Robert et al. [81], all of them coming to similar conclusions.

In the same vein, Ronzon et al. [82] mention in their research that, in broad terms, Eastern European Member States typically exhibit higher employment rates in biomass production sectors compared to their counterparts in other EU Member States. Baltic and Central European Member States have expanded the scope of their bioeconomies; however, the percentage of workers in less productive sectors was greater in these countries compared to Northern and Western Member States. Our research highlights these aspects, as the differences between the values of the indicators are not high enough to distinguish the analyzed countries into different clusters, but a detailed analysis of the evolution of each country included in the analysis shows these variations in terms of the percentage of employees in the bioeconomy and biomass producing and converting sectors.

In terms of the evolution of value added and turnover generated by the bioeconomy and biomass producing and converting sectors, the results show clear progress, with EU countries clearly making sustained efforts to transition to a greener and more sustainable economy. This concept of added value is probably one of the most discussed, since the political discourse surrounding the bioeconomy predominantly centers on the proportion of value added for those who produce biogenic raw materials, especially in the context of envisioning a thriving bio-based industry, as Kuosmanen et al. [83] argue in their research.

The results of the research show that the countries grouped in Cluster_1 recorded a pro-growth in 2020 compared to 2015, with the average value added increasing from 48.64 k€ per employee to 53.87 k€ per employee (i.e., an increase of 10.8%), and turnover increasing from 175.54 k€ per employee to 189.02 k€ per employee (corresponding to an increase of 7.7%), for both variables the increase being slightly lower than the average increase recorded at EU village level in the same period. As for the component countries of Cluster_2, the results of the research indicate a slowdown in the average growth rate between 2015 and 2020. The average value added per employee increased by only 5.5% (from 79.12 k€ in 2015 to 83.51 k€ in 2020) and the average turnover per employee even decreased by −2.7% (from 302.67 k€ in 2015 to 294.48 k€ in 2020), both values of these variables examined being below the EU average.

A possible interpretation of the results obtained could be that the countries grouped in Cluster_2_2020 are geographically located in the northern part of Europe (Sweden, Finland), countries for which the importance of sectors that do not necessarily produce a high added value (forestry, paper, wood products and furniture) predominates. In comparison, the rest of the countries included in Cluster_2 (Ireland and the Netherlands) have an economy based, to a greater extent, on higher value-added products or services (food, beverage and tobacco or bio-based chemicals, pharmaceuticals, plastics and rubber). It is evident that this state of affairs needs to change, and the countries grouped in Cluster_2_2020 (especially the Nordic countries) are striving to adapt to the new bioeconomy paradigm, as noted by Kristinsson and Jórundsdóttir [41], who state that current business and innovative practices will not work for this generation, so companies need to be much more flexible and innovative. Similar concerns have also been published recently by Solheim et al. [84], Scordato et al. [85] or Margeirsson and Bjarnadottir [86].

A remarkable evolution is observed in the values of the indicators specific to the countries grouped in Cluster_3, countries mainly located in Central and Eastern Europe, as well as the Baltic States. The level of added value per employee in the biomass producing and converting sectors increased on average by 24% in the period 2015–2020 (from 17.65 k€ to 21.89 k€), while the level of turnover per employee increased by 17.6% (from 60.21 k€ to 70.81 k€), both variables being above the European average in the same period.
There are a number of published studies mentioning the same evolution of the Baltic and Central and Eastern European countries, of which we can mention the conclusions of the research published by Bălan and Cismas [87] who state that bioeconomy is an element of economic development that helps CEE countries to bridge the gap with the other countries of the western continent. Similarly, Kirs et al. [88] suggest that a significant potential for sectoral labor productivity improvements is identified in CEE countries, where the design and implementation of bioeconomy strategies could kickstart an accelerated bioeconomy transition.

As regards the two European countries gathered in Cluster_4_2020 (Belgium and Denmark), it should be mentioned that the results of the analysis indicate a particularly good performance in terms of the evolution of the variables investigated in the period 2015–2020, which fully justifies the emergence of this cluster. Thus, in terms of values in 2020, the evolution of the value added per employee had an average growth more than 2 times higher than the EU average (107.19 k€ compared to the EU average value of 44.44 k€), while the average value of turnover per employee is more than 2.3 times higher than the EU average (i.e., 389.02 k€ compared to the EU average of 153.79 k€).

The results obtained in relation to the countries that are part of Cluster_4_2020 are not accidental, considering that Belgium is home to an important cluster of companies in the bio-based chemicals, pharmaceuticals, plastics and rubber, as well as food, beverage and tobacco sectors. The public policies promoted have continuously supported the development of all sectors of the bioeconomy, such as bio-based electricity [51,89,90]. Also, as regards Denmark’s performance, published studies mention the development of the same specific bioeconomy sectors as in Belgium, and in addition, in this country, agriculture plays a much more important role than in the neighboring country [91,92].

A very interesting comparison of the results obtained from our research can also be made with the research published by D’Adamo et al. [93] and Morone et al. [94]. Their studies present the socio-economic indicator for the bioeconomy (SEIB), a novel metric surpassing traditional measures like turnover per worker and value added per worker. SEIB integrates multiple socio-economic parameters with weighted values, offering a comprehensive assessment of bioeconomic sector performance. Based on the methodology described, the authors produce a top ranking of European countries according to the SEIB index. Comparing the top ranking with the clustering, as they resulted from our research, we find that there is a significant overlap of results obtained at different times and using different methodologies.

Compared to the ranking published by D’Adamo et al. [93], we observe that 90% of the countries below the European average are grouped in Cluster_3_2000, which could be defined as the cluster of EU countries with the lowest performance in bioeconomy. Four of the six countries in the top 10 according to the SEIB index are grouped in Cluster_1_2000 and two countries in the top 3 according to the SEIB index are grouped in Cluster_2_2000. As for the countries in Cluster_4_2000, they are also in the top performing countries in terms of the socio-economic indicator for the bioeconomy. Thus, the importance of the results obtained through our research is confirmed, as they cover an important knowledge gap related to the performance of EU Member States regarding the bioeconomy and biomass producing and converting sectors.

As the results of the research suggest, there has been significant progress among EU Member States in the period since the adoption of the Paris Agreement. This progress is due to the involvement of all stakeholders, both at European and national levels. However, looking at the results achieved, we can say that there is still much to be completed in terms of transition towards a sustainable economy through the development of the bioeconomy. Moreover, as Ronzon et al. [95] states, many Northern and Western EU Member States are currently in the initial phases of the bioeconomy transition whereas in Eastern and Central Europe, achieving such a transition has proven challenging.
6. Conclusions

Acknowledging the pivotal role of bioeconomy statistics in informing evidence-driven policymaking at both national and European levels, especially in the context of an increasingly vital shift towards a sustainable, carbon-free economic model, our aim has been to present an additional perspective to the existing research. We sought to supply an array of supplementary data to bolster policymaking in this domain.

Given the substantial volume of data available, coupled with the limited number of analogous studies published thus far, we opted for a hypothesis generation approach in our research. Our intention was to explore potential patterns within the accessible data utilizing a hierarchical cluster analysis, as opposed to employing a hypothesis testing technique. Drawing from data released by the European Commission’s Joint Research Centre and Eurostat for the years 2015 and 2020, we employed a hierarchical cluster analysis as both an exploratory tool and a means of generating hypotheses. Our primary objective was to assess the advancement of EU Member States in relation to the bioeconomy and the sectors involved in biomass production and conversion, particularly in the timeframe subsequent to the adoption of the Paris Agreement.

The main results of the present research relate to the identification of relevant and consistent clusters over time, grouping EU countries according to bioeconomy performance, in order to identify high-performing countries that can serve as models of good practice, but also countries whose performance needs to be strengthened and further improved.

A first set of results shows a straight separation of countries according to geographical area, with countries located in Western Europe outperforming the Baltics and Central and Eastern Europe between 2015 and 2020.

A second important conclusion highlighted by the present study refers to the above average growth recorded by the Baltic countries and the EEC in terms of the variables analyzed. At the same time, the results obtained indicate the enormous growth potential existing in these tariffs, in the period analyzed showing growth rates more than 20% higher than the EU average. This potential must be directly supported by targeted strategies and policies, requiring a joint effort at national level as well as at the level of the European Commission, in case of success, the potential gain will far exceed the efforts made.

A third important conclusion of this study is the identification of a number of EU countries that can provide examples of good practice and become role models at European level and beyond. Here we can mention the countries that have emerged in Cluster _4_2020 (i.e., Belgium and Denmark) as successful examples, demonstrating superior performance in terms of progress in the bioeconomy and biomass production and conversion sectors.

It is also important to consider the limitations inherent in this type of predictive analysis when interpreting the results of this research. The accuracy of the results may be impacted by a lack of consistent data, forecasting errors in the model employed or unpredictable political, economic or social factors that can also affect future developments. Moreover, due to the significant lag in the publication of the data, the results of the implementation of policies aimed at correcting certain imbalances will be reflected with a delay in the available data.

Author Contributions: Conceptualization, D.F., G.H.I., T.M.C., M.N., M.N.C. and O.A.C.; Methodology, D.F., G.H.I. and T.M.C.; Writing—original draft, D.F. and G.H.I.; Writing—review and editing, D.F., G.H.I., T.M.C., M.N., M.N.C. and O.A.C. All authors have read and agreed to the published version of the manuscript.

Funding: This work was supported by a grant from the Romanian Ministry of Research, Innovation and Digitalization, the project with the title “Economics and Policy Options for Climate Change Risk and Global Environmental Governance” (CF 193/28.11.2022, Funding Contract No. 760078/23.05.2023), within Romania’s National Recovery and Resilience Plan (PNRR)—Pillar III, Component C9, Investment I8 (PNRR/2022/C9/MCID/I8)—Development of a program to attract highly specialized human resources from abroad in research, development and innovation activities.

Institutional Review Board Statement: Not applicable.
Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

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

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