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Estimating employment and value added in the bioeconomy of EU regions

A methodological proposal

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Abstract

The analysis and monitoring of the bioeconomy at the regional level is of interest for policy design and evaluation, notably regarding the objectives of the European Union's (EU) Bioeconomy Strategy (2018) of creating jobs and opportunities for sustainable regional economic development. Although some initiatives provide estimates of the size and/or regional distribution of the bioeconomy in some countries, there are no homogeneous datasets allowing the analysis of the regional dimension of the EU's bioeconomy.

This report describes a methodology to estimate employment and value added of the bioeconomy sectors at the NUTS2 (regional) level in the EU. The approach consists of a systematic combination of bio-based shares (defined as the share in biomass content of all products produced by a given sector) from the publically available JRC-Bioeconomics database with Eurostat regional statistics for allocating employment and value added of the bioeconomy sectors amongst regions. When missing from Eurostat data sources, regional series are estimated by applying various criteria to regionalise national statistics. Finally, a range of missing data estimation algorithms are executed in order to complete the dataset.

Preliminary results evidence that the proposed methodology manages to fill in the majority of missing series and data in the initial raw datasets. Therefore, we are able to extract some key figures and trends for the regional bioeconomies in the EU. We then discuss our results through comparisons with available official statistics, other previous estimates and expert feedback to identify the limitations of the methodology and, based on that, potential future improvement. The main challenges identified in this process are related to the absence of data for some sectors at the regional level, requiring assumptions about the regional distribution of employment and value added within a country, as well as the use of national bio-based shares at the regional level, masking regional heterogeneities in the use of biomass for production.

1 Introduction

The launch of the first Bioeconomy Strategy of the European Union (EU) in 2012 (European Commission, 2012), and its subsequent update in 2018 (European Commission, 2018) with concrete actions are considered important enablers for the European Green Deal objective of climate-neutrality by 2050 (European Commission, 2019), but also those of territorial cohesion. The fifth objective of the EU's Updated Bioeconomy Strategy (European Commission, 2018), "Strengthening European competitiveness and creating jobs", states:

> *"[…] The bioeconomy offers important opportunities for new jobs, regional economic development and improved territorial cohesion, also in remote or peripheral areas. It has the potential to provide an important source of income diversification for farmers, foresters and fishermen, and to boost local rural economies through increased investment in skills, knowledge, innovation and new business models, as recommended in the 2016 Cork 2.0 declaration"* (European Commission, 2018).

The EU Bioeconomy Strategy also triggered the need to describe, monitor and model the bioeconomy. Among others, the SAT-BBE[(1)] – "Systems Analysis Tools Framework for the EU Bio-Based Economy Strategy"-research project (2012-2015) of the EU Framework Programme 7 (FP7) brought clarity on the sectoral scope of the bioeconomy and on key monitoring indicators, including turnover and employment (SAT-BBE 2015). However, despite the recognized importance of the bioeconomy for territorial cohesion and regional development opportunities, this project only focuses on the EU and Member States level of analysis. The following year, another FP7-funded project was launched – the BERST project – to tackle regional questions. This project informed on employment from bio-based industries at the NUTS3 level in 12 Member States out of the 27 that comprise the European Union, by using existing statistics. However, the BERST project does not propose any way of disentangling the performance of bio-based industries that are reported together with non-bio-based (e.g. chemistry, textile, etc.).

Consequently, to date there is no comprehensive statistics on the socio-economic performance of bio-based industries in all regions of the EU. This would however respond to the interest expressed by European stakeholders during workshops organised for the design of the JRC – Bioeconomy Monitoring System (Giuntoli et al., 2020, Robert et al., 2021) and reiterated in stakeholder workshops held in the framework of the H2020 BioMonitor project (Piotrowski et al., 2019).

The monitoring of the bioeconomy at the regional level would additionally have implications for the evaluation of other related and/or overlapping policies. As stated by Robert et al. (2020), the bioeconomy is integrated in a complex policy context, in which we can identify some shared common objectives with other policies and strategies, such as the Common Agricultural Policy (CAP), the Renewable Energy Directive, the EU Cohesion Policy or the strategies related to the development of rural areas. In June 2021, the European Commission published the Communication "A long-term Vision for the EU's Rural Areas - Towards stronger, connected, resilient and prosperous rural areas by 2040" (European Commission, 2021). In this document, the bioeconomy is identified as one of the sectors that could provide opportunities for rural areas in terms of the modernization and strengthening of both the food sector and the bio-based industry:

> *"[The bioeconomy] can help the EU accelerate progress towards a circular and low-carbon economy and will contribute to the modernisation and strengthening of its food sector as well as the industrial base of rural areas. Sustainable bio- and circular economy will create new, more diverse value chains and greener, more cost-effective processes, while protecting biodiversity and the environment"* (European Commission, 2021).

Given all the above, the availability of socioeconomic indicators of the regional bioeconomy will allow evaluating aspects such as the regional distribution of bio-based activities, its contribution to economic growth and employment creation by areas, as well as evaluating the results of the policies aimed at achieving these results.

(1) Project website: https://www.wur.nl/en/project/sat-bbe.htm

The aim of this report is to describe a methodology for the regionalisation of employment and value added in the bioeconomy sectors for the European NUTS2 regions. The proposed methodology is based on a systematic combination of national bio-based shares (defined as the share in biomass content of all products produced by a given sector) with regional statistics for allocating employment and value added of the bioeconomy sectors amongst the EU NUTS2 regions of the EU. This method is based on data sources from Eurostat and on the JRC-Bioeconomics dataset[(2)]. The national bio-based shares calculated by Ronzon et al. (2020) are applied to regional statistics. When missing from Eurostat data sources, regional series are estimated by applying various criteria to regionalise national statistics.

Such approach presents some challenges related with the filling of missing regional employment and value added data in Eurostat statistics for the bioeconomy sectors. For this reason, after compiling these pieces of information, we apply a range of missing data estimation algorithms in order to complete the dataset. To make future updates possible, we also took special care to base our calculations on publicly available data sources that are regularly updated.

It should be noted that the approach is still under development, so the version described in this report is still a preliminary one. Consequently, the methodology still presents some substantial limitations, such as the absence of data to estimate employment and added value at the regional level or the use of national bio-based shares at the regional level. The latter limitation mainly affects to partially bio-based manufacturing sectors (such as chemicals and textiles), as well as the production of bioelectricity. The biomass content present in the output of these sectors can be very heterogeneous among regions within a country. Based on these limitations, some potential improvements and research lines are proposed to continue refining the methodology.

This report is structured as follows. Section 2 describes in detail the proposed approach, as well as each of the three stages that comprise it. Section 3 presents and discusses some preliminary results of the application of the method. A comparison with official data is also made when these are available. Section 4 proposes some potential improvements based on the limitations of the approach identified by the authors and nominated experts. Section 5 concludes.

(2) This dataset is available in: https://datam.jrc.ec.europa.eu/datam/perm/dataset/7d7d5481-2d02-4b36-8e79-697b04fa4278?category=BIOECONOMY

2 Preliminary methodology

According to the EU's Bioeconomy Strategy, the bioeconomy *"covers all sectors and systems that rely on biological resources (animals, plants, micro-organisms and derived biomass, including organic waste), their functions and principles"* (European Commission, 2018). The focus of this report are non-service sectors that fall within the scope of the definition of bioeconomy according to the European bioeconomy strategy. The selected sectors are shown in Table 1.

Table 1. Delimitation of the bioeconomy sectors by 2-digit NACE Rev. 2 codes

INDUSTRY	BIOECONOMY SECTORS (1)
Agriculture, Forestry and Fishing	A01 - Agriculture A02 - Forestry A03 - Fishing
Manufacturing sectors	C10 - Manufacture of food products C11 - Manufacture of beverages C12 - Manufacture of tobacco products C13* - Manufacture of textiles C14* - Manufacture of wearing apparel C15* - Manufacture of leather and related products C16*- Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials C17* - Manufacture of paper and paper products C20* - Manufacture of chemicals and chemical products C21* - Manufacture of basic pharmaceutical products and pharmaceutical preparations C22* - Manufacture of rubber and plastic products C31* - Manufacture of furniture
Bio-energies	D35* - Electricity, gas, steam and air conditioning supply (D35.1.1* - Production of electricity)

(1) For sectors with codes flagged, only their bio-based activities are considered.

Source: By authors

According to Table 1, a total of 16 sectors are considered as contributors to the bioeconomy.

- A01, A02, A03, C10, C11 and C12 are considered fully bio-based, meaning these sectors produce only biomass.

- The remaining sectors (C13, C14, C15, C16, C17, C20, C21, C22, C31 and D3511) are considered "hybrid sectors" in the sense that the products they produce contain biomass and fossil-, mineral-based or synthetic content. The present report targets the manufacture of bio-based products only, as well as electricity generated from biomass.

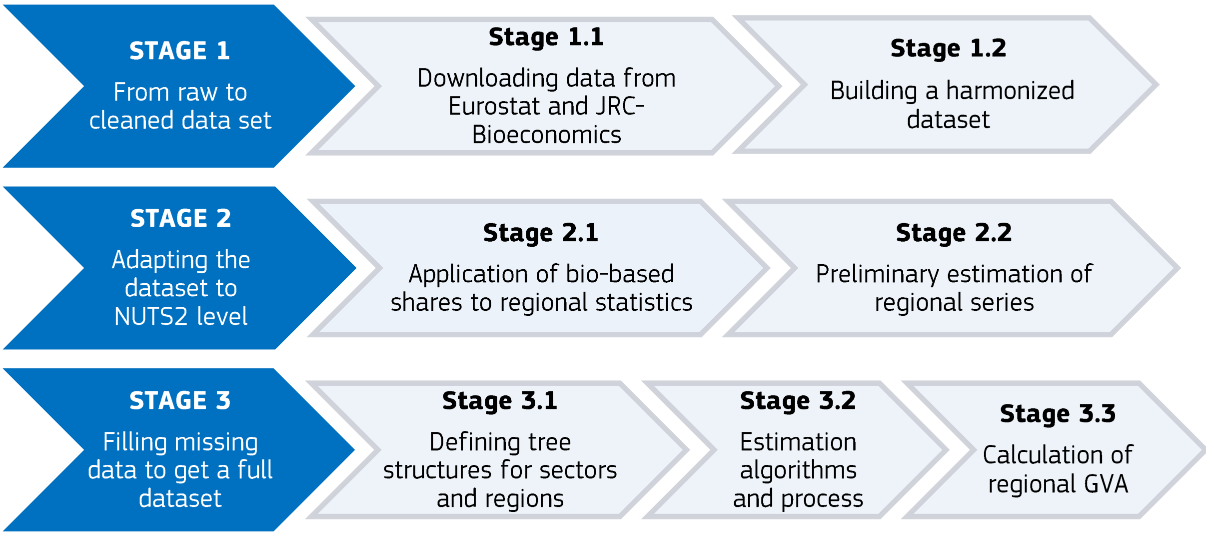
Note that printing, construction and waste management also fall under the EU definition of the Bioeconomy. The quantification of their bio-based share is work-in-progress but they could also be addressed by the methodology presented in this report once national bio-based shares are available.

The methodological approach proceeds in three main stages represented at Figure 1. They are briefly described below:

- Stage 1 addresses the compilation and harmonisation of both Eurostat and JRC-Bioeconomics (Ronzon et al., 2022) data on employment (number of people employed, both employees and self-employed) and gross value added (million euros, hereinafter GVA) in bioeconomy sectors at the national and NUTS2 levels.

- Stage 2 quantifies the bio-based contribution of hybrid sectors in regional data sources compiled at Stage 1 and provides preliminary estimates of series for which Eurostat does not provide a regional breakdown. The latter is based on the use of related explanatory variables. The aim is to adapt the dataset to the definition of bioeconomy according to the European Commission.
- Stage 3 deals with the estimation of missing data, starting with employment. For this purpose, a set of estimation algorithms are combined in an iterative process to fill the missing values in the gaps. Subsequently, this stage also addresses the calculation of sectoral gross value added in the absence of available data from Eurostat.

Figure 1. General overview of the methodological approach



Source: By authors

2.1 Stage 1. From raw to cleaned dataset

2.1.1 Stage 1.1. Downloading data from Eurostat and JRC-Bioeconomics database

For replication and future update purposes, Eurostat and the publicly available JRC-Bioeconomics (Ronzon et al., 2022)[3] databases are the main data sources for our calculations (see Table 2). They are compiled within a single dataset with national (NUTS0), regional (NUTS2) and sectoral (NACE) disaggregation for the period 2008-2019.

(3) This data can be accessed and explored in: https://datam.jrc.ec.europa.eu/datam/mashup/BIOECONOMICS/

Table 2. Data sources available in Eurostat by sector and levels of territorial units

Bioeconomy sectors	Data sources (1)			
	Employment data		Gross value added data	
	NUTS 0 (Country)	NUTS 2 (Region)	NUTS 0 (Country)	NUTS 2 (Region)
Primary sectors (A)		nama_10r_3empers		nama_10r_3gva
A01		ef_lf_main (ef_olfreg)		agr_r_accts
A02		lan_lcv_fao		lan_lcv_fao
A03				
Manufacturing (C)	JRC-Bioeconomics	sbs_r_nuts06_r2	JRC-Bioeconomics	
C11, C12, C13, C14, C15, C16, C17, C20, C21, C22 and C31		sbs_r_nuts06_r2		
Energy (D)		sbs_r_nuts06_r2		
D3511		sbs_r_nuts06_r2		

(1) *Green: available indicators in Eurostat; Grey: explanatory data sources available from Eurostat. Red: neither indicators nor explanatory data sources in Eurostat.*

Source: By authors

2.1.2 Stage 1.2. Building an harmonized dataset

Once the raw dataset is obtained, it is necessary to apply some harmonization and consistency procedures to achieve a cleaned dataset appropriate for the estimation process: (1) the existence of flagged values in Eurostat data sources and (2) the heterogeneity in the NUTS classification across these data sources. The flags problem is easily solved: those values flagged by Eurostat as unreliable (u) are removed from the database. They are therefore considered as missing data and are estimated at Stage 3.

The second problem is related with modifications in the territorial units used in Eurostat data. Three different versions of the NUTS classifications are employed, namely, the NUTS-2010, NUTS-2013 and NUTS-2016 versions. To address these inconsistencies, the 2016 version is taken as a reference and former NUTS versions are matched with their NUTS-2016 equivalent(s). This is possible as long as there is geographical equivalence between territorial units of different versions of NUTS. This occurs when a specific region is re-labelled in a more recent version of NUTS classification, without undergoing changes in its territorial boundaries, or when the recoding of the region is due to minor changes in its borders (e.g. the cases of Greece or France).

If there is no geographical equivalence among the territorial units of different versions of NUTS classifications (e.g. the case of Ireland), only the values referring to territorial units from the NUTS-2016 version, generally available from 2015 onwards, are included in the database. The values from previous years are considered as missing, and are estimated at Stage 3.

2.2 Stage 2. Adapting the dataset to NUTS2 level

2.2.1 Stage 2.1. Application of bio-based shares to regional statistics

This step aims to provide initial estimations for the bio-based activities in hybrid sectors C13, C14, C15, C16, C17, C20, C21, C22, C31 and D3511 in terms of employment and value added. In the absence of published regional bio-based shares, the same national bio-based shares as the ones mobilised in JRC-Bioeconomics are applied to regional statistics. These shares are computed using an output-based approach, so they represent the relative content of biomass in the final production of each sector listed in Table 1 (see Ronzon et al., 2020, for further details). The bio-based shares are different for each one of the 27 EU member states, and depends on the proportion of biomass present in the *product mix* of each sector at the country level.

2.2.2 Stage 2.2. Preliminary estimations of regional series

Some sectors of the bioeconomy are not informed at the NUTS2 level neither in terms of employment nor gross value added. This is mainly the case of subsectors A01, A02 and A03, which are not reported in Eurostat's regional accounts. As this circumstance can be a drawback in the later estimation stages, it is desirable to have preliminary estimates of employment and value added for at least two of the three sectors.

For some series, Eurostat does provide some data sources that may contain explanatory variables, or that may serve as a proxy to make a regional distribution of the value added of the above-mentioned sectors (see grey cells in Table 2):

- In the case of sector A01 (Agriculture), we can identify two data sources that allow us to make a preliminary estimate of employment and the gross value added within this sector. The Farm Structure Survey provides information on total agricultural employment (both employees and self-employed persons) by NUTS2 regions (el_lf_main). The Economics Accounts for Agriculture contain estimates of gross value added by NUTS2 regions (agr_r_accts). Both sources of information are respectively used to regionally distribute employment and value added of sector A01.
- In the case of sector A02 (forestry), we distribute national data on employment and gross value added from the forestry sector across the different NUTS2 territorial units proportionally to the area occupied by forests (lan_lcv_fao).

In the current state of the methodology, we do not have information at the regional level for A03 and D3511 sectors. Its related series will be considered as missing value and, subsequently, calculated in Stage 3.

2.3 Stage 3. Filling missing data to get a full dataset

2.3.1 Stage 3.1. Defining tree structures for regions and sectors

For the estimation process (stage 3.2), data must be organized according to classification tree structures for GEO (NUTS regions) and NACE (economic sectors). Thus, we assume that the EU27 value (the parent) for a specific indicator must be always the sum of its 27 Members States (its children). Simultaneously, the value of the same indicator for these 27 Members States must equalize the sum of the NUTS2-level regions that comprise each country. The same constraints must be fulfilled for the considered economic sectors. The sum of the values of each 2-digit NACE sector (the children) considered must coincide with the aggregate value in the corresponding overarching section (A, C and D; the parents). In turn, the sum of values for theses sections should meet the aggregate value for each indicator.

It should be noted that (1) not all 2-digit NACE sectors are considered and (2) only bio-based activities within the considered sectors are accounted. In this sense, the value of sections C and D would not equalize official releases, but the sum of the bio-based activities within them. This does not apply to section A, as all its subsectors are considered fully bio-based.

2.3.2 Stage 3.2. Estimation algorithms and process

Once the tree structures are defined, we propose a range of algorithms to fill the missing gaps in the dataset (see Table 3). These algorithms follow a scaling technique that aims to fill the missing data and to balance iteratively GEO and NACE classification trees. Specifically, two classes of algorithms are proposed to estimate the missing values:

- Balancing algorithms: they check if the sum of the value of children is consistent with the value of the parent for each indicator.
- Filling in missing data: they assign a value to a missing cell when some conditions are met.

The algorithms described in Table 3 can be combined in different forms to build sequential estimation processes and achieve a complete and consistent dataset through them. Figure 2 shows the estimation process designed for this purpose. It consists of iterative estimations with three differentiated steps. In each step, the indicated algorithms are applied iteratively in the order in which they appear in the corresponding figure. When no more missing values are filled, then the process goes to the following step.

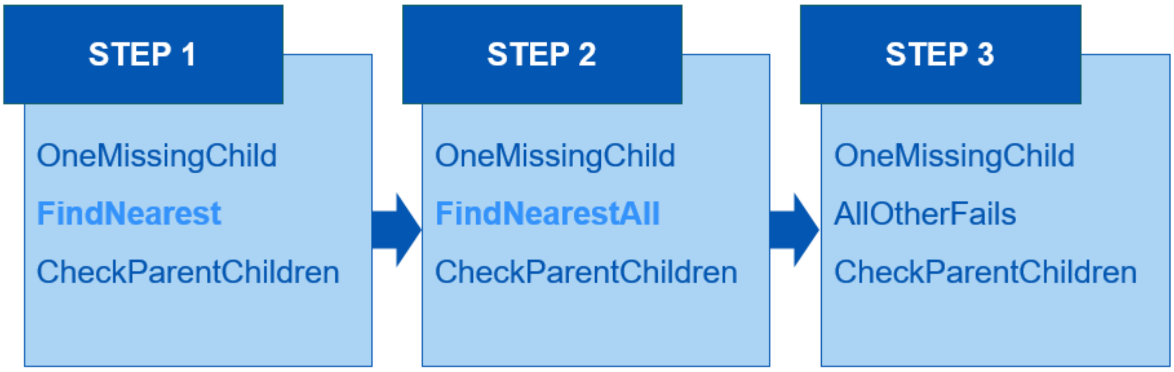
In the current state of the methodology, Step 3 is not applied for the manufacturing subsectors. The main utility of Step 3 is to fill in the missing values of sectors A03 and D3511. In practice, the application of this algorithm to these sectors ensures that fishing data (A03) are estimated as the difference between the aggregate A and the sum of A01 and A02 data for both employment and value added. For D3511, the application of this step implies that the regional estimates are proportional to the value of each region for D35.

Table 3. Algorithms to balance the dataset and filling the missing data

Algorithm	Condition(s)	Action(s)
CheckParentChildren	**If:** • Value of the parent <= value of sum of the children.	**Then:** • Parent gets the value of the sum of the children • Possible missing children get the value 0.
OneMissingChild	**If:** Only one missing child exists	**Then:** The child gets the value representing the difference between the Parent and the sum of the values of the rest of children.
FindNearest	**If:** One or some observations from an indicator are missing	**Then:** • The missing cell is filled with its nearest value of the surrounding years. • Then, only the replaced values are iteratively scaled to equalize (Sum of Children = Value of Parent).
FindNearestAll	**If:** One or some observations from an indicator are missing	**Then:** • The missing cell is filled with its nearest value of the surrounding years. • All children (both existing and replaced) are scaled to equalize (Sum of Children = Value of Parent).
AllOtherFails	**If:** Other filling algorithms fail.	**Then:** The gap between the sum of children and the parent is equally distributed over the missing cells.

Source: By authors

Figure 2. Representation of the estimation process including FindNearest in Step 1 and FindNearest in Step 2



Source: By authors

2.3.3 Stage 3.3. Calculation of regional GVA

At the end of Stage 3.2, our dataset comprises NUTS2 level data for employment in all bioeconomy sectors. Regarding gross value added data, the data sources compiled at Stage 1 and explanatory variables employed at Stage 2 only permit to inform sectors A01 (agriculture) and A02 (forestry) at the regional level, as well as obtaining A03 by difference in Stage 3.2. Therefore, our dataset comprises no regional value added data for C and D subsectors.

In order to reconstruct the missing value added time series, we assume that the national labour productivity of a given sector (defined as gross value added per person employed, see Equation 1) also holds in the regions of that country (Equation 2). National labour productivity is computed at the 2-digit NACE sector level.

$$\boldsymbol{LP}_{\mathbf{n,c,y}} = \mathbf{GVA}_{\mathbf{n,c,y}} \;/\; \mathbf{E}_{\mathbf{n,c,y}} \qquad (1)$$

Where the G*VA* denotes gross value added, *E* the employment, *LP* the labour productivity, *n* refers to the 2-digit level NACE sector, *c* the country and *y* is the year.

$$\boldsymbol{G}\mathbf{VA}_{\mathbf{n,r,y}} = \mathbf{E}_{\mathbf{n,r,y}} \times \mathbf{LP}_{\mathbf{n,c,y}} \qquad (2)$$

Where *r* denotes the region.

Once the regional value added for C and D subsectors is calculated, we have a complete dataset.

3 Results based on the preliminary methodology

3.1 Presentation of main results

The whole methodology consists of estimating the employment and gross value added data not released by Eurostat at the NUTS2 level and to disentangle the contribution of bio-based activities within hybrid sectors. The data filling evolution is represented on Table 4 for each step of the methodology presented at section 2. Despite the high number of missing data in the initial raw database (63.6%), the methodology allows to provide an almost complete dataset at the end of Stage 3. Thus, we obtain 96.4% of employment cells completed 95.5% of GVA cells (covering 97.7% of total amount of GVA in million euros). In terms of total amounts coverage, the regional cells accounts for 99.5% of total number of jobs in the EU bieconomy, and 97.7% of total GVA.

Table 4. Overview of the filling in missing data process by stages (number of cells)

	Employment		Value Added		Total	
	Completed values	Missing values	Completed values	Missing values	Completed values	Missing values
Initial database (Stage 1)	42,961 (60.3%)	28,319 (39.7%)	8,899 (12.5%)	62,381 (87.5%)	51,860 (36.4%)	90,700 (63.6%)
After preliminary estimates (Stage 2)	47,406 (66.5%)	23,874 (33.5%)	12,894 (18.1%)	58,386 (81.9%)	60,300 (42.3%)	82,260 (57.7%)
After the estimation process (Stage 3.2)	68,694 (96.4%)	2,586 (3.6%)	28,934 (40.6%)	42,346 (59.4%)	97,628 (68.5%)	44,932 (31.5%)
After regional Value Added calculation (Stage 3.3)	68,694 (96.4%)	2,586 (3.6%)	67,500 (94.7%)	3,780 (5.3%)	136,194 (95.5%)	6,366 (4.5%)

Source: By authors

Figure 3 provides a general idea of the heterogeneity in regional employment and gross value added across Europe. In general, the regions with highest level of employment in the bioeconomy are located in Eastern Europe, while regions with highest volume of gross value added are distributed across Western Europe.

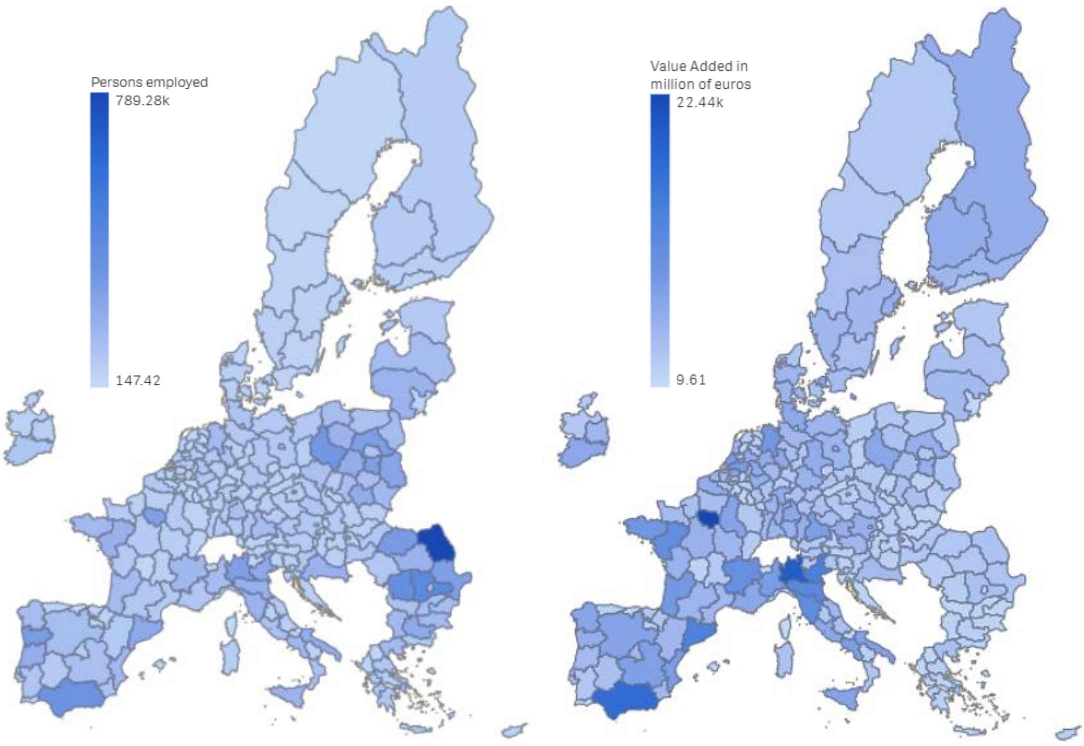
Figure 4 and Figure 5 respectively show those regions with a larger bioeconomy sector in terms of both employment and gross value added (4). The sectoral composition of regional bioeconomies is also illustrated. Regarding employment, the regions with the highest share of jobs in the bioeconomy belong to Eastern European countries (Romania, Bulgaria and Poland) and, to a lesser extent, to Greece. In these regions, agriculture employment represent a high share of total employment.

In terms of gross value added, the sectoral composition of regions represented in Figure 5 presents a high degree of heterogeneity. Therefore, no clear patterns or clusters can be extracted in terms of geographical location or sectoral specialisation. We can either way identify some regions that show higher specialisation in

(4) As the methodology is still in a preliminary status, the results may still present significant deviations from statistics. This is especially relevant in those sectors for which Eurostat does not provide regional data, as well as hybrid (partially bio-based) sectors, where the application of national bio-based shares may hide regional disparities in bio-based production. Sections 4.2 and 4.3 further develop the limitations of the methodology as well as potential improvements.

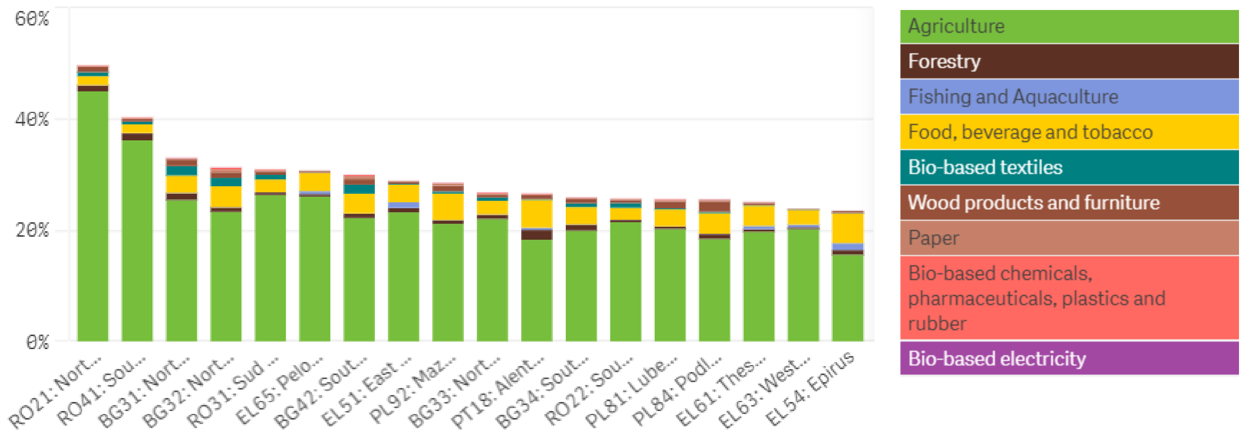
some specific sectors. It is the case of Thessaly (EL61), which generates more than 10% of its total gross value added from the agriculture sector; Wallon Bravant (BE31), which seems to show a high specialisation in bio-based chemicals, pharmaceuticals and plastics industries, as well as Trier (DEB2), in which the food, beverage and tobacco sector represents a high share of its bioeconomy.

Figure 3. Employment (left) and Gross value added (right) in the bioeconomy by NUTS2 regions (2017)



Source: By authors (see disclaimer at footnote 5)

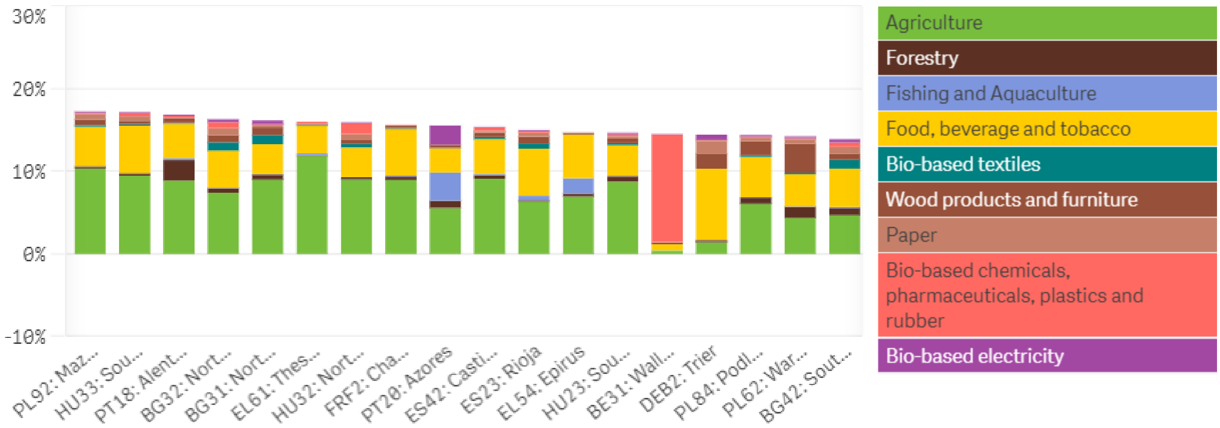
Figure 4. Contribution of the bioeconomy to total regional employment in selected regions (18 largest contributors, share in % by region, 2019)



Source: By authors (see disclaimer at footnote 5)

The mismatch between the regions that generate the highest gross value added and those that create more jobs in the bioeconomy sectors reveal divergences in the level of productivity, possibly explained by the differences in their sectoral composition (5).

Figure 5. Contribution of the bioeconomy to total regional gross value added in selected regions (18 largest contributors, share in % by region, 2019)



Source: By authors

3.2 Comparison of preliminary results with existing literature

As commented at Section 1, there is no equivalent dataset published to the authors' knowledge. Comparisons of our results with other sources can therefore only be done for specific regions and specific points in time for which quantification of employment and/or value added generated in bioeconomy sectors has been performed. In many occasions, the quantitative methodology, the scope delimitation or even the units employed may differ from our work. The cases of Flanders (Belgium) and Andalusia (Spain) are illustrated below and compared with our results.

The 'Bioeconomy Regions in Europe' report, prepared by Bio-based Industries Consortium (2017) collects relevant qualitative and quantitative information related to bio-based activities and bioeconomy clusters within some European regions. One of these regions is Flanders (BE2), for which the report provides information on employment and value added for both fully and partially bio-based sectors. Table 5 shows the comparison of these numbers with those resulting from our methodological application for both employment and gross value added, respectively.

In general, our results are close to the data provided by Bio-based Industries Consortium (2017), although there are some significant discrepancies. Regarding employment estimates, the use of different units yields to major differences in those sectors that rely most on temporary, part-time and unpaid labour force. This is particularly visible in sector A (agriculture, forestry and fishery), for which the Bio-based Industries Consortium reports approximately 100.000 Full-time Equivalent (FTE) employment versus 42,000 persons employed according to our methodology. Gross value added data are however concordant for that sector, which suggests that the discrepancy observed in employment terms is mainly due to the use of different units of measure.

Moreover, information on employment and turnover in bioeconomy sectors for the Spanish region of Andalusia (ES61) is released in the Andalusian Circular Bioeconomy Strategy (EABC in Spanish) (Junta de

(5) The authors admit that levels of productivity within regions are approximated with the national labour productivity of the country they belong to in the absence of better data. This shortcut remains an avenue for future improvements (see sections 4.2 and 4.3.4).

Andalucía, 2018). Table 6 shows the comparison of our employment results for Andalusia with that source[6]. This comparison presents similar characteristics to that of Flanders. In general, our estimates respect the characteristics of the sectoral composition of the bioeconomy in Andalusia. However, some significant discrepancies are produced. With regards to the sector A, our resulting numbers overestimate agriculture employment by around 4,000 people. On the other hand, there is an underestimation of the same size in the number of person employed in both the forestry and fishing sectors. Regarding the C and D sectors, C13-C15 (textile), and C31 (manufacture of furniture) are the activities whose estimates present a higher relative deviation.

Table 5. Comparison of our results for Flanders with data from the 'Bioeconomy Regions in Europe' report (2017)

	Bio-based employment (2015)			**Bio-based Gross Value Added** (2015)		
	BIC *Full-Time Equivalent*	**Our estimates** *Number of persons employed*	**Deviation** (%)	**BIC** *Million euros*	**Our estimates** *Million euros*	**Deviation** (%)
A	113,308	42,017	-62.9%	2,088.24	2,112.41	1.2%
C10-12	63,191	68,744	8.8%	5,638.25	5,687.06	0.9%
C13-15	5,926	5,579	-5.9%	378.9	337.81	-10.8%
C16	6,486	7,739	19.3%	295.15	507.77	72.0%
C17	8,662	7,757	-10.4%	622.59	757.77	21.7%
C20 and C22	3,086	3,061	-0.8%	508.4	603.86	18.8%
C21	4,168	4,849	16.3%	1,598.09	1,282.31	-19.8%
D3511	570	348	-38.9%	191.2	85.64	-55.2%
TOTAL	**203,147**	**144,543**	**-28.8%**	**11,320.82**	**11,511.70**	**1.7%**

Source: BIC (2017, p10) and authors' estimates

(6) Only Employment data is consider for comparison purposes, as the EABC reports Turnover instead of GVA.

Table 6. Comparison of our results for Andalusia with data from the Andalusian Circular Bioeconomy Strategy (EABC)

	Bio-based employment (2014)		
	EABC *Number of persons employed*	**Our estimates** *Number of persons employed*	**Deviation** (%)
A01	212,325	216,116	1.8%
A02	6,818	2,605	-61.8%
A03	7,195	1,669	-76.8%
C10	41,723	43,170	3.5%
C11	4,742	4,978	5.0%
C12	0	0	-
C13-15	5,006	3,731	-25.5%
C16	4,530	4,621	2.0%
C17	2,801	2,626	-6.2%
C20-C22	1,884	1,380	-26.8%
C31	1,982	3,807	92.1%
D3511	95	104	9.5%
TOTAL	**289,101**	**284,808**	**-1.5%**

Source: Junta de Andalucía (2018) and authors' estimates

4 Discussion

4.1 Implications of the results

The bioeconomy is one of the key enablers to fulfil the EU objectives of climate neutrality and territorial cohesion. Once the methodology is improved and stabilised, it will provide a dataset on employment and gross value added in bioeconomy sectors for the NUTS2 territorial units of the EU. This data set can inform on the regional distribution of bio-based activities and the contribution of bioeconomy activities to growth and job creation in regions.

Besides observing the evolution of the fifth objective of the EU's Bioeconomy Strategy on territorial cohesion, the regional analysis of the bioeconomy is also relevant for other policies that directly affect rural areas. The Common Agricultural Policy (CAP) explicitly mentions the bioeconomy in some of its objectives and result indicators of rural development (see Table 7). In the European Commission's Communication "A long-term Vision for the EU's Rural Areas - Towards stronger, connected, resilient and prosperous rural areas by 2040", published in June 2021, the bioeconomy (and more especially of the agri-food sector) is highlighted as an important supporter of rural development processes, and as a factor of resilience to "*climate change, natural hazards and economic crises*" (European Commission, 2021).

Table 7. CAP's results indicators related to bioeconomy

Objective reference	Description
R.15	Renewable energy from agriculture, forestry and from other renewable sources: Supported investments in renewable energy production capacity, including bio-based (in MW)
R.39	Developing the rural economy: Number of rural businesses, including bio-economy businesses, developed with CAP support

Source: Results indicators of the CAP

In addition to policy monitoring, regional data could also support policy development activities, in particular regarding the elaboration or revision of national and regional bioeconomy strategies in EU Member States. The regional heterogeneities presented in section 3 highlight the opportunities of regional bioeconomies. These are precious evidences for better targeting bioeconomy strategies and enhance policy efficiency. On more operational grounds, the identification of high (low) performer regions proves useful at the time of promoting stakeholders' exchanges and the diffusion of best practices (identifying obstacles or bottlenecks for the uptake of bio-based industries).

4.2 Limitations of the methodology

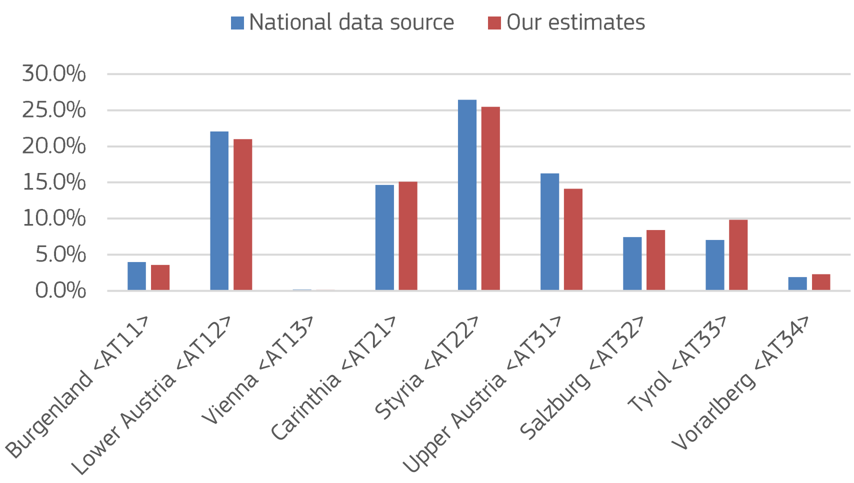
The absence of Eurostat data on employment and gross value added at the NUTS2-level for forestry (A02), fishing (A03) and the production of electricity (D3511) posed a challenge for the elaboration of a complete dataset on bioeconomy activities at the regional level.

We mobilise the FAO forest areas indicator as a proxy for distributing employment and value added in the forestry sector at the NUTS2 level. It ensures that fishing data (A03) are estimated as the difference between the aggregate A and the sum of A01 and A02 data.

While these assumptions permit filling the data gaps for sectors A02 and A03, the use of the forest area criterion for the distribution of A02 data assumes a homogenous labour intensity and economic productivity of forests over national territories. This is a limitation of our methodology as labour intensity and economic productivity may largely differ, for example, between temperate and Mediterranean forests, or according to the pulp production versus wood extraction orientation of some forests. Therefore, the distribution of employment and gross value added data might work better for those countries that dispose of more homogeneous forest types and outcomes over their territory than for those countries that combine different types of forests over their territory (e.g. France, Italy, Spain and Germany in a lesser extent). The existence of possible regional labour productivity differentials is an additional limitation.

Austria illustrates the case of a country with rather homogeneous forest types (Figure 6). Our regional estimates of value added indeed align with those provided by national official statistics.

Figure 6. Percentage of national value added at basic prices of the A02 (forestry) sector in Austria (2016).



Source: Prepared by authors with data from Statistics Austria (2021) and own estimations.

France illustrates the case of a country with more heterogeneous forest types (see Figure 7). The criterion of forest area underestimates forest employment in North-Eastern regions, such as Alsace or Lorraine, and overestimates it in Southern regions like Aquitaine or Languedoc-Roussillon.

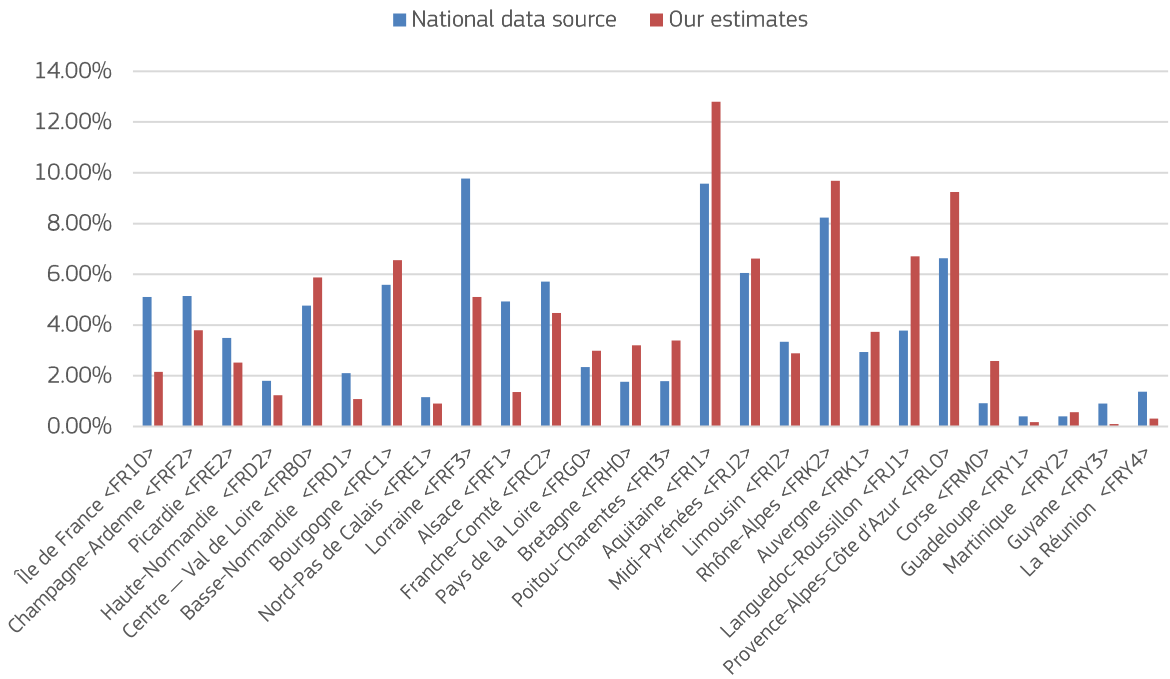
A second limitation is due to the application of national bio-based shares at the regional level on sub-sectors C and D, which gives an approximate measure of the number of persons employed and gross value added created in regions. We recognise that deviations to the national share occur in reality. For example, a NUTS2 region hosting a Bioeconomy cluster is likely to present a higher bio-based share than at the national level. Similar approximations have been tested in Italy by the Research Center for Agricultural Policies and Bioeconomy (CREA-PB) and did not yield satisfactory results for Italian regions being heterogeneous in terms of industrial specialisation.

A third limitation is due to the assumption that national labour productivity is kept the same for each NUTS2 region within a same country, with the exception of the A01 (Agriculture) sector, for which Eurostat provides data on both employment and gross value added at the NUTS2 level. This assumption can lead to some deviations in countries that present a high degree of territorial economic disparities.

Finally, the use of the NUTS-2016 equivalent in order to deal with the many changes in NUTS classification over the observed time period (2008-2019) has resulted in loss of data for some specific regions. In the case of Ireland, previous NUTS2 regions could not be matched with the NUTS-2016 ones causing the loss of Irish regional data for the years 2008 to 2014. Similar cases are found in one Polish region (region PL12 is recoded as PL9 and split into PL91 and PL92), one Hungarian region (region HU10 is divided in HU11 and HU12) and Lithuania (LT00 is divided into LT01 and LT02).

In order to sense the order of error associated to our estimates, we have engaged into a process of data (in)validation with nominated national experts participating in Task 1 of the European Bioeconomy Policy Forum (EBPF) working group.

Figure 7. Percentage of national employment in the A02 (forestry) sector in France (2016).



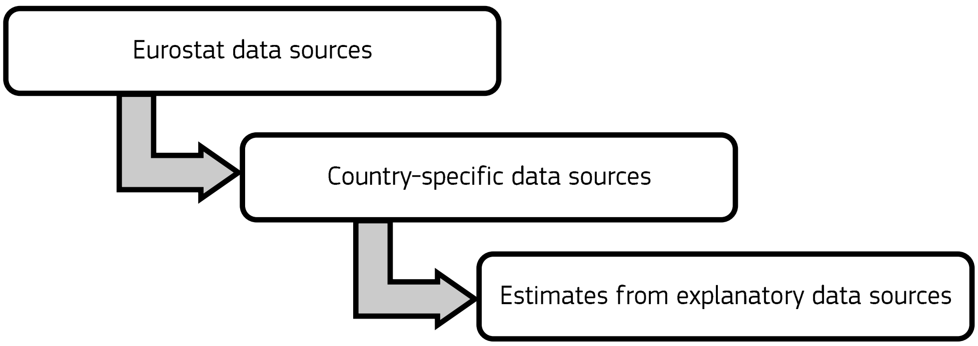
Source: Prepared by authors with data from INSEE (2017) and own estimations.

4.3 Future lines of action

4.3.1 Integrating regional statistics from country-specific data sources

Member States may publish additional data sources that complement or expand the information made available by Eurostat. For instance, the national statistical office from Italy (ISTAT) elaborates regional accounts with disaggregation for sectors A01, A02 and A03, both for employment and value added. In this sense, a potential next step is to identify the regional statistics available in each Member State that can provide relevant information for the estimation of the size of the sectors of the bioeconomy at the regional level. This information would be integrated into our information system following the hierarchical order shown in Figure 8.

Figure 8. Order in which data sources would be integrated into the initial dataset



Source: By authors

The Eurostat data sources providing regional statistics would have the highest priority to be introduced into the dataset. Then, this information would be complemented with additional regional statistics from country-specific data sources if available. Last, in absence of relevant data sources from both Eurostat and country-specific institutions, we will use the estimates derived from the application of the criteria indicated in the methodology section 2.

4.3.2 Estimates for A02 and A03 sectors

The use of the FAO forest areas indicator as a proxy for distributing employment and value added in the forestry sector at the NUTS2 level permits filling the data gaps for sectors A02 and A03. However, this is also a limitation, as labour intensity and economic productivity may largely differ between temperate and Mediterranean forests, for example.

Given the above, it is desirable to find criteria that allow refining the estimates for A subsectors, especially A02 and A03.

- On the one hand, a corrective coefficient for the productivity level of forests is required to adjust the distribution of employment and value added according to forest types.
- On the other hand, it is also desirable to find or design criteria in order to distribute employment and gross value added in the fisheries sector amongst regions. A potential approach would be to follow Natale et al. (2013), which obtains estimates for both employment and gross value added by ports (7) using the number and size of their associated vessels (8). The regional estimates could therefore be calculated from these estimates through aggregation of the values of the ports located within each NUTS2 territorial unit.

4.3.3 Adjustment of bio-based shares to regions

It would be also desirable to adjust the national bio-based shares to the regions, so to consider the territorial distribution of bio-based activities. In this sense, the location of bioeconomy clusters can be important information to detect the concentration (or not) of the different bio-based activities over the territory. Expert knowledge would also be precious complementary information.

4.3.4 Calculation of gross value added for C and D subsectors

An important future task is to explore more realistic assumptions to calculate the regional gross value added than the use of national labour productivity. A possible approach would be to adjust the regional gross value added employing Wages and salaries (*sbs_r_nuts06_r2, V13320: Wages and salaries, million euro*), which is the only potentially explanatory variable available at the regional level from this data source.

In general, a relationship between regional productivity and average worker earnings is identified by some authors (see Rice et al., 2006, or Florida et al. 2011). In some cases, worker wages are used as proxy of labour productivity (e.g. Kemeny and Storper, 2014). However, the academic literature also identifies the existence of a gap between the productivity and wages, due to factors such as the efficiency salaries or institutional factors (minimum wages collective bargaining; see e.g. Basile and De Benedictis, 2008, Rusinek and Torjerow, 2011, Koning and Marcolin, 2014, Kampelmann et al, 2018).

Given the above, even though not totally accurate, the regional distribution of gross value added using wages and salaries as proxy could provide estimates that are closer to the reality than those resulting from applying the national value added per worker.

(7) Related dashboard: https://fishreg.jrc.ec.europa.eu/web/fishaqua-socioeco/coastal-communities
(8) This information is available in the EU Fleet Register (https://webgate.ec.europa.eu/fleet-europa/index_en)

5 Conclusions

In this report, we describe a methodology to estimate employment and gross value added of the bioeconomy sectors at the regional level. This method is based on data sources from Eurostat and the JRC-Bioeconomics dataset. The bio-based shares calculated by Ronzon et al. (2020) are applied to national statistics. After compiling these pieces of information, a range of missing data estimation algorithms are executed in order to complete the dataset.

Preliminary results suggest that the proposed methodology can be a way forward to address the estimation of bioeconomy size at the regional level, which is still a data-poor arena, as evidenced by the high share of missing data (63.6%) within the initial raw dataset. The comparisons of the results obtained with some official statistics allow us to identify some positive aspects in the data, but also the existence of significant discrepancies that should be addressed in the future. In this sense, as we work on a large-scale dataset, it is important to validate the results with expert knowledge. This validation process must be considered as an iterative process of modifying the procedures and/or the algorithms applied to improve the results. Consequently, we identified some relevant future lines of action that may serve to progressively improve the accuracy of our estimations:

- First, it is desirable to find criteria that allow refining the estimates for A subsectors, especially A02 and A03. On the one hand, a corrective coefficient for the productivity level of forests is required to adjust the distribution of employment and gross value added according to forest areas. On the other hand, it is also desirable to find or design criteria in order to distribute employment and gross value added in the fisheries sector amongst regions.
- Second, it is also necessary to adjust the national bio-based shares to the regions, so to consider the territorial distribution of bio-based activities. In this sense, the location of bioeconomy clusters can be important information to detect the concentration (or not) of the different bio-based activities over the territory. Expert knowledge would also be precious.
- Third, another important future task is to explore more realistic assumptions to calculate the regional gross value added than the use of national labour productivity. The latter can indeed hide possible regional economic disparities.
- Lastly, the use of national data sources is also contemplated to obtain more disaggregated and relevant information for our estimation problems. Nominated experts have already been consulted on these aspects and are helping on the identification of such national data sources.

The JRC organized a follow-up consultation with experts on November 23rd, 2021, in the framework of the European Bioeconomy Policy Forum's Knowledge for Bioeconomy Working Group - Task 1 - "Improving the estimation of socio-economic indicators for the European bioeconomy". Main feedback from these consultations are reflected in the Annex. Further discussions and exchanges are foreseen to let room for the adjustments deemed necessary.

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Annex. Workshop summary report

European Bioeconomy Policy Forum
Knowledge for Bioeconomy Working Group
Task 1: Improving the estimation of socio-economic indicators for the European bioeconomy

23 November 2021
10.00-12.00 CET
Venue: Online - Webex

[Extract from Summary Report]

Bioeconomy employment and value added in EU regions
Jesús Lasarte López and Tévécia Ronzon, Project officers; Robert M'barek; JRC.D.4 Economics of Agriculture:

Jesús Lasarte presented the methodological approach for the regionalisation of the socio-economic indicators, presented on an interactive dashboard with data on employment and value added at NUTS2 level with restricted access to the experts group.

The advantage and drawbacks of three different approaches found in the literature for the quantification of these indicators were presented: i) pure regional statistics; ii) regional statistics combined with bio-based shares and iii) implementation of regional data from ad hoc surveys. The presenter explained why the methodology applying bio-based shares to statistics from Eurostat and DataM agro-economics data portal was eventually chosen as the way forward.

The general overview of the selected methodology was then described. It was highlighted the need to use proxies and inter-variable correlation for those sectors where no regional data is available (e.g. relationship between employment and value added in the forestry sector with the share of forest land) to downscale the quantification. The approach developed tries to fill data gaps by means of algorithms in order to obtain a harmonised and complete database.

The resulting interactive dashboard with the preliminary results was presented, including the four different sheets covering the time evolution, sectoral composition, European overview and the underlying data.

Some data validation has been already performed, e.g. comparing the results from the JRC for certain regions with data from BIC (Bio-based Industries Consortium), the Andalusian Bioeconomy Strategy and other data sources. The JRC estimation shows good alignment with such sources albeit for some regions and sectors the discrepancy increases. The main source of uncertainty appears to be the national bio-based shares applied to the regional level.

Jesús asked the participants for feedback on the preliminary results obtained as well as for new sources of regional data, especially for manufacturing and energy sectors, that could feed the methodology developed.

Discussion on the methodology and improvement avenues

Many experts welcomed the work presented and asked for some time to look and analyse the preliminary results. Having regional data on the bioeconomy is crucial, especially for those countries with regional competences in certain policies. The JRC underlined that these are preliminary results and they could be published in the second half of 2022.

Some experts already pointed to regional data for certain bioeconomy sectors that could be useful for this work, which will be shared with JRC. The importance to take into consideration the territorial heterogeneity when applying national statistics or bio-based shares to downscale the estimation was raised. Performing country-based research was suggested for this purpose.

Some additional comments and suggestions were also provided:

- Regional clusters of manufacturing sectors may be a useful contact point to provide some regional data for specific sectors.
- Other monitoring frameworks related to the bioeconomy with regional data could also be considered. In this regard, some experts raised the importance of studying the contribution of the bioeconomy to the circular economy.
- Some regions are developing the bioeconomy strategy faster than countries, which can have implications for regional statistics.
- Some small countries with advance regional initiatives and data could serve as pilot to validate the methodology.

- The ranking of the regions may not be triggered by the development of the bioeconomy sectors but by the size of the regions, so it was proposed to show ranks of regions not in absolute numbers but by relative numbers (shares). It was also proposed to review the level of sectoral disaggregation in some figures.

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