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Brief Report

Developments of Economic Growth and Employment in Bioeconomy Sectors across the EU

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Abstract: The development of the bioeconomy—or the substitution of fossil-based materials and energy by bio-based solutions—is considered a strategic economic orientation by the European Commission and its Green Deal. This paper presents a methodology to monitor the contribution of the bioeconomy to jobs and growth within the European Union (EU) and its Member States. Classified as an "output-based" approach, the methodology relies on expert estimations of the biomass content of the bio-based materials produced in the EU and the subsequent calculation of "sectoral" bio-based shares by using Eurostat statistics on the production of manufactured goods (prom). Sectoral shares are applied to indicators of employment, and value added is reported in Eurostat–Structural business statistics. This paper updates the methodology and time series presented in 2018. The bioeconomy of the EU (post-Brexit composition) employed around 17.5 million people and generated €614 billion of value added in 2017. The study evidences structural differences between EU national bioeconomies, which become more pronounced over time, especially in terms of the level of apparent labour productivity of national bioeconomies. Finally, this paper describes cases of transition over the 2008–2017 period.

Keywords: bioeconomy; bio-based products; employment; value added; apparent labour productivity; European Union; regional development

1. Introduction

The bioeconomy consists of producing and transforming biomass for the provision of food, feed, materials, energy, and related services to European citizens. Some of the materials and energy that we consume can be replaced by equivalent materials or energy, made partly or entirely from biomass. As stated in the two consecutive bioeconomy strategies of the European Union (EU) [1,2], the substitution of fossil-based materials and energy by bio-based solutions is considered a strategic economic orientation by the European Commission, as it could potentially lessen environmental pressures while strengthening green innovation, markets, and jobs in the EU. Moreover, a circular bioeconomy constitutes a non-negligible piece in the architecture of the Green Deal launched by the President of the European Commission at the end of 2019 [3]. By supporting greater circularity in the industry and creating growth and employment in rural areas, the implementation of the Bioeconomy Action Plan is an integrative part of the Circular Economy Action Plan of the Green Deal [4]. National and regional bioeconomy strategies exist or are being developed in EU Member States. Striving towards a more sustainable, resource-efficient economy based on renewable resources, the initiatives

reflect the heterogeneity of countries and regions and their specific policy priorities [5,6]. In support of the EU Bioeconomy Strategy, the Joint Research Centre of the European Commission hosts the Knowledge Centre for Bioeconomy [7] that is responsible for the preparation of a monitoring system for the bioeconomy [8]. The Knowledge Centre also channels knowledge and scientific evidence among researchers, policymakers, and other stakeholders with the aim of enhancing the knowledge base for policymaking.

The aforementioned policies' required monitoring systems include a quantification of socio-economic developments in the sectors of activity that form the bioeconomy. Since the concept of bioeconomy emerged in the political agenda, the bioeconomy's contribution to the economy has been estimated for different points over time and across locations. Quantification methods rely on estimating "bio-based shares", which are consequently applied to the national GDP or other economic indicators. Two main approaches are mobilised for quantifying bio-based shares: (i) input-based approaches, which measure the proportion of biomass in inputs used for the production of bio-based products [9–13] and (ii) output-based approaches, which measure the biomass content of bio-based products [14–18]. Both approaches are relevant and form the two pillars of a combined methodology currently under investigation [19]. A first overview of measuring frameworks employed in different member countries of the International Sustainable Bioeconomy working group (ISBWG) for the quantification of the bioeconomy was presented in 2018 [20]. It depicted differing approaches and indicators to measure and monitor progress, corresponding to the countries' economic, social, legal, and natural resources set-up as well as the specific objectives of national bioeconomy strategies. The authors conclude on a lack of harmonised methodologies and on the resulting difficulties of cross-comparing results across countries. To the best of our knowledge, apart from the European Commission and nova-Institute publications based on a common "output-based" approach [16,17,21,22] and online dashboards since 2017 [23], there has been no other cross-country comparison realised with a harmonised methodology. In these publications, performance indicators cover the sub-sectors of the bioeconomy and have been quantified for all EU Member States over the 2008–2017 period. Sectoral details are provided for the biomass production sectors (agriculture, forestry, and fisheries and aquaculture), bio-based manufacturing sectors (the manufacture of food, beverages, tobacco, bio-based textiles, bio-based wearing apparel, leather, wood products and furniture, bio-based chemicals, bio-based pharmaceuticals, and bio-based plastics), and the production of bioelectricity.

The quantifications have been used in the policymaking process for the reviewed [24] and updated European Bioeconomy Strategy [2]; the 2017 Communication, "The Future of Food and Farming" [25] (p. 21); the economic transition factsheet of the 2018 Communication, *Our Vision for A Clean Planet for All* [26] (p. 2); and the 2019 *Reflection paper: towards a Sustainable Europe by 2030* [27] (p. 53). The approach or resulting quantifications serve different countries, e.g., Croatia [28] and Norway [18], and macro-regions, e.g., BIOEAST [29] and the Nordic Council of Ministers [30]. Examples of further recent usages are the European Investment Bank [31], FoodDrinkEurope [32] (p. 11), and Euronews [33,34].

In this paper, Section 2 describes the "output-based" approach employed by the Joint Research Centre of the European Commission (JRC) and the nova-Institute and the methodological changes applied compared to their last publication [16]. Section 3 presents the updated results for the 2008–2017 period, together with an analysis of time dynamics and national specificities. Conclusions are drawn in Section 4.

2. Methodology and Data

2.1. Methodology for the Calculation of Sectoral Bio-based Shares

The estimation of the socio-economic indicators presented in this study follows and updates the methodology described in [16,22]. The methodology was based on the following two steps:

1. Compiling and harmonising existing statistics for the activity sectors that fully belong to the bioeconomy, as reported in the classification of Economic Activities in the European Community (NACE) [35]: agriculture (NACE code A01), forestry (A02), fishing (A03), the manufacturing of food (C10), beverages (C11), tobacco (C12), and paper (C17).

2. Estimating "bio-based shares" for sectors which only partially belong to the bioeconomy, as reported in the NACE classification (i.e., sectors that produce products made of biomass as well as of fossil-, mineral-based or synthetic feedstock): the manufacture of textiles (C13), wearing apparel (C14), leather (C15), wood products (C16), furniture (C31), chemicals (C20), pharmaceuticals (C21), plastics and rubber (C22), and the production of electricity (D3511).

There were two steps involved in estimating bio-based shares. Firstly, for each manufactured product listed in the statistical classification of products by activity (CPA, 8-digits level), industrial and market experts were interviewed by the nova-Institute (http://nova-institute.eu/). These experts determined (i) how much of the EU production volume was bio-based (min–max range) and (ii) the bio-based content of this fraction of bio-based products (min–max range). The multiplication of the two gives a "product bio-based share". Experts' estimates were retrieved for the years 2008 and 2016. A linear development was assumed when the product bio-based shares changed over this period. Estimates for 2016 were kept for 2017. Average product bio-based shares were calculated from the min–max ranges. The results presented in this paper are only derived from average product bio-based shares.

The second step consisted of estimating the "sectoral bio-based shares". Based on Eurostat statistics on the production of manufactured goods (prom DS-066341) [36], the production value of all bio-based products that belong to a given NACE sector was divided by the total production value of that sector. In order to reflect the evolution of national production mixes, this step was performed per EU Member State and per year (from 2008–2017).

Finally, sectoral bio-based shares were applied to Eurostat structural business statistics (sbs_na_ind_r2) [37], assuming that the proportion of value added and employment generated from the production of bio-based manufactured products in a given NACE sector was equal to the proportion of bio-based production into total production expressed in value terms for that sector.

Note that the bio-based share of the D3511 'Production of electricity' sector was derived from the Eurostat energy balances (nrg_bal_peh) [38] by dividing all bio-based energy products on total gross energy production, expressed in energetic terms. Bio-based energy products are primary solid biofuels (code R5110-5150_W6000RI), charcoal (R5160), pure biogasoline (R5210P), pure biodiesels (R5220P), other liquid biofuels (R5290), biogases (R5300), and renewable municipal waste (W6210).

2.2. Indicators and Data Sources

Our study reports on the following indicators by bioeconomy NACE sector, country, and year [23]:

- Value added at factor cost; this "is the gross income from operating activities after adjusting for operating subsidies and indirect taxes" [39]. It is measured at nominal prices in this study, as in the Eurostat sbs_na_ind_r2 data source.
- The number of people employed; this is "the total number of persons who work in the observation unit, as well as persons who work outside the unit who belong to it (. . .) and are paid by it" [39].
- Apparent labour productivity; this is defined as value added at factor costs divided by the number of persons employed. (https://ec.europa.eu/eurostat/databrowser/view/tin00152/default/table?lang=en)
- Location quotient; this refers to the ratio of the proportion of persons employed in the bioeconomy in a given Member State on the European proportion. A location quotient greater than 1 means that the labour market of the Member State is more "concentrated" in the bioeconomy than the EU-27 labour market.

The national accounts from Eurostat were the data source for compiling employment data (Eurostat nama_10_a64_e) and value added data (Eurostat nama_10_a64) for agriculture (NACE A01), forestry (A02), and fishing and aquaculture (A03) [40,41]. Estimates on manufacturing sectors (C10 to C22) and the production of bioelectricity (D3511) were derived from the Eurostat structural business statistics (sbs_na_ind_r2) [37] as well as corresponding sectoral bio-based shares. The latter were determined from expert knowledge, Eurostat prom DS-066341 (manufacturing NACE sectors), and Eurostat nrg_bal_peh (NACE D3511) [36,38].

Compared with the methodology described in Ronzon and M'Barek [16], the number of data sources used for information on agriculture, forestry, and fishing and aquaculture were reduced to only the Eurostat national accounts. Although this option allowed for more consistency across sectors and indicators (data harmonisation), it did introduce differences with Ronzon and M'Barek's estimates [16]. In addition, after Brexit, the benchmark for calculating bioeconomy location quotients changed from the EU-28 to the EU-27 post-Brexit, which is another cause for the dataset's difference to former versions.

3. Results

3.1. Jobs and Wealth in the Sectors of the Bioeconomy

The bioeconomy of the EU post-Brexit (i.e., EU-27) employed around 17.5 million people, and generated €614 billion of value added in 2017 according to our last estimates. This represents 8.9% of the EU-27 labour force and 4.7% of the EU-27 GDP (Note that the turnover is estimated at €2.2 trillion. In this study, we used the value added—rather than turnover—as an indicator of economic performance, as the sum of turnover across sectors leads to double counting).

The agri-food industry is prominent in the bioeconomy, employing three quarters of the bioeconomy's workers (53% in agriculture, and 25% in the food, beverages, and tobacco industry), and generating two thirds of the bioeconomy value added (35% from the food, beverages, and tobacco industry, and 31% in agriculture). Sectoral performances for the EU-27 are presented in Table 1.

Table 1. Number of persons employed, value added, and apparent labour productivity by sector of the bioeconomy (EU-27, 2017).

Sector	Workers	Value Added	Apparent Labour Productivity
	(Number of Persons Employed)	(€ million)	(€000 per Person Employed)
Agriculture	9,273,470	188,519	20
Forestry	517,480	25,301	49
Fishing	166,610	6698	40
Manufacture of food, beverages, and tobacco	4,398,761	215,311	49
Manufacture of bio-based textiles	692,906	21,103	30
Manufacture of wood products and furniture	1,424,540	47,268	33
Manufacture of paper	607,528	43,580	72
Manufacture of bio-based chemicals, pharmaceuticals, plastics, and rubber (excluding biofuels)	83,209	9617	116
Manufacture of liquid biofuels	20,506	3216	157
Production of bioelectricity	22,550	4208	187
Bioeconomy	**17,503,992**	**613,637**	**35**

The number of persons employed in the EU bioeconomy did not decrease in 2017, which was the first time that this number did not decrease over the 10 years monitored. Instead, the bioeconomy gained 126,000 workers compared with 2016. Indeed, the strong decline in agricultural employment observed in previous years drastically reduced by −38,600 workers in 2016–2017 while the food

and beverage industry was a strong employer for the second consecutive year (+127,000 workers in 2016–2017).

The EU bioeconomy also experienced a peak in economic growth in 2017, which was the last year monitored (+7.2% of total value added compared with 2016). Economic growth was observed in all sectors of the bioeconomy, with the leading sectors being agriculture (+€20.5 billion), the food and beverage industry (+€7.2 billion), and the manufacture of bio-based chemicals, pharmaceuticals, and plastics (+€7.4 billion).

3.2. Intra-EU Specialisation in the Bioeconomy and Labour Productivity Levels

If we consider 3-year averages over 2015–2017, updated estimates confirmed the grouping of countries that was observed from data collected in 2015 [16] (see Figure 1, right). Figure 2 provides sector-wise information with (light) dark grey cells indicating a performance (lower) higher than the EU-27's for the country in rows and the sector in columns. This grouping of countries is as follows:

- Eastern Member States, Portugal, and Greece (green group) were characterised by a labour market that was highly specialised in the bioeconomy (location quotient ≥ 1.5) and a below-average apparent labour productivity of the bioeconomy (≤ half the EU-27 level). In these countries, a high proportion of bioeconomy jobs were located in biomass production sectors (agriculture, forestry, and fishing and aquaculture) and labour-intensive production sectors such as the manufacturing of textiles and/or wood products (see dark grey cells in Figure 2).
- Estonia and Central Member States (purple group) were characterised by a labour market that was less specialised in bioeconomy (location quotient ≤ 1.3). Their bioeconomy also had a higher apparent labour productivity (between half the EU-27 level and the EU-27 level) than the previous group, particularly in agriculture, forestry, and bio-plastics manufacturing.
- Western Member States (orange group) were characterised by a low specialisation of their labour market into the bioeconomy (location quotient ≤ 0.9) and an apparent labour productivity of the bioeconomy that was above the EU-27 level (but less than double the EU-27 level). The bioeconomy of these Member States was also more diversified in high productive biomass manufacturing sectors than former groups (see dark grey cells in Figure 2).
- The characteristics of the former group were exacerbated in Northern Member States (red group), with a low specialisation of their labour market into the bioeconomy (location quotient ≤ 0.9) and an apparent labour productivity of the bioeconomy which was more than double the EU-27 level.

Very generally, Eastern Member States tend to employ more people in biomass production sectors than other EU Member States. Baltic and Central Member States have diversified their bioeconomy, but the proportion of workers in low productive sectors was higher than in Northern and Western Member States. The latter showed a more diversified bioeconomy into high labour-productive manufacturing sectors (see dark grey cells in Figure 2).

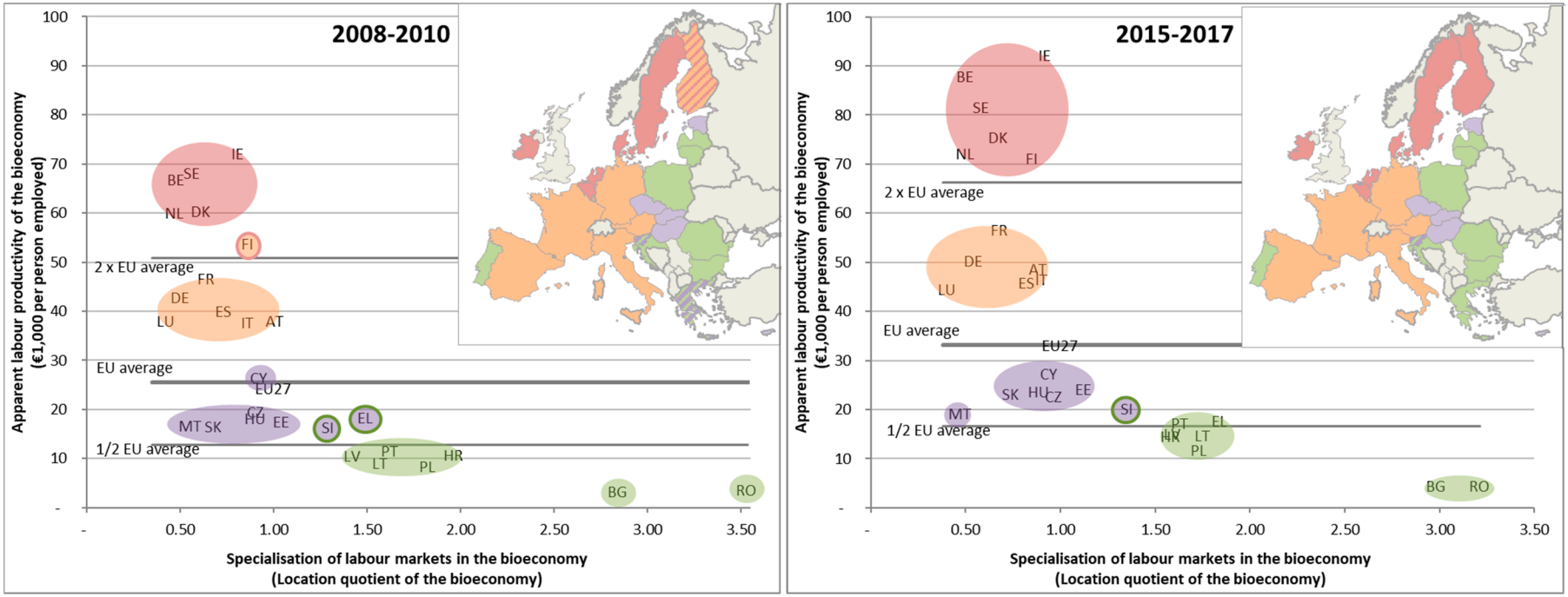

Figure 1. Bioeconomy patterns across EU-27 Member States in 2008–2010 (left) and 2015–2017 (right). Note: The 27 EU Member States are referred to by their two-letter code: Austria (AT), Belgium (BE), Bulgaria (BG), Croatia (HR), Cyprus (CY), Czech Republic (CZ), Denmark (DK), Estonia (EE), Finland (FI), France (FR), Germany (DE), Greece (EL), Hungary (HU), Ireland (IE), Italy (IT), Latvia (LV), Lithuania (LT), Luxembourg (LU), Malta (MT), Netherlands (NL), Poland (PL), Portugal (PT), Romania (RO), Slovakia (SK), Slovenia (SI), Spain (ES), and Sweden (SE).

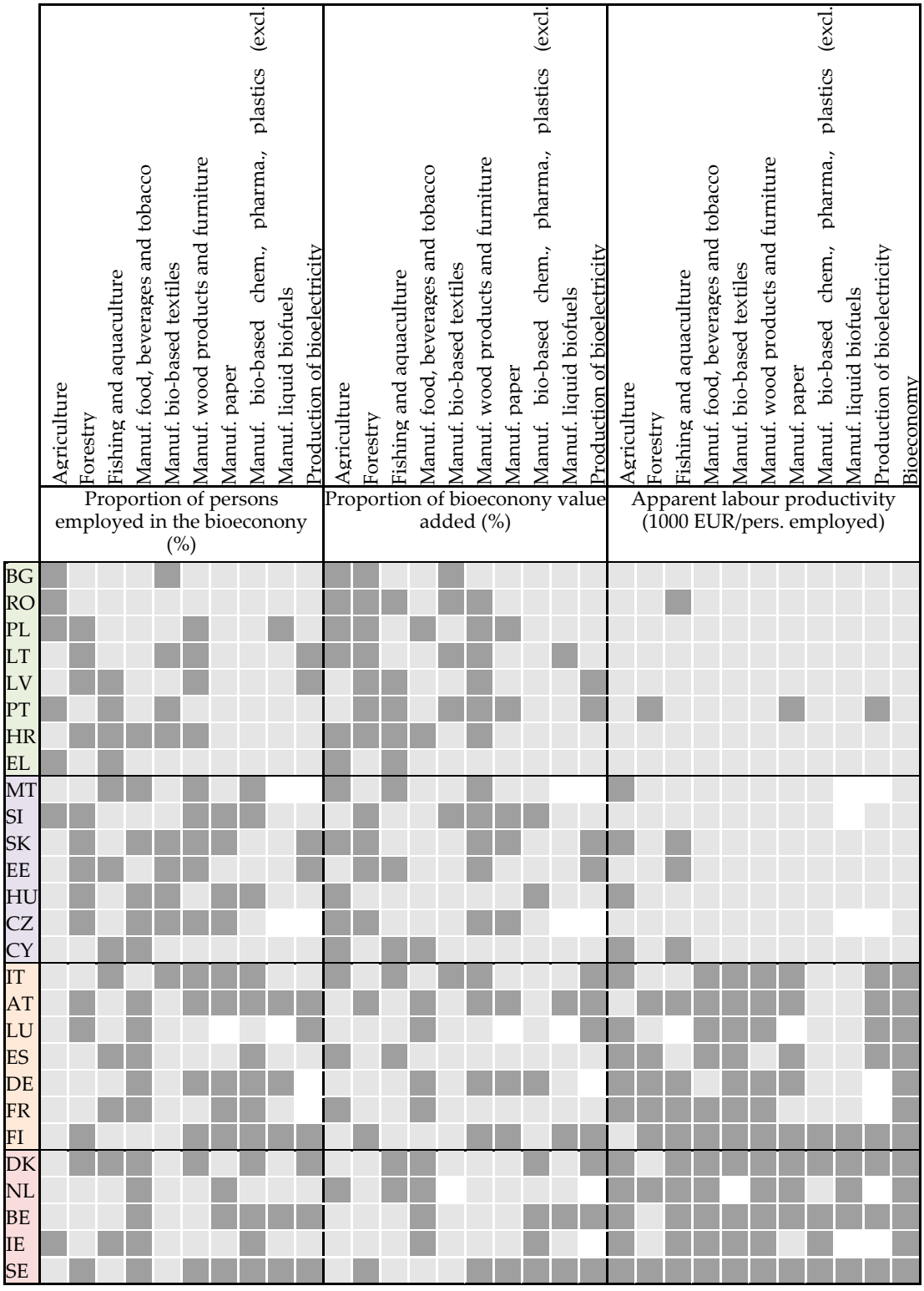

Figure 2. Comparative proportion of persons employed, value added, and level of apparent labour productivity by sector (EU Member States compared to EU-27, 2015–2017 averages). Below EU-27 level in light grey, above EU-27 level in dark grey, missing data in white.

3.3. Strengthened Intra-EU Differentiation Processes Over Time

As the bioeconomy develops in Member States, its contribution to jobs and wealth evolves. The comparison between the average situation in 2008–2010 and 2015–2017 (Figure 1) shows the following:

- The level of apparent labour specialisation (Y-axis) increased in all Member States. In the EU-27 as a whole, it rose from €25,000 to €33,000 per person employed (3-year averages). Note that the apparent labour productivity is not corrected for inflation and part of the increase may be due to inflation.
- The specialisation of national labour markets into the bioeconomy (X-axis) did not substantially change between 2008–2010 and 2015–2017, with the exception of countries classified in the green group.

Individual trajectories are illustrated with arrows in Figure 3, with the arrows' starting points referring to the positions of Member States on the scatter graph in 2008–2010 and the arrows' end points referring to their position in 2015–2017. Gains in apparent labour productivity were concentrated in Western and Northern Member States. Member States within the red group saw remarkable increases of between €12,000 and €21,000 per person employed (by decreasing order of the amount by which they increased: Belgium, Ireland, Finland, Denmark, Sweden, and the Netherlands). As a result, the productivity gap on the aggregated bioeconomy widened over time between the Eastern and Central Member States plus Portugal and Greece (green and purple groups) and Western and Northern Member States (orange and red groups).

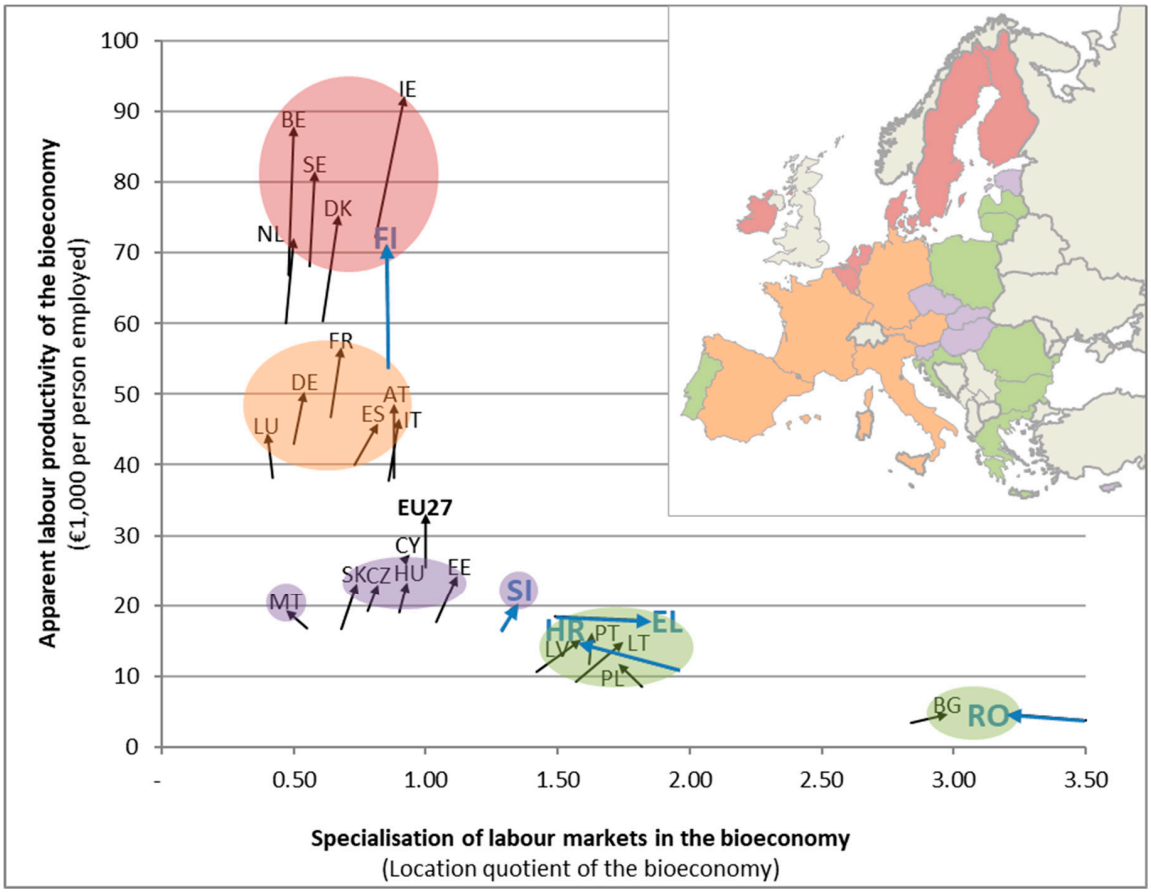

Figure 3. Evolution of the location quotient and apparent labour productivity in the bioeconomy of the 27 EU Member States, 2008–2010 to 2015–2017 (cases shown in blue are those discussed in Section 3.4 below).

3.4. Bioeconomy Transitions Among EU Countries: Some Illustrative Cases

Finland's individual trajectory is a remarkable example of a bioeconomy transition. With an apparent labour productivity of the bioeconomy that was almost equivalent to double the EU-27 level in 2008–2010, Finland (FI) occupied an intermediate position between orange and red Member State groups in Figure 1 (left). Over ten years, Finnish labour productivity has grown faster than at the aggregated EU-27 level, reaching €71,000 per person employed in 2015–2017 (above double the EU-27 level). Consequently, it was among the highest-performing EU bioeconomies in terms of apparent labour productivity in 2015–2017 (red group, see Figure 1 (right)), confirming the trend in Ronzon and M'Barek [16]. Such a transition has been driven by productivity leaps in the manufacturing of bio-based chemicals, pharmaceuticals and plastics, forestry, and the manufacture of paper (not shown).

Slovenia (SI) and Greece (EL) could have been examples of transitioning Member States between the green and purple groups as they occupied intermediate positions in 2008–2010 (Figure 1 (left)). Their bioeconomies indeed exceeded the threshold of half of the EU-27 level, but their labour markets showed similar levels of specialisation into bioeconomy employing sectors to the Member States of the green group. The two countries' 10-year evolution is quite divergent. On the one hand, Slovenia has maintained its intermediate position in the EU landscape in 2015–2017. No major restructuring of its labour market occurred, but the apparent labour productivity of bioeconomy sectors evolved at a similar pace to that of the EU-27 aggregate. On the other hand, Greece was deeply affected by the 2008 economic crisis during which bioeconomy sectors acted as a buffer against unemployment [16], in particular the biomass production sectors. The 'buffer role' of the bioeconomy reinforced the Greek labour market's specialisation into the bioeconomy. Nonetheless, the Greek bioeconomy shows the characteristics of a Member State in the green group in 2015–2017 (Figure 1 (right)).

Among the green group of Member States, Croatia (HR) and Romania (RO) are notable examples of a de-specialisation of labour markets in the bioeconomy (captured by decreasing location quotients, Figure 3). The proportion of persons employed in the bioeconomy reduced from 20% to 14% in Croatia and 36% to 29% in Romania (3-year averages comparison 2008–2010 vs. 2015–2017). The reduction of bioeconomy labour forces mainly occurred in agriculture, shrinking from 11% to 6% in Croatia and from 31% to 24% in Romania. Over the same period, Croatian labour productivity increased at a similar pace to that of the EU-27, with Croatia moving to a similar position to that of Slovenia on Figure 1 (right). On the other hand, no noticeable gains of labour productivity were observed in Romanian agriculture, undermining the restructuring narrative that usually accompanies agricultural outflows.

4. Concluding Remarks

The updated estimates regarding employment and value added of the bioeconomy in the EU depict positive developments. Firstly, total employment in the bioeconomy rose from 2016–2017, breaking the cycle of continuous decreases in persons employed over the 2008–2016 period. Reduced outflows from agriculture and a striving food and beverage industry permitted this break. Secondly, the level of apparent labour productivity rose from €25,000 to €33,000 per person employed in the EU from 2008–2010 to 2015–2017.

More contrast was found at the sub-regional level. Indeed, the present study evidences structural differences between national bioeconomies across the EU. The bioeconomy of Eastern Member States, Portugal and Greece was particularly geared towards biomass production in the agriculture, forestry, and fishing and aquaculture sectors and reached below-average levels of apparent labour productivity in almost all sectors of the bioeconomy. Estonia and Central Member States showed bioeconomies that were more diversified into manufacturing sectors than the former group. More than half of the bioeconomy labour force work in low-productivity sectors of the bioeconomy, i.e., agriculture, the manufacture of bio-based textile, wood products and furniture, and fishing and aquaculture. The overall apparent labour productivity of these bioeconomies is higher than in the former group but is lower than in Western and Northern Member States, which have diversified their own bioeconomies into high labour

productivity manufacturing sectors (e.g., the production of bioelectricity, the manufacture of bio-based chemicals, bio-based pharmaceuticals, bio-based plastics, and paper).

Our observations of the dynamics over time showed that the apparent labour productivity of Northern and Western bioeconomies increased faster than in other EU Member States. Not only did the East-West productivity gap widen over the 2008–2017 period, but there was no transition from a below EU-27 level of apparent labour productivity to an above EU-27 level. Such results indicate, on the one hand, the heterogeneity of the EU's bioeconomy; on the other hand, they raise questions about untapped potential in the EU. These questions are the focus of the macro-regional BIOEAST initiative, "Central and Eastern European initiative for knowledge-based agriculture, aquaculture and forestry in the bioeconomy". Also observing internal disparities in the European Research Area, the BIOEAST initiative aims at reinforcing research and innovation in 11 Central and Eastern European Member States to untap their bioeconomy potential and develop an innovative, inclusive, and climate-ready bioeconomy in the macro-region [42]. Moreover, there is evidence of the buffer role of the bioeconomy in times of economic crisis. For example, in the aftermath of the 2008 economic crisis, bioeconomy sectors showed lower unemployment trends than the rest of the economy in EU countries such as Bulgaria, Greece, Hungary, Lithuania and Latvia and to a lesser extent in Germany, Ireland, and the United Kingdom. Therefore, the lower apparent labour productivity in Eastern and Southern Member States' bioeconomies could reveal a large employment capacity, which reinforces the resilience of the whole sector. In summary, our results support the necessity of targeted bioeconomy strategies that—apart from the overarching goal of achieving more environmental sustainability—balance economic and social objectives. Finally, we would like to note that the current study focuses on measuring the socioeconomic characteristics of the biomass producing and manufacturing sectors that were core sectors in the first EU Bioeconomy Strategy [1]. The second and current EU Bioeconomy Strategy [2] also includes bioeconomy services, e.g., restauration, waste treatment, food retail trade, and research into and repair of bio-based products. Measuring jobs and wealth creation in bioeconomy services poses new methodological challenges; while the estimation of the bio-based content of bio-based products is appropriate for determining the bio-based share of manufacturing sectors, it is less relevant for certain service sectors. Indeed, what is the bio-based share of recreation or sport activities that partly rely on nature services?

While analytical methods for the bioeconomy still evolve, the present article illustrates the role of the EU's bioeconomy as strategic for guaranteeing safe food supply, offering a "buffer role" for employment, and providing important potential for the transition to an innovative, resource-efficient, and competitive economy.

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