



Report
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Socioeconomic Indicators to Monitor Norway's Bioeconomy in Transition

Marco Capasso and Antje Klitkou

NIFU

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Preface

This report gives an assessment of socioeconomic indicators for the Norwegian bioeconomy. The report is an outcome of a project funded by Innovation Norway (project no. 2019/106506) in collaboration with the Research Council of Norway. The objective of this project was to compare the Norwegian bioeconomy with the bioeconomy of other European countries, to compare Norwegian bioeconomic sectors with other Norwegian economic sectors, and to analyse regional specialization for bioeconomic activities in Norway.

The study has been carried out by Marco Capasso and Antje Klitkou, researchers at the Nordic Institute for Studies in Innovation, Research and Education (NIFU). The authors would like to thank: Marit Heller, Krister Moen, Trond Einar Pedersen, Sigridur Thormodsdottir, Marit Valseth and Oskar Aalde, for useful comments and suggestions; Idiano D'Adamo and Piergiuseppe Morone, for advices about the computation and application of sectoral bioshares; Borregaard AS, Designindustrien, LMI Legemiddelindustrien, Norner AS, Norsk Industri, Norsk Komposittforbund and Teko Bransjeforening, for contributing to the interview process; and Innovation Norway and the Research Council of Norway, for financing the project. The responsibility for any error and the views expressed are solely of the authors.

We do hope that the study is useful in itself and that it opens up for future research projects in this area.

Oslo, January 2020

Espen Solberg
Head of Research

Marco Capasso
Project Leader

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Summary

Environmental challenges at global scale are forcing countries to re-examine their economic structure and adopt new economic concepts. The bioeconomy is a concept increasingly used to circumscribe that part of the economy which depends on the utilization of biomass.

Our study has replicated recent analyses of the European bioeconomies, to assess the features and evolution of the Norwegian bioeconomy. We find that:

- the Norwegian bioeconomy is characterised, as for other Nordic countries, by a high productivity and a relatively low share of workers in bioeconomic sectors;
- the Norwegian bioeconomy has strongly increased its productivity in recent years;
- an astonishingly high peak in productivity is registered for Fishing and Aquaculture, whose value added has evolved massively;
- Pharmaceuticals are experiencing a dramatic shift toward bio-based production and thus contributing to qualitative changes in the Norwegian bioeconomy.

A need to measure the whole bioeconomy in Norway

The "bioeconomy", meant as the economic system connected to the valorisation of biomass, has long existed in Norway. However, the view of the bioeconomy as a unique entity, with an attached value arising from the current climate challenges, is a novel concept, bringing new challenges with it. The concept is novel because the battle towards climate change eliminates the traditional logical discontinuities between agriculture, forestry and fishery which were grounded in different production systems, but that today show a peculiar quality of representing environmentally sustainable economic cycles. The value added in the bioeconomy should be conceptualized, and operationalised, as the sum of several components, each one related to a particular economic sector, having its own peculiarities in terms of technology and markets.

Aligning with previous European analyses

The European Union has recently been covered by quantitative analyses of the bioeconomy (Ronzon et al. 2017), and results about the EU bioeconomy's value added have specifically been summarised by Ronzon and M'Barek (2018). Their analysis is sector-based, in the sense that it builds upon statistics which follow industry NACE codes; Norway is not present among the countries they have studied. Based on their work, we provide a novel analysis of the processes of value creation in Norway, in order to assess the current situation and the ongoing evolution of the Norwegian bioeconomy. A comparison with the European countries allows us to define the Norwegian bioeconomy within a broader international context, as well as to assess whether changes in the Norwegian bioeconomy mirror changes occurring at European scale. Our specific analysis of Norway is based methodologically on what has been done by Ronzon et al. (2017) and Ronzon and M'Barek (2018) about the European Union case, but it also builds upon previous socio-technical analyses of the Norwegian bioeconomic potential (NHO 2015) and previous quantitative overviews of the Norwegian bioeconomic context (Falk-Andersson, Forbord, and Vennesland 2016; Mikkelsen 2017).

"Pure" and "hybrid" bioeconomic sectors

If we follow a NACE classification of sectors, thus adopting a traditional categorization of economic sectors, the main issue is understanding which NACE sectors can be defined as bio-economic and which ones are not. A good starting point is referring to the sectors that most easily can be associated to the bioeconomy; those sectors are, following Ronzon and M'Barek (2018): A01, A02, A03; C10, C11, C12, C15, C16, C17. They can be summarised as: the bioeconomic primary sectors (Agriculture, Forestry, Aquaculture and Fishing) plus the types of manufacturing that almost exclusively use biomaterials as main inputs (food, beverages, tobacco, leather, wood products excl. furniture, paper). Notice they are all classified at 2-digit NACE coding.

However, a more comprehensive view of the Norwegian bioeconomy should also consider what Ronzon and M'Barek (2018) call "hybrid" sectors: C13 (textiles), C14 (clothes), C31 (furniture), C20 (chemicals), C21 (pharmaceuticals), C22 (plastics and rubber), C2014 (other organic basic chemicals), C2059 (other chemical products), D3511 (electricity). For these sectors, only a part of the production can be considered as "bio-based". For each of these sectors, Ronzon and M'Barek (2018) estimate a bio-based percentage which varies across EU countries.

We use interviews with Norwegian experts to define possible differences between the "bio-based" shares of Norwegian "hybrid" sectors and the average of the "bio-based" share of the same "hybrid" sector across the three EU Nordic countries

(Denmark, Sweden and Finland), as based on Ronzon and M'Barek (2018) estimates. For one of the “hybrid” sectors, production of electricity, we define the Norwegian “bio-share” looking at the energy mix overview (“varedeklarasjon”) from the Norwegian energy directorate (Noregs vassdrags- og energidirektorat, NVE). We then apply such “bioshares” to the data, made available by Statistics Norway at country-level, on value added and employment in the Norwegian sectors, in order to assess the features and evolution of the Norwegian bioeconomy. By using a novel algorithm to disentangle 2-digit sectoral information at county-level, we are also able to restrict the geographic scale of our analysis, and examine the development of the bioeconomy in the different Norwegian counties. The following table shows the data on employment and value added (year 2017) in “pure” bioeconomic sectors (highlighted in green) and “hybrid” bioeconomic sectors (highlighted in orange), on which we apply the bioshares as inferred from our interview (right column; the data sources are described in the main text of the report); the value added and employment are for the entire sectors and not only for their “bio” components.

Sector	NACE code	Persons employed	Value added (millions NOK)	Bioshare
Agriculture	01	34700	16112	1
Forestry	02	3800	5419	1
Fishing	031	9473	13491	1
Aquaculture	032	8028	30110	1
Manufacture of food, beverages and tobacco	10, 11, 12	51625	45573	1
Manufacture of textiles	13	2855	1916	0.15
Manufacture of wearing apparel	14	1762	1044	0.40
Manufacture of leather	15	156	66	1
Manufacture of wood products	16	13910	8800	1
Manufacture of wooden furniture	31	5266	3477	0.40
Manufacture of paper	17	2899	2981	1
Manufacture of chemicals (excl. NACE 2014 and 2059)	20	7166	11215	0.10
Manufacture of pharmaceuticals	21	2532	6076	0.50
Manufacture of plastics and rubber	22	4759	4004	0.03
Manufacture of other organic basic chemicals	2014	1272	1990	0.20
Manufacture of other chemical products n.e.c.	2059	871	1311	0.05
Production of electricity	3511	4288	28032	0.001

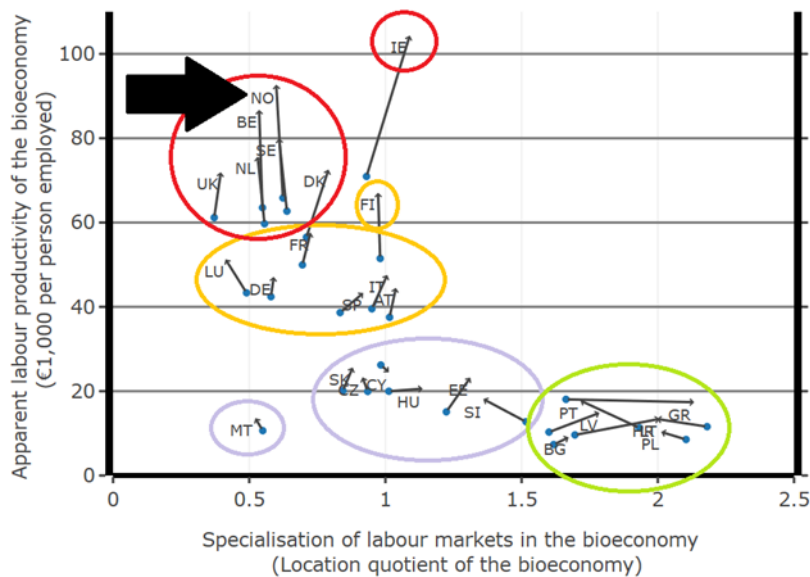
Bioeconomic “pure” (green) and “hybrid” (orange) sectors: NACE industry code; persons employed; value added; bioshare (as inferred from interviews). Persons employed and value added are shown for the entire sectors (and not only for their bio-based parts). Source: NIFU/Statistics Norway.

High and increasing productivity

According to our results, Norway belongs to the “Nordic bioeconomy cluster” previously identified by Ronzon and M'Barek (2018) with some of the EU countries:

the Norwegian bioeconomy is characterised, as for other Nordic countries, by a relatively low share of workers employed in bioeconomic sectors and, at the same time, by a very high labour productivity in the same sectors (see the following figure, showing the evolution of the location quotient and apparent labour productivity in the bioeconomy of Norway and of the 28 EU Member States, 2008–2015). In other words, while not many workers are employed in the Norwegian bioeconomy, their socioeconomic impact is high. This is due not only to a high productivity across all bioeconomic sectors, as expected given the level of development of the Norwegian economy, but also to an astonishingly high peak in productivity in fishing and aquaculture, whose value added has evolved massively during the last ten years.

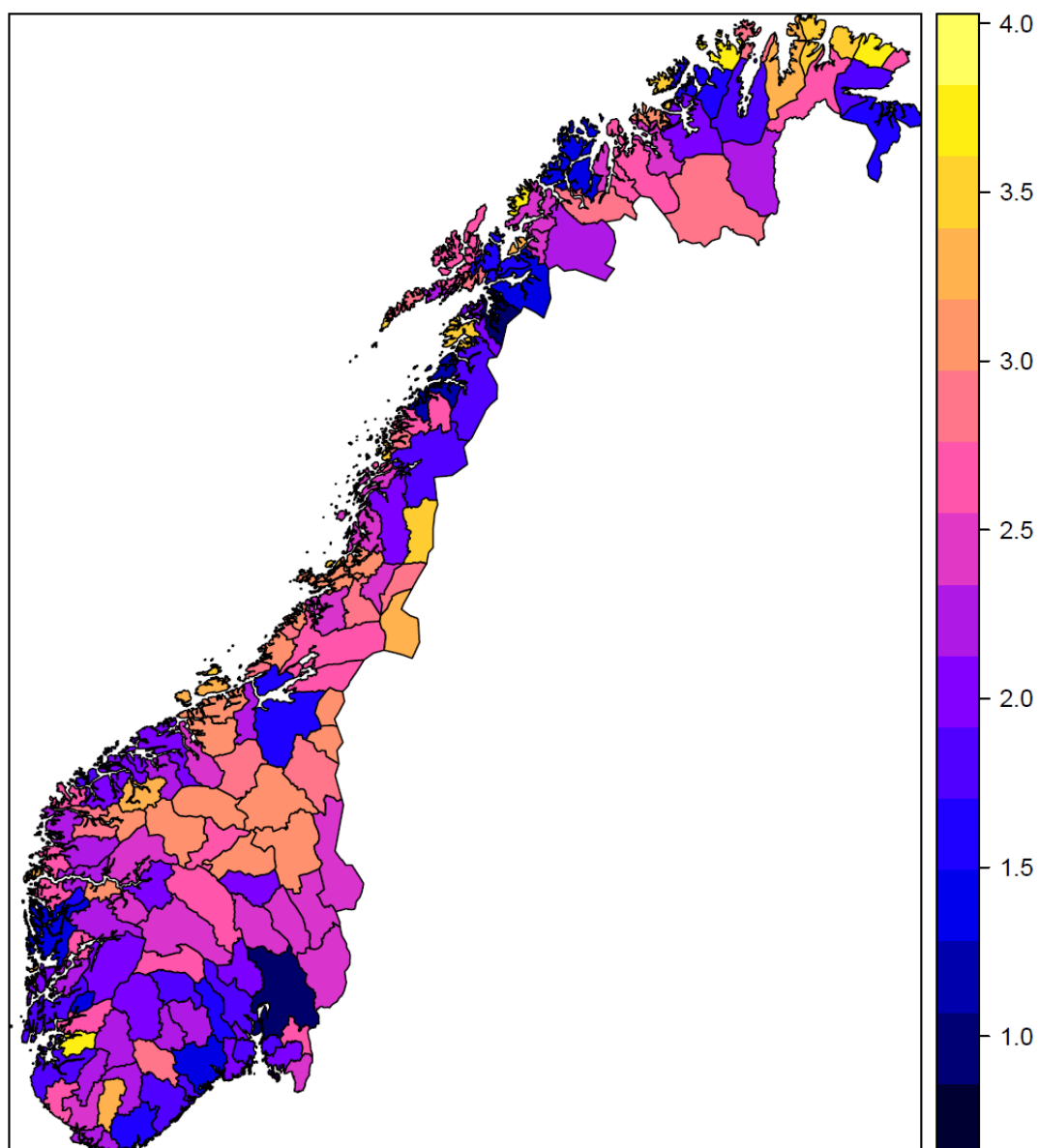
As a whole, the Norwegian bioeconomy has strongly increased its productivity in recent years. Sectors connected to food and beverages, which already had a high weight within the Norwegian bioeconomy, are still increasing their contribution to the Norwegian value added; at the same time, pharmaceuticals are experiencing a dramatic shift toward bio-based production and thus contributing also to qualitative changes in the Norwegian bioeconomy. We need to point out that seemingly stable measures of value added for some sectors, for instance in forestry and in paper manufacturing, may hide strong internal dynamics within the sectors, aimed at curbing pressures from foreign competition.



Evolution of the location quotient and apparent labour productivity in the bioeconomy of Norway and of the 28 EU Member States, 2008–2015. Note that Romania is missing since it is out of scale (location quotient of 3.77). Source: NIFU/Statistics Norway.

Regional distribution and specialisation

All the counties of Norway contribute to the Norwegian bioeconomy, even if differences in the contribution are registered both quantitatively and qualitatively. The counties on the Western coast, and especially Hordaland and Sogn og Fjordane, enjoy a high productivity in the fishing and aquaculture sectors. Moreover, we detect productivity peaks in Nordland for food production, in Nord-Trøndelag for paper manufacture, in Møre og Romsdal for forestry and furniture. Also Hedmark and Østfold are highly productive in forestry, while Østfold in particular shows a high contribution to the whole bioeconomy due to its productivity in agriculture, chemicals, wood products and paper. Telemark and Vestfold contribute to the bioeconomy also through bio-based chemicals and plastic, while in Akershus and in the Southern counties the pharmaceutical sector (highly productive everywhere in Norway, and with an increasing share of bio-components) shows a productivity peak. The following figure shows the employment in the bioeconomy as percentage (in logarithm) of the total local employment, for each labour market area of Norway (year 2017).



Employment in the bioeconomy as percentage (in logarithm) of the total local employment, for each labour market area of Norway (year 2017). Source: NIFU/Statistics Norway.

Exploring the bioeconomic context further

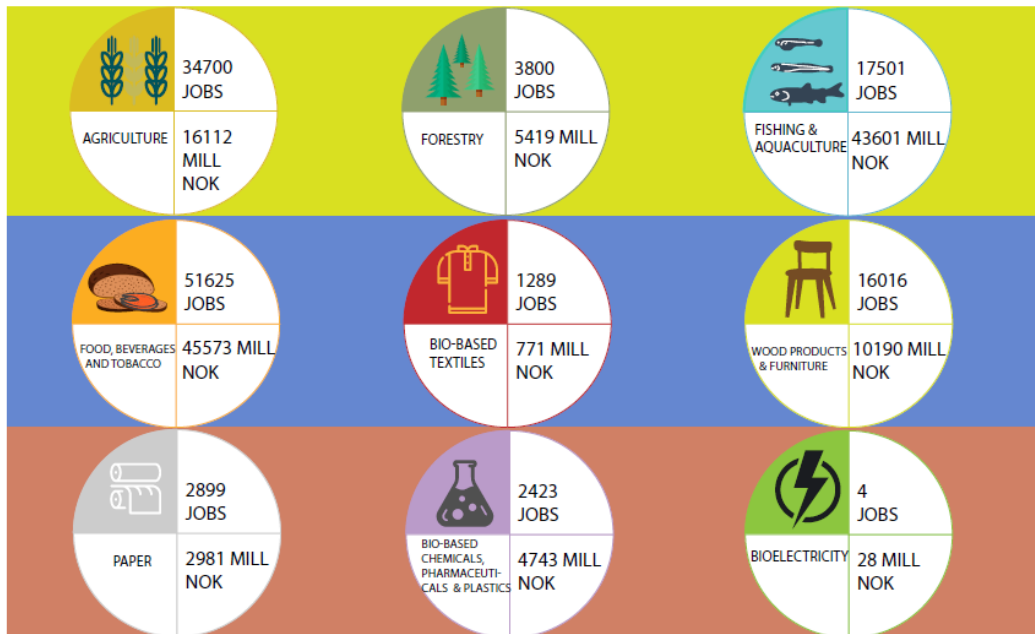
Our empirical analysis leads to formulate a general reflection about the definition of bioeconomy and its implications for socioeconomic quantitative studies. Traditionally, when it comes to define the bioeconomy in quantitative terms, and to estimate its value in monetary terms, researchers tend to focus only on the sectors which constitute the “green” economy (agriculture and forestry) and the “blue” economy (fishing and aquaculture). The articles by Ronzon et al. (2017) and by Ronzon and M’Barek (2018) have extended the boundaries of the bioeconomy

from the primary sectors to include secondary sectors which are still connected to biomass, even if less directly. This is the approach we have followed in our study, in order to compare our results for Norway with what already found for European Union countries. However, we think that researchers could take a further step: more sectors could, in the future, be included in the analysis, starting with the construction sectors and the waste collection and treatment sectors. In addition, we signal the methodological difficulties arising from an economy's openness: when a country, like Norway, is highly active in international trade, trading also biomass and bio-based products, then additional assumptions are needed to circumscribe and measure the country's bioeconomy.



BIOECONOMY

EMPLOYMENT 130,257 WORKERS
 VALUE ADDED 129,418 MILLION NOK
 LABOUR PRODUCTIVITY 994,000 NOK
 PER PERSON EMPLOYED



NORWAY

DATA 2017

Source: Socioeconomic Indicators to Monitor Norway's Bioeconomy in Transition, 2019

1 Introduction

The environmental challenges connected to climate change have made it a necessity to look for new ways of production and consumption. For instance, the cycles of production should change in order to reach a new equilibrium between CO₂ produced and CO₂ stored, which is compatible with a stable temperature in the world. A sustainable cycle can be reached through a higher utilization of organic materials which derive from "recently" living beings ("biomass"), so that the cycle of the production for human utilization is consistent with a lifecycle where photosynthesis prevents the level of CO₂ in the air to increase. The "bioeconomy", meant as the economic system connected to the valorisation of biomass, has long existed in Norway. However, the view of the bioeconomy as a unique entity, with an attached value arising from the current climate challenges, is a novel concept, bringing new challenges with it. The concept is novel because the battle against climate change eliminates the traditional logical discontinuities between agriculture, forestry and fishery which were grounded in different production systems, but that today show a peculiar quality of representing environmentally sustainable economic cycles. It brings new challenges because an increased activity in the bio-economy can occur more easily if new paths to value creation can be identified, thus providing also at the private level incentives to an activity that is collectively desirable.

By value creation, we refer to the value of the primary resources plus the value that is added to the primary resources along the value chain, by working on the resources and transforming them into something more useful and/or less easily available. The "value added", for each stage of transformation of the bioresource, can thus be measured in monetary terms, as the difference between the amount of money paid for the bio-good after and before the transformation. Notice that such amount crucially depends on the transformation chosen: a type of transformation that is more difficult to achieve and which provides a more useful transformed good will correspond to a higher value added. Therefore, a higher knowledge of the final markets and a higher technological ingenuity in the transformation process would be necessary to maximise such value added. Moreover, a proper consideration of side-streams and residues, allowing a valorisation of what would oth-

erwise go wasted, will provide, in the aggregate, a higher value added in the "bioeconomy". That is why recycling processes, economies of scope and cascading use of bioresources become key elements for a maximisation of the value added in the bioeconomy. When put in a comparative perspective, the increasing use of such processes would allow to provide the right incentives for a restructuring of the whole economy, which in turn allows to achieve the desired environmental goals. But to properly observe how the restructuring is taking place, it is necessary to develop a clear idea of the "structure" of the bioeconomy, intended as its composition in terms of economic sectors. The value added in the bioeconomy should then be conceptualized, and operationalised, as the sum of several components, each one related to a particular economic sector, having its own peculiarities in terms of technology and markets.

The European Union has recently been covered by quantitative analyses of the bioeconomy (Ronzon, Piotrowski, M'Barek, & Carus, 2017), and results about the EU bioeconomy's value added have specifically been summarised by Ronzon and M'Barek (Ronzon & M'Barek, 2018). Their analysis is sector-based, in the sense that it builds upon statistics which follow industry NACE codes; a difficulty that the authors had to face and overcome, in their analysis, was indeed the association of NACE codes to the bioeconomy. However, a sector-based analysis allows an easier understanding of how the bioeconomy interacts with a nation's economic structure, and of how its value results from the economic contribution of organizational and geographical units that are sectorally defined. Additionally, the study by Ronzon and M'Barek (Ronzon & M'Barek, 2018) investigates diversities in bioeconomic value creation across European countries, and is able to point at an untapped potential for bioeconomic value creation in Central and Eastern Europe.

Norway is not present among the countries studied by Ronzon and M'Barek (Ronzon & M'Barek, 2018). Our study provides a novel analysis of the processes of value creation in Norway, in order to assess the current situation and the ongoing evolution of the Norwegian bioeconomy. A comparison with the European countries allows us to define the Norwegian bioeconomy within a broader international context, as well as to assess whether changes in the Norwegian bioeconomy mirror changes occurring at European scale. Our empirical analysis leads to formulate a general reflection about the definition of bioeconomy and its implications for socioeconomic quantitative studies.

2 Materials and Methods

2.1 Method

Our specific analysis of Norway is based methodologically on what has been done by Ronzon et al. (2017) and Ronzon and M'Barek (2018) about the European Union case; it also builds upon previous socio-technical analyses of the Norwegian bioeconomic potential (NHO, 2015) to deepen previous quantitative overviews of the Norwegian bioeconomic context (Falk-Andersson, Forbord, & Vennesland, 2016; Mikkelsen, 2017).

The first goal is understanding how much value added can be found in the Norwegian bioeconomy, according to the sectors that pertain to the bioeconomy. If we follow a NACE classification of sectors, thus adopting a traditional categorization of economic sectors, the main issue is understanding which NACE sectors can be defined as bioeconomic and which ones are not. A good starting point is referring to the sectors that most easily can be associated to the bioeconomy. Those sectors are, following Ronzon and M'Barek (Ronzon & M'Barek, 2018): A01, A02, A03; C10, C11, C12, C15, C16, C17. They can be summarised as: the bioeconomic primary sectors (Agriculture, Forestry, Aquaculture and Fishing) plus the types of manufacturing that almost exclusively use biomaterials as main inputs (food, beverages, tobacco, leather, wood products excl. furniture, paper). Notice they are all classified at 2-digit NACE coding.

This is possible to retrieve with an almost perfect correspondence. Indeed, Statistics Norway (the national Norwegian statistical office) provides figures for value added, at country level for whole Norway, using a high disaggregation of industries. This means that it is possible to retrieve figures, for value added, about: Crop and animal production, hunting and related service activities; Forestry and Logging; Manufacture of food products, beverages and tobacco products; Manufacture of wood and wood products, except furniture; Manufacture of paper and paper products. Notice that this covers all the "pure" bioeconomic sectors, with the exception of leather, which is mixed with other textile types of manufacturing and therefore is not accounted on its own. Notice also that these are the same sectors which NHO Mat og Drikke (a section of the main Norwegian industry association)

has considered in the rapport «Mot Bioøkonomien» of 2016 (NHO, 2015) when showing the total employment and production value of the bioeconomy in Norway (see footnote 2 at page 7 of NHO, 2015).

However, a more comprehensive view of the Norwegian bioeconomy should also consider what Ronzon and M'Barek (2018) call “hybrid” sectors: C13 (textiles), C14 (clothes), C31 (furniture), C20 (chemicals), C21 (pharmaceuticals), C22 (plastics and rubber), C2014 (other organic basic chemicals), C2059 (other chemical products), D3511 (electricity). For these sectors, only a part of the production can be considered as “bio-based”. For each of these sectors, Ronzon and M'Barek (2018) estimate a bio-based percentage which varies across EU countries. Following a methodology first outlined by Ronzon et al. (2017), the authors first compile a product-level assessment of bio-based percentage (this is made through expert interviews and it is uniform across countries), and then, by checking the relative shares of products within the production of each sector in each country (possible mainly through the ProdCom statistics compiled by Eurostat), are able to reach an assessment of bio-based percentage which varies both across sectors and across countries (for the bio-electricity case, a different procedure is adopted based on energy balances shown by Eurostat). For instance, they can say to which extent the textile sector is “bio-based” in Denmark; such “bio-based share” is then used to assess how much of the value added of the whole textile sector in Denmark should be ascribed to the Danish bioeconomy value added. Notice that, through the database published by Ronzon and M'Barek (Ronzon & M'Barek, 2018),¹ it is possible to obtain the “bio-based share” for each “hybrid” sector of each EU country, but not the product-level expert assessment which, combined with the figures of ProdCom for the Norwegian sectors, would allow to infer a specific “bio-based” share of the Norwegian “hybrid” sectors. Therefore, as a general rule, we will use interviews with Norwegian experts (see Section 2.3) to define possible differences between the “bio-based” shares of Norwegian “hybrid” sectors and the average of the “bio-based” share of the same “hybrid” sector across the three EU Nordic countries (Denmark, Sweden and Finland), as based on Ronzon and M'Barek (2018) estimates. For one of the “hybrid” sectors, production of electricity, we will define the Norwegian “bio-share” looking at the energy mix overview (“varedeklarasjon”) from the Norwegian energy directorate (Noregs vassdrags- og energidirektorat, NVE).

When moving to county-level analysis, the sectoral aggregation available at Statistics Norway, from what concerns value added, becomes coarser. Figures for value added and employment are available at county level only with the A38 classification (see the next subsection for details). This means that, in order to target

¹ Retrievable at <https://datam.jrc.ec.europa.eu/datam/perm/od/7d7d5481-2d02-4b36-8e79-697b04fa4278/download/dataset.zip>

sectors which are, at least to some extent, bioeconomic, we often need to disentangle different 2-digit components of value added within the same A38 group. To this purpose, we base ourselves on the number of employees working, in each county, in each 2-digit sector; the number is produced by an aggregation of establishment-level data made available to us by Statistics Norway (2019). As a starting point, we will assume that all workers in a given 2-digit sector have the same productivity (meant as value added per worker), independently of where they are located in the country. The country-level productivity is computed by using country-level data for value added and employment, which are available at 2-digit level. We use the country-level productivity to provide a first estimate of what the value added would be for a whole A38 group in each single county; this is done by multiplying the 2-digit country-level productivities times the 2-digit county-level numbers of employees, and then aggregating the 2-digit figures into an A38 figure. Using this first estimate as an initialization, we then apply a software algorithm (written by us and available on request) to adjust the figures for county-level 2-digit value added, in order to satisfy two constraints: a) the sum of our estimates of the county-level value added for all 2-digit sectors within an A38 sector, within each county, must equal the official county-level value added of the same A38 sector, in the same county, as provided by Statistics Norway; b) the sum across all counties of our estimates of the county-level value added, for each 2-digit sector, must equal the official country-level value added of the same 2-digit sector, as provided by Statistics Norway. In order to reach these goals, each iteration of the algorithm provides a slight adjustment of the labour productivity within each 2-digit sector and within each county, and it also allows spillovers of productivity across sectors (by assuming that some workers in a 2-digit sector may contribute to the value added of other 2-digit sectors of the same county within the same A38 sectoral group). This procedure is repeated for each year and allows us to obtain estimates of value added for each 2-digit sector and for each county. By applying the “sectoral bioshares”, as inferred from our interviews, to each 2-digit sector, we are then able to provide a description of value added and labour productivity for all the bioeconomic activities of each county of Norway. The procedure is working properly for all the A38 groups considered in our analysis, with the exception of “Refined petroleum, chemical and pharmaceutical products”; for this A38 group, the strong heterogeneity between the 2-digit sectors included leads to unreliable results. Therefore, we will complement our county-level analysis, not only for these particular sectors but for all the bioeconomic sectors, by considering also turnover per employee as an additional productivity proxy.

Indeed, while county-level measures of value added must be reconstructed through the algorithm described above, measures of turnover and employees can be obtained, at any geographic scale of analysis, by aggregating establishment-

level “micro-”data from Statistics Norway (2019). In particular, Statistics Norway compiles a dataset describing several variables, including turnover and number of employees, as well as NACE code of the sector, for each establishment in Norway (see the next subsection for details). Therefore, for comparison with our county-level estimates of bioeconomic value added, we will also provide county-level measures of turnover per employee. Notice that here we refer to turnover, in a given county or region, as the sum of the turnovers of all companies located in the region. Unlike for value added, whose meaning does not change when summed across different units, measures of turnover acquire a different interpretation when summed across different units (Ronzon & M’Barek, 2018 point out well the possible problems deriving from turnover “double counting”). Our measures of turnover for employee, in bioeconomic sectors of each county, will therefore not represent a precise measure of labour productivity, but will instead signal the level of bioeconomic activity in each geographic area considered. Metaphorically, we could say that a high total turnover in a sector in a geographical region is a figure for the “thickness” of the sectoral value chain in the same region. By pairing measures of turnover per employee with measures of value added per employee, we can thus provide the reader with a clearer idea of how bioeconomic activities are spread across the different counties of Norway. Given that, when using the turnover variable, we can focus on even smaller geographic areas (since we are aggregating data at establishment-level), we will show also figures about the distribution of bioeconomic activities across labour market areas of Norway. Labour market areas are larger than municipalities and smaller than counties; to define them, we follow the classification by Juvkam (2002).

2.2 Data

The data on value added for Agriculture, Forestry, Fishing and Aquaculture are taken from the dataset "09170: Production account and income generation, by industry 1970 - 2018" of Statistics Norway ("Value added at basic prices. Current prices (NOK million)"; update from 29.08.2019, downloaded on 16.09.2019).

The data on value added, and on employees, of all manufacturing sectors are taken from the dataset "08596: Principal figures for establishments in manufacturing, by industry (SIC2007) 2007 - 2017" compiled by Statistics Norway (respectively "Value added (factor) (NOK million)" and "Persons employed (persons)"; update from 15.04.2019, downloaded on 02.07.2019). In particular, the values for sectors with NACE codes 10, 11 and 12 have been retrieved already as a unique group, without need of further aggregation (since they correspond to manufacture of food, beverages and tobacco, which are considered completely as bio-products); the values for sectors with NACE codes 16 and 17 have been retrieved directly at

2-digit level, without need of aggregation; the values for sectors with NACE codes 13, 14, 15, 20, 21, 22 and 31 have been retrieved at 3-digit level and then aggregated at 2-digit level (since the higher aggregation level already available mixes together sectors having different bioshares); the values for sectors with NACE codes 2014 and 2059 have been retrieved at 4-digit level and then aggregated at 2-digit level (since they are analysed separately).

The data on employees for Agriculture are taken from the Labour Force Survey dataset “lfsa_egan22d: Employment by sex, age and detailed economic activity (from 2008 onwards, NACE Rev. 2 two-digit level)” compiled by Eurostat (update from 08.08.2019, downloaded on 22.08.2019). The data on employees for Forestry are taken from the Labour Force Survey dataset “for_emp_lfs: Employment in forestry and forest-based industry” compiled by Eurostat (update from 08.08.2019, downloaded on 22.08.2019). The data on employees for Fishing are taken from the dataset “07811: Fishermen, by fishing as source of livelihood (C) 1945 - 2017” compiled by Statistics Norway (update from 08.11.2018, downloaded on 22.08.2019). The data on employees for Aquaculture are taken from the dataset “03214: Fish farming of salmon, rainbow trout and other marine species. Number of workers and labour input, by type of production (C) 1986 - 2018” compiled by Statistics Norway (update from 20.06.2019, downloaded on 22.08.2019).

The data on value added and employees for sector 3511 (Production of Electricity) are taken from the dataset “sbs_na_ind_r2: Annual detailed enterprise statistics for industry (NACE Rev. 2, B-E)” compiled by Eurostat (update from 19.08.2019, downloaded on 22.08.2019).

The data on value added for all sectors of Norway, grouped together, are taken from the dataset “NY.GDP.FCST.CN: Gross value added at basic prices (GVA) (current LCU)” compiled by the World Bank (update from 24.04.2019, downloaded on 25.06.2019).

The data on employees for all sectors of Norway, grouped together, are taken from the Labour Force Survey dataset “lfsa_egan22d: Employment by sex, age and detailed economic activity (from 2008 onwards, NACE Rev. 2 two-digit level)” compiled by Eurostat (update from 28.08.2019, downloaded on 04.09.2019).

The conversion of value added from the Norwegian currency to Euros (used for comparisons between Norway and European Union countries) has been performed using conversion rates from the European Central Bank (downloaded on 04.09.2019; for each year, conversion rates from July, 1st have been considered).

Data on value added and employees for each county of Norway have been extracted from the dataset “11713: Regional accounts, by industry (C) 2008 – 2017” compiled by Statistics Norway (update from 11.10.2018, downloaded on 26.06.2019); in particular, data at A38 disaggregation have been used for all sec-

tors except “Wood, wood products and paper products”, while data at “main industries” disaggregation, as called by Statistics Norway, have been used for “Wood, wood products and paper products”. Notice that, for primary sectors, differences in the employment numbers may exist between the labour force survey source (used for our statistics at national level) and the regional accounts source (used for our statistics at county level); some discrepancies may thus occur between productivity figures across different geographic scales. The results we show at county-level are based on averages across years 2015, 2016 and 2017, in order to “average out” possible estimation mistakes.

Finally, we use micro-level data from Statistics Norway, extracted from the “Virksomhet og Foretak” (“Establishments and Enterprises”) dataset for year 2017, about turnover and number of employees of each establishment located in Norway. In particular, the municipality location and the NACE industry code available for each establishment allow us to build figures of turnover per employee at the level of labour market area and at the level of county. Both types of information will be used by us in the section on the regional analysis of the Norwegian bio-economy.

2.3 Interviews

The design of the analysis required an assessment of the bio-share of the different hybrid sectors by experts. The experts belong to following manufacturing sectors (in brackets: the organisation for which the experts currently work):

- C13: Manufacture of textiles (Teko Bransjeforening)
- C14: Manufacture of wearing apparel industry (Teko Bransjeforening)
- C20: Manufacture of chemicals and chemical products (Norsk Industri, Borregaard and Norner)
- C21: Manufacture of basic pharmaceutical products and pharmaceutical preparations (LMI Legemiddelindustrien)
- C22: Manufacture of rubber and plastic products (Norner and Norsk Komposittforbund)
- C31: Manufacture of furniture (Designindustrien)

We identified at least one expert in each of the industries and organised interviews with at least one of those experts, either as face-to-face interviews or as telephone or Skype-based interviews, lasting between 30 minutes and one hour. All interviews were recorded and transcribed; for anonymity purposes, no names of the interviewees will be mentioned, but only their affiliation. For the interviews we created an interview guide which the interviewees received in advance to be able to be prepared for our questions (the interview guide is available on request).

In the interviews we asked the interviewees to give an assessment of the bio-share for their respective sector, based on value added or turnover. We asked also if the experts could distinguish between different product groups and if they had observed changes in the bio-share over the last 10 years. We asked them also to tell us how well they know the sector and how precise can their assessment be. To support this information gathering process, we had computed the development of the bio-shares for the respective sectors in each of the neighbouring Nordic countries, Denmark, Finland and Sweden and calculated also the average for those three Nordic countries, all based on the existing EU-study by Ronzon and M'Barek (2018). Then the experts could discuss the differences and/or similarities with those countries. We finalised the interviews by asking if they could see some differences with regard to the regional specialisation, within Norway, in the sector of interest.

The information regarding following three sub-sectors were collected by a combination of interviews with the firms Norsk Industri, Borregaard and Norner, as well as on open available statistics:

- C20.14: Production of other organic raw materials
- C20.59: Production of chemical products not mentioned elsewhere
- D35.11: Production of electricity.

In the following we summarise the main information from the interviews with regard to the bio-share in the respective sector, a discussion of the differences compared to the other Nordic countries, eventual trends – both in the past and in the future, some problems related to the assessment of the bio-share, and we highlight main product groups and regional specialisation, including names of larger companies and their location (if mentioned by the interviewees).

3 Results

3.1 Information from the interviews

3.1.1 Manufacture of textiles (NACE: C13)

The interviewee concluded that the bio-share is ca. 15% for Norway and that the share has been rather constant over the last 10 years.

There is very little production of textiles in Norway. There was much more after WW2 but in the seventies and eighties those textile plants mostly closed. Today the production is mainly restricted to knitting yarn from wool, to polyester-based fishing nets, and textile elements in oil spill containment booms.

There are three main companies producing woollen knitting yarn: Sandnes Ullvare in Rogaland, Hillesvåg outside Bergen, and Rauma Ullvare in the Åndalsnes-area. Gudbrandsdal Ullvare in Lillehammer is the only vertically integrated manufacturer of upholstery fabrics in Scandinavia and is producing woollen textiles for furniture, hotels, restaurants and cruise ships, and national costume fabrics. An increasing share of the wool comes from Norwegian sheep, collected and sorted by Nortura's subsidiary Norilia.

It was pointed out that most of bed clothing sold by Norwegian brands is actually not produced, but only designed, in Norway. An example for this is Mascot Høie at Brekklandet. There is just a small bed clothing company in Mysen, called Nordicform, which is importing down fillings and cotton to sew them together in Norway.

The interviewee assessed that the main textile producers in the three Nordic countries Denmark, Finland and Sweden use mainly synthetic raw materials rather than biological resources. In particular, it can be said that the other Nordic countries do not produce as much woollen textiles as Norway.

In Sweden there exist some production of technical textiles, for the automotive industry and for pulp and paper machinery, based on synthetic fibres. The production of wood-based viscose has been previously developed, but today Domsjö Fabriker only produce the cellulosic material to export it to customers in Asia, who produce viscose out of it.

In 2018, in Finland the development of a new wooden fibre has been started by the fibre technology company Spinnova company. This will probably contribute to increase the share of Finland's bio-share in the textile industry, in the years to come.

3.1.2 Manufacture of wearing apparel industry (NACE: C14)

The bio-share in the wearing apparel industry (C14) is higher than for the textile industry (C13) and was assessed to be ca. 40%, with a rather constant share over the last 10 years.

There is no production of wearing apparel based on synthetics in Norway, with the exception of survival suits for fishing and offshore industries. They are 100% synthetic.

The production of sportswear, outdoor equipment and other technical clothes is almost totally outsourced to countries like China, Vietnam, Cambodia and Portugal. Those clothes are more or less synthetic, with the exception of merino wool for underwear. However, the design is Norwegian and is presented by brands like Norrøna in Asker, Bergans located in Hokksund or Helly Hansen, an originally fully Norwegian company which has developed into an international company headquartered in Oslo.

The main domestic industry for wearing apparel is concentrated in the production of woollen underwear, knitted sweaters and woollen national costumes. Such products have a large domestic market in Norway, but not in the other Nordic countries where the corresponding production is much lower.

While most of the Norwegian wearing apparel production has been moved abroad, there is still some capacity in Norway, mainly in relation to wool-made clothes. Their producers are concentrated in the region around Bergen, like Oleana in Ytre Arna, Janus, Hillesvåg ullvarefabrikk, Dale of Norway in Vaksdal, and Rauma ullvare in Møre og Romsdal.

3.1.3 Manufacture of chemicals and chemical products (NACE: C20)

The bio-share in the chemical industry was assessed to be about 10%. This share has been rather constant over the last 10 years. The sector is rather small compared to Finland and Sweden. We downloaded from Amadeus a list of the most important companies in Norway in terms of turnover and got this commented by one of the interviewees with regard to the use of renewable biological resources.

The Norwegian chemical industry is concentrated in one sub-sector: 20.1 "Manufacture of basic chemicals, fertilisers and nitrogen compounds, plastics and synthetic rubber in primary forms". In addition, there come some activities in 20.3

“Manufacture of paints, varnishes and similar coatings, printing ink and mastics”, 20.4 “Manufacture of soap and detergents, cleaning and polishing preparations, perfumes and toilet preparations” and 20.5 “Manufacture of other chemical products”.

In the sub-sector 20.11 “Manufacture of industrial gases” we find very few companies, specialised in the production of industrial gases and mainly based on fossil resources. The international group AGA AS, with its Norwegian branch located in Oslo, should be mentioned here.

Sub-sector 20.13 “Manufacture of other inorganic basic chemicals” is rather strong in Norway. There are several companies specialised in the production of inorganic basic chemicals, where renewable organic resources such as charcoal are used only to some minor degree as a reduction agent, as for the case of for Elkem AS, with headquarter in Oslo and production in several places including Kristiansand.

Sub-sector 20.14 is accounted for separately and the same applies for 20.59.

Manufacture of fertilisers and nitrogen (20.15) compounds is rather strong in Norway and not based on renewable organic resources. The main company is here Yara with headquarter in Oslo.

In sub-sector 20.16 “Manufacture of plastics in primary forms” there are mainly companies, in Norway, specialised in manufacturing polymers, especially producing PVC, PE and polystyrene, and they use only fossil resources. However, this can change in the future because there is an increasing demand for bio-based packaging materials.

Subsector 20.30 “Manufacture of paints, varnishes and similar coatings, printing ink and mastics” is using some plant-based oils such as tall oil in the production of paints. The most important company is Jotun in Sandefjord.

Sub-sector 20.41 “Manufacture of soap and detergents, cleaning and polishing preparations” exploits some plant-based oils. The biggest company in Norway is Lilleborg AS in Oslo.

When comparing this sector with the three other Nordic countries, it can be said that the chemical industry in Finland and in Sweden are larger than in Norway, but Denmark’s chemical industry is probably smaller. The bio-shares previously estimated for Sweden are quite unstable, between 8% and 35% (probably partially due to some technical artefact in the estimation of the shares) The shares for Finland look more reliable.

3.1.4 Manufacture of other organic raw materials (NACE: C2014)

The bio-share of this sub-sector is assessed to be ca. 20%. This assessment is based on a combination of the interviews and available statistical information provided

by Amadeus, Statistics Norway and Eurostat about the turnover of the sub-sector and of main companies in the sub-sector. Compared with Finland, Sweden and Denmark, Norway's bio-share is slightly lower.

In sector C2014 we find companies like Borregaard, located in Sarpsborg in Østfold, specialised in the conversion of spruce into chemicals, and Dupont Nutrition Norge, specialised in the production of alginates (with the headquarter in Sandvika and production site near Haugesund). Borregaard is also producing 20 million of litres second-generation bioethanol per year, used as a biofuel.

3.1.5 Manufacture of chemical products not mentioned elsewhere (NACE: C2059)

For this sub-sector a bio-share of 5% has been assessed. This assessment is based on a combination of the interviews and available statistical information provided by Amadeus, Statistics Norway and Eurostat about the turnover of the sub-sector and of main companies in the sub-sector. Compared with Finland, Sweden and Denmark, Norway's bio-share is estimated to be slightly lower.

Main companies are the Norwegian branch of BASF, located in Oslo and specialised in the production of fish-based omega-3, and Life Technologies AS, since 2014 acquired by the global actor Thermo Fisher Scientific, also located in Oslo and specialised in biotechnology and diagnostics. In 2019, Adesso BioProducts AB took over Perstorp's biodiesel plant in Fredrikstad, producing 110.000 tons of first-generation biodiesel from raps. This plant was in turn taken over by Perstorp in 2016; it had previously been started by Uniol (which went bankrupt in 2010) and then taken over by North Sea Biodiesel (which went bankrupt in 2014).

3.1.6 Manufacture of basic pharmaceutical products and pharmaceutical preparations (NACE: C21)

The bio-share in the pharmaceutical industry was assessed to be about 50%. This share has increased from 10% over the last 10 years. The interviewee assessed that the bio-share of the sector will increase to 70-80% in the future.

There are two groups of products in this industry, standing for altogether 37 billion NOK of turnover: Pharmaceuticals (24 billions), Diagnostics (13 billions). In addition, there comes Medtech (3.5 billions), which is part of another sector (32.50 Manufacture of medical and dental instruments and supplies). It was pointed out that 90% of all exported goods from this sector are originally produced in Norway.

When comparing Norway with the three other Nordic countries, the interviewee pointed out that Norwegian pharmaceutical industry has the highest specialisation in delivering new types of vaccines for aquaculture fish, in order to decrease the use of antibiotics. Regarding human pharmaceuticals, Norway and Finland are about the same level, while Denmark and Sweden are much stronger.

There are many global companies which are located in Norway, although not with their headquarters: especially their research teams are often present in the country, and they are also guiding smaller Norwegian companies by investing in them with the aim to buy them later.

A big player for the Norwegian export is GE Health Care. They are located in Oslo and in Lindesnes in Norway, and they are going to invest billions of euros over the next years to raise even further their export.

The “red biotech” industry is concentrated in Oslo and in the Eastern part of Norway, which together host around 70% of the national research in the field. Incubators, spin-offs, companies and clusters are often located in this region. Other activities connected to red biotech are around Bergen and Trondheim, while Tromsø has a high importance for aquaculture-related biotech.

3.1.7 Manufacture of rubber and plastic products (NACE: C22)

The bio-share for the manufacture of thermoplastic products made of polymers and rubber is less than 1%, according to our interviews. However, the bio-share for resin-based composite plastic products lies between 1 and 5%. For the sector C22 as a whole, the bio-share would be around 3%.

Regarding bio-based packaging, it is important to mention Elopak, a company specialised in paper-based packaging solutions for liquid food. They use forest-based PE to cover the cartons. However, also in this case most of the production occurs outside Norway, but the headquarter and the design and development departments are located in Oslo, Norway. The main production sites are in the Netherlands, as a result of a cooperation with the Finnish firm UPM. The manufactured cartons are imported to Norway by the dairy firms TINE and Røros Meieri. The enterprises mentioned above contribute, altogether, to the 1% (maximum) Norwegian bio-share of thermoplastic products made of polymers.

A different case is represented by CocaCola, whose PET plant bottle has a 25% bio-share; however such product is not completely produced in Norway, but just expanded at a filling plant.

There is one Norwegian company specialised in the production of plastic bags made of biological materials: BioBag International AS. Earlier the company produced bags in Northern Norway (in Rognan), but the company is now a global

player with headquarter in Askim, in the south-eastern region of Norway. All production plants are outside Norway.

There are some plans, for the future, to produce PE from biological resources (bio-ethanol), in Norway at Bamble. The realisation of these plans depends on investors. In comparison to especially Finland and Sweden, the bio-share of the Norwegian industry is still rather small.

3.1.8 Manufacture of furniture (NACE: C31)

The bio-share of the manufacturing industry of furniture was assessed to be about 40%. The interviewee assessed that there will be a higher bio-share in the future since the demand for bio-based furniture is increasing.

A main feature of this industry is that the main renewable biological materials used are either wood (for frames etc.) or wool (for the textile elements). The wool comes from Norway, while the wood is mainly imported from Sweden, Poland and the Baltic countries, especially when the wooden elements are clearly visible.

The furniture industry is concentrated in Southern Norway and in Møre og Romsdal; it is not present in Northern Norway.

The following main sub-sectors are active in Norway:

- The sub-sector 31.01 “Manufacture of office and shop furniture”: here we find manufacture of office chairs, mainly at the Håg-plant at Rørø.
- The sub-sector 31.02 “Manufacture of kitchen furniture” is not so developed and the production is spread over the country. There exist a large number of smaller firms specialised in producing kitchen furniture. The three largest Norwegian producers are Sigdal, Norema and Huseby; they are specialised in producing the kitchen cabinet doors, while the insides of the cabinets are mostly produced in Sweden.
- The sub-sector 31.03 “Manufacture of mattresses” is important and concentrated in Southern Norway and in Møre og Romsdal (Jensen nearby Svelvik, south for Drammen, Ekornes in Fetsund, east for Lillestrøm and Wonderland in Åndalsnes in Møre og Romsdal).
- The sub-sector 31.09 “Manufacture of other furniture” includes the production of sofas, sofa beds and sofa sets, furniture for bedrooms. There is a vast production of upholstered seats with wooden frames, spread over the country.

In comparison to the other Nordic countries, the interviewee assessed that Denmark has a higher bio-share due to a very profitable solid wood furniture production, while Sweden has a lower bio-share than Norway, and Finland is probably at the same level as Norway (the interviewee has however declared to have limited knowledge of the domestic market within Finland).

3.1.9 Production of electricity (NACE: D3511)

The bio-share of electricity production is maximum 0,1% (we will use a 0.1% bio-share in our analysis). This information is derived from the interview with Norsk Industri as well as from data provided by Eurostat.

Eurostat has data about Gross electricity production from liquid biofuels, biogas and renewable municipal waste. Altogether this amounted in 2017 to 204,000 GW-hours, while the total electricity production was almost 149 000,000 GW-hours, which is about 0.14%.

Electricity prices are rather low due to the availability of hydropower and biological resources are more used for manufacturing or for heat production.

3.2 Value added

We can now apply the Norwegian sectoral “bioshares” inferred from our interviews, to compute measures of value added and employment in the Norwegian bioeconomy. Figure 3.1 reports the evolution of the value added of the whole Norwegian bioeconomy between years 2008 and 2017. The current total value of approximately 130 billion Norwegian Crowns (NOK) has been reached following a strong increase from an initial value of around 76 billion NOK in year 2008. Two macro-sectors seem to have been determinant for the increase. First, the value added from fishing and aquaculture (NACE code 03) has grown from around 12 billion to more than 43 billion NOK: an impressive growth spurt for the sector, especially considering that the sector is classified as a “pure” biosector and the increase in value added cannot thus be ascribed to substitutions of nonbiological inputs with biomass. Secondly, the production of food, beverages and tobacco (NACE codes 10, 11, 12, considered altogether) has followed a regular, but still steep, path of growth, leading from a value of around 31 billion to more than 45 billion NOK. Given that some of the products from fishing and aquaculture are processed within Norway, it is likely that part of the growth of the food sector value depends partially on the processing of fish produced in Norway. As a result, in year 2017 fishing, aquaculture, food, beverages and tobacco contributed, taken together, to 89 billion NOK; if we also sum the value added of agriculture, which has grown from 12 billion to 16 billion NOK, then we can see that the total value added from food-related sectors amount in year 2017 to 105 billion NOK: more than 80% of the total value added of the Norwegian bioeconomy.

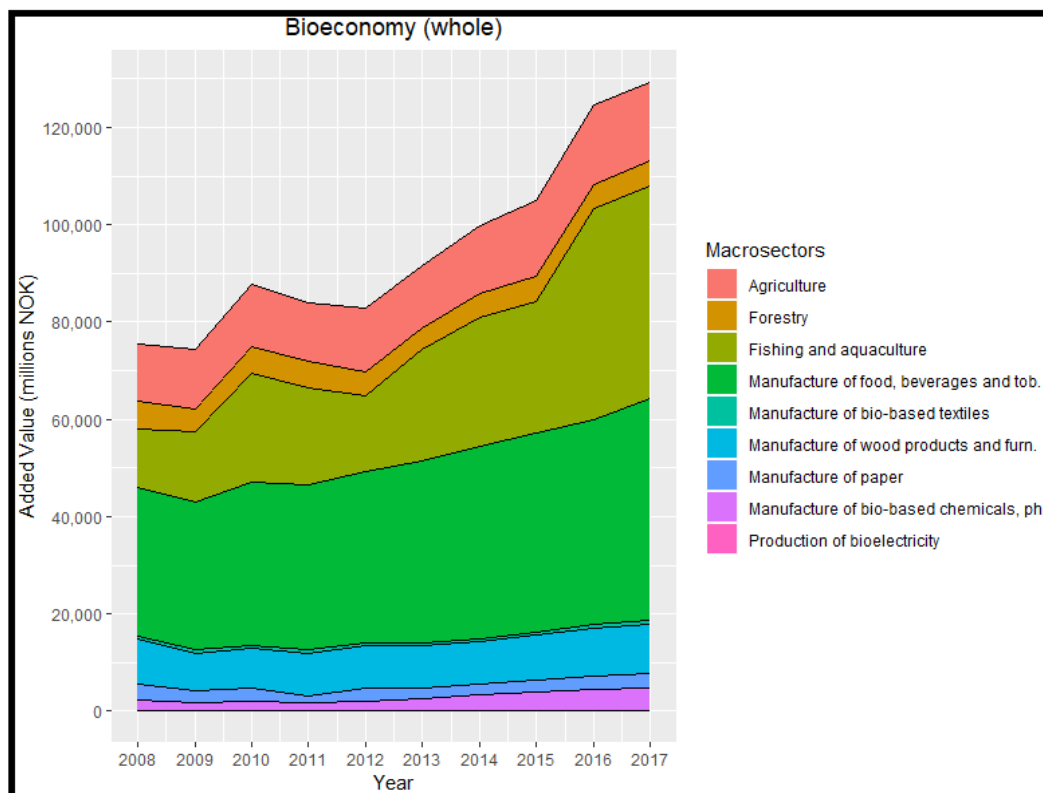


Figure 3.1. Added value in the bio-macrosectors of Norway. Source: NIFU/Statistics Norway.

The Forestry sector (NACE code A02) contributes to the bioeconomy with a value added of 5.4 billion NOK (in year 2017), having almost recovered to the initial value of 5.7 billion (in year 2008) after a decline which touched its low point in year 2013 with 4.2 billion NOK. The Paper sector (NACE code C17) has followed a similar path: in year 2008 its value added was 3.4 billion NOK, then it has faced a strong turbulence for some years, touching a low at 2.2 billion (in year 2014) before partially recovering and almost reach 3 billion in year 2017. The macrosector producing wooden products and furniture (NACE codes C16 and C31) has experienced ups and downs during the last ten years, but its value added has in the end reached a higher value in year 2017 (10.2 billion NOK) than in 2008 (9.1 billion). However, both the turbulence and the final increase seem to be due mainly to events in the wood products sector (NACE code C16), while the “hybrid” furniture sector (NACE code C31) has experienced a slight decrease in value added, as can be seen in Figure 3.2 (for hybrid sectors, we are considering and showing only the value added related to their bioshare).

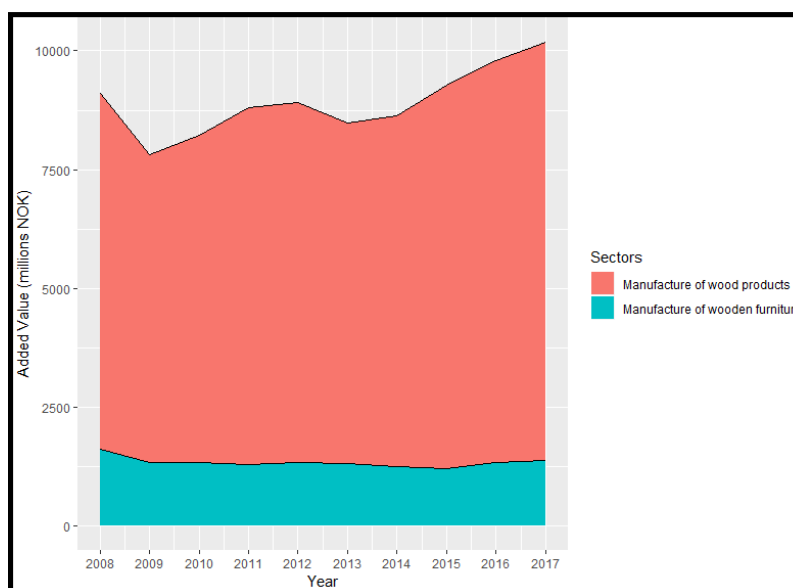


Figure 3.2. Added value from (bio-) wood products and furniture. Source: NIFU/Statistics Norway.

A particular phenomenon can be observed concerning the macrosector for bio-based chemicals, pharmaceuticals, plastics and rubber: as can be seen in Figure 3.1, its value added has almost doubled within ten years, going from 2.6 billions NOK to more than 5 billion. The macrosector components are shown in Figure 3.3: in front of a decline of bio-based chemicals (NACE sector C20; the decline involves also the subsectors C2014 and C2059 which have a different bioshare), the bio-based plastic and rubber (C22) and the bio-based pharmaceuticals (C21) have experienced an increase in value added. For the latter case of bio-based pharmaceuticals, in particular, the increase has been dramatic: from 0.3 billion in year 2008 to more than 3 billion in 2017, a growth spurt which can only partially be explained by an increase in the sector's bioshare and which witness the stronger weight held today by pharmaceuticals in the Norwegian bioeconomy.

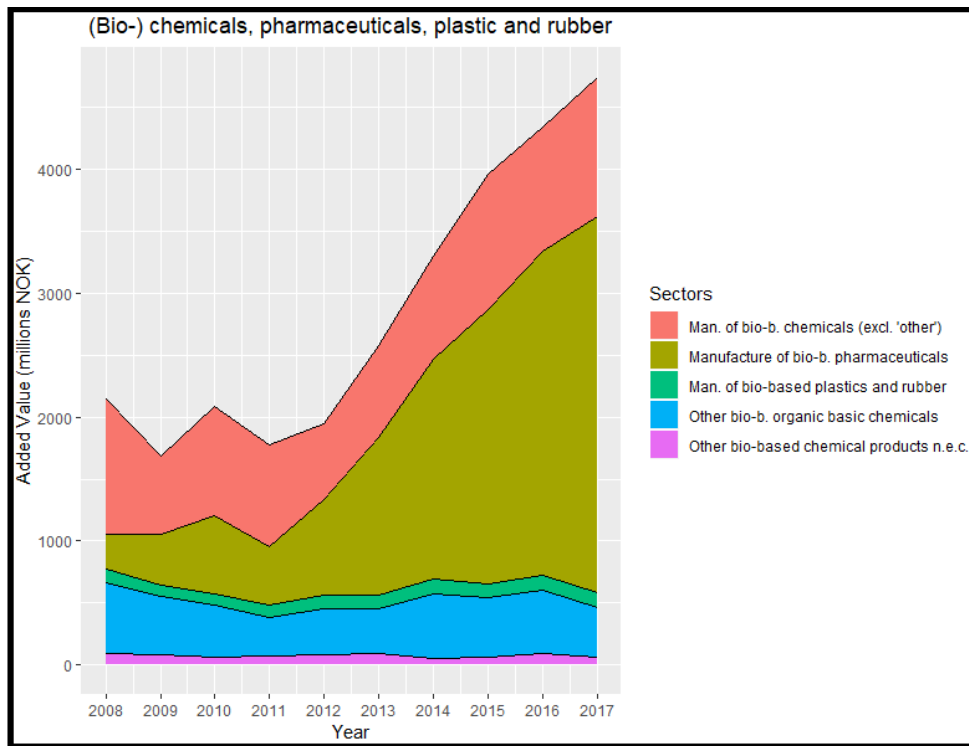


Figure 3.3. Added value from bio-based chemicals, pharmaceuticals, plastics and rubber. Source: NIFU/Statistics Norway.

Finally, there are two macrosectors which are currently playing a minor part in the bioeconomy, namely manufacture of Textiles and textile-related products (NACE codes C13, C14, C15, considered altogether in Figure 3.1) and production of Bioelectricity (NACE code D3511). The value added from the manufacture of textiles and textile-products amounts to around 0.8 billion NOK (in year 2017) and has been approximately constant since 2008, the only variations deriving from Sector C14 (manufacture of wearing apparel, see Figure 3.4). A low contribution to the bioeconomy can be registered from the production of bioelectricity, whose value added oscillates between 0.02 and 0.04 billion NOK.

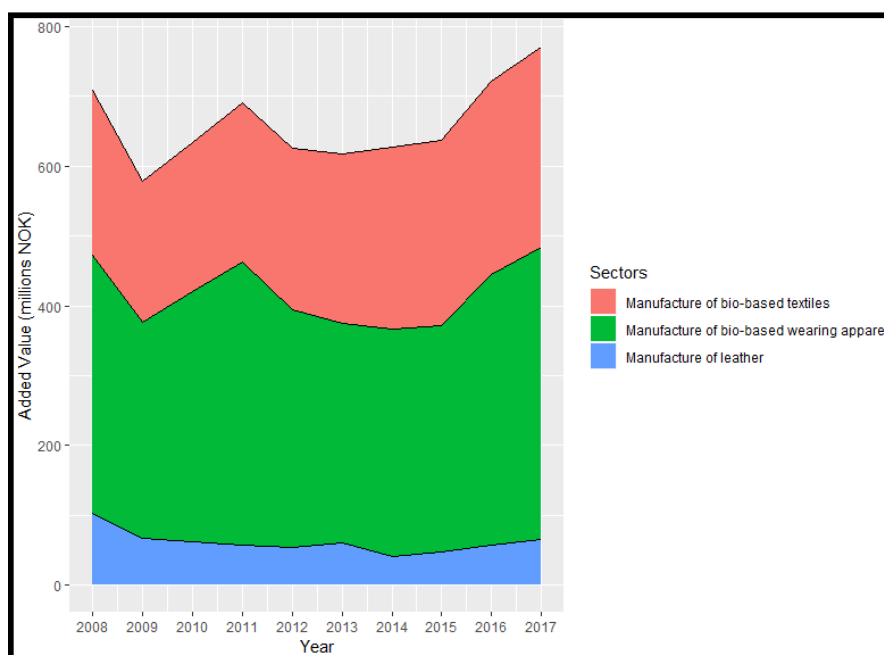


Figure 3.4. Value added from (bio-) textiles and wearing apparel. Source: NIFU/Statistics Norway.

3.3 Employment and productivity

We now turn to sectoral employment figures, to understand whether the labour force mirrors the movements observed in terms of sectoral value, and how labour productivity has evolved during the last decade. A summarising figure for all the bioeconomic macrosectors is shown through Figure 3.5. We can immediately see that the total number of people employed by the Norwegian bioeconomy has decreased: in year 2008 the bioeconomy was giving employment to 144.227 people, while in 2017 the number has shrunk to 130.472. The decrease has been driven by several macrosectors; an important role has been played by Agriculture, going from almost 47 to less than 35 thousand employed. The decline of Forestry has been less steep, moving from around 4300 to 3800 employed. Among the primary sectors, an opposing trend has been registered by Fishing and Aquaculture, whose employment total has increased by roughly 2500 units from a starting figure of around 15000 employed in year 2008.

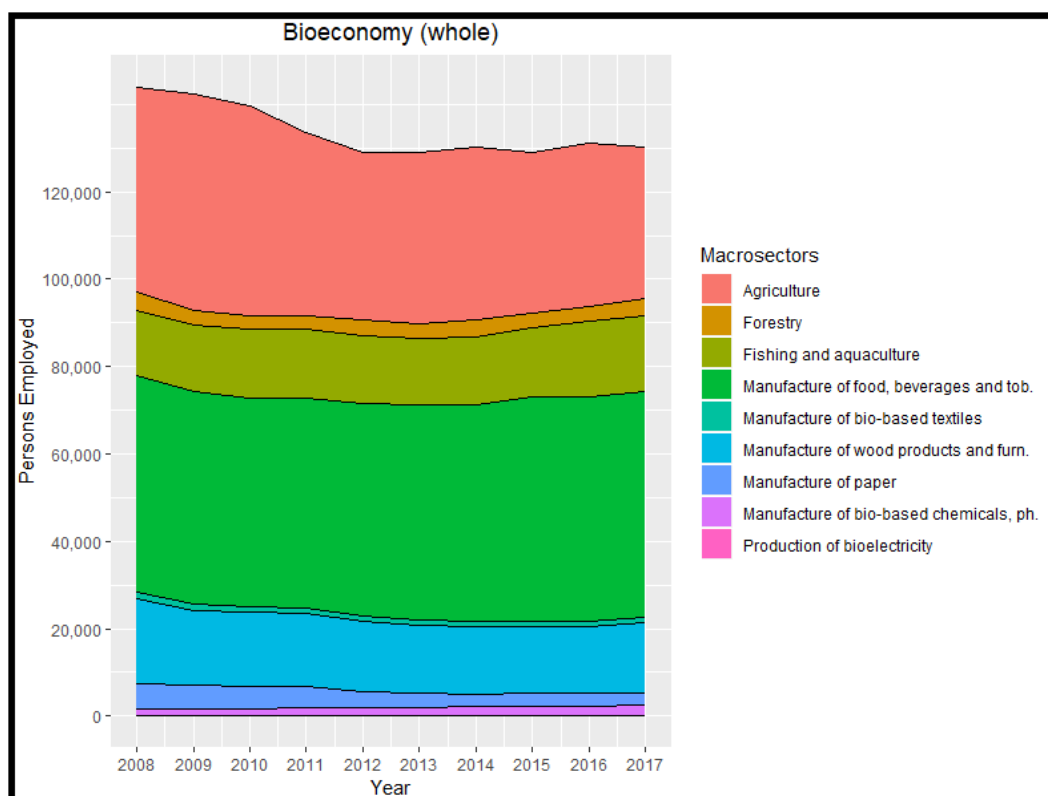


Figure 3.5. Employment from all the bio-macrosectors of Norway. Source: NIFU/Statistics Norway.

Within manufacturing sectors, strong and steady decrease has been registered for production of Paper, which was employing almost 6000 people in year 2008 and only less than 3000 in year 2017. A milder decrease has hit the macrosector of Wood products and Furniture, moving from almost 20 to around 16 thousands units (see Figure 3.5), with a relative decrease much higher for what concerns its Furniture component (see Figure 3.6; remember that Furniture is a “hybrid” sector, therefore the figure shows only the bio-related share of the sector’s employed). For what concerns textile-related sectors, the employment has partially recovered from a decline experienced soon after year 2008, a decline suffered particularly by leather producing firms (NACE sector C15; see Figure 3.7).

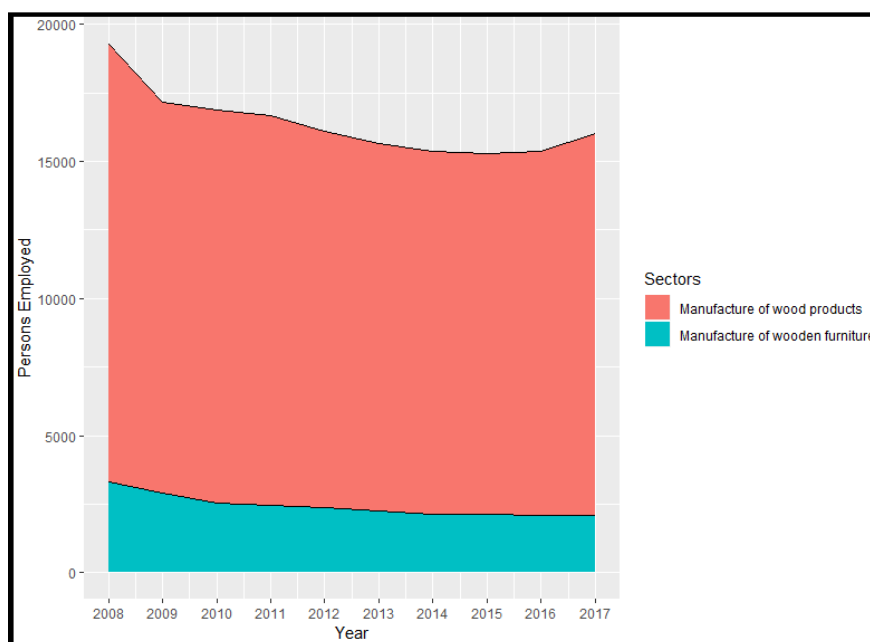


Figure 3.6. Employment from (bio-) wood products and furniture. Source: NIFU/Statistics Norway.

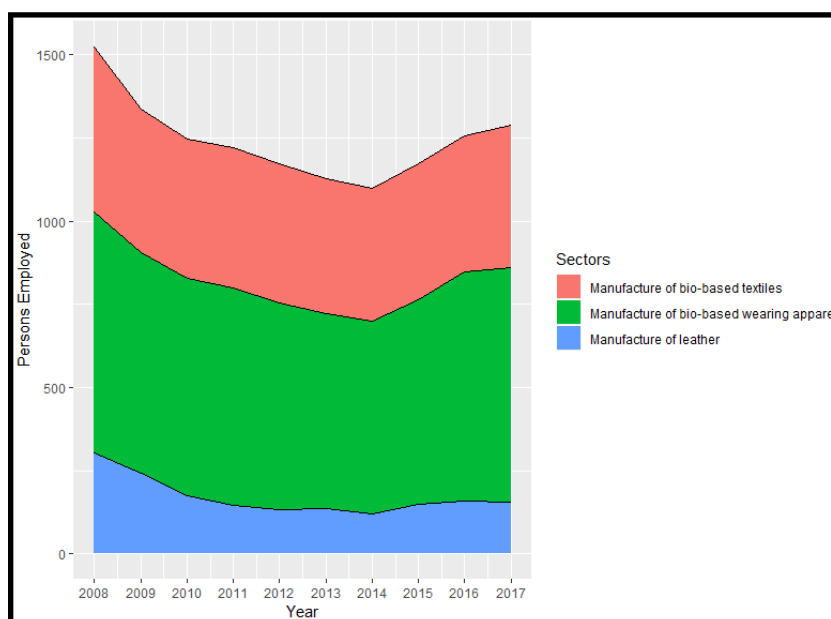


Figure 3.7. Employment from (bio-) textile-related sectors. Source: NIFU/Statistics Norway.

In contrast, the macrosector for bio-based chemicals, pharmaceuticals, plastics and rubber has increased its employment from around 1500 to around 2500 (see Figure 3.1). The sectoral composition shown in Figure 3.8 highlights the major role played by Pharmaceuticals (NACE sector C21) which has quadrupled its employ-

ment, compensating decreases from Plastics and Rubber and from Chemicals (notice, however, the good performance from Manufacture of other organic basic chemicals, NACE sector C2014).

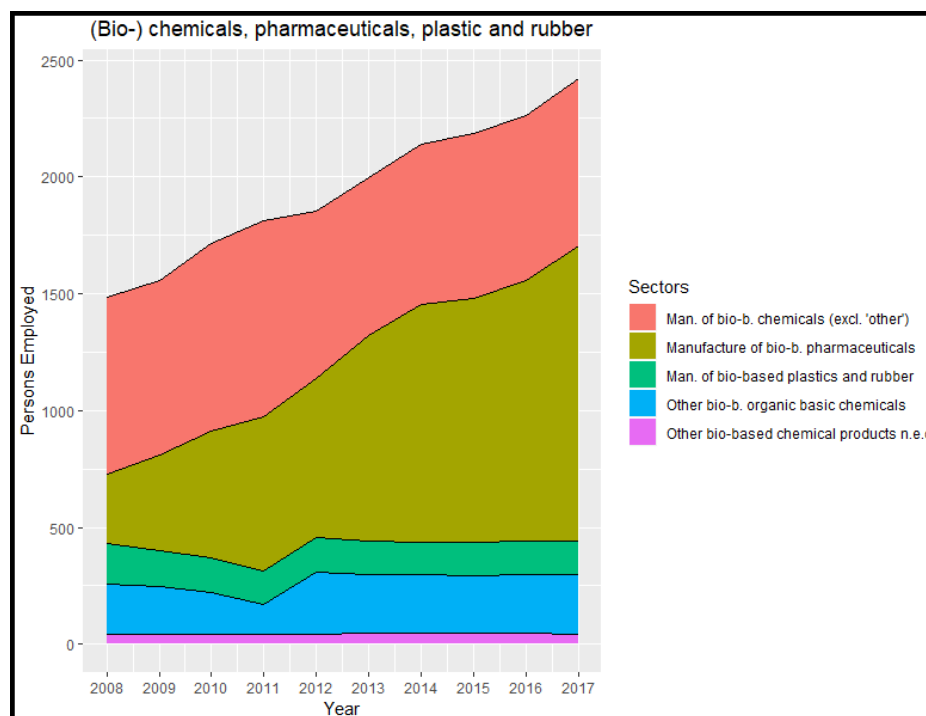


Figure 3.8. Employment from (bio-) chemicals, pharmaceuticals, plastic and rubber.
Source: NIFU/Statistics Norway.

Last, but perhaps most importantly, we must mention the contribution from the macrosector Food, beverages and tobacco (NACE sectors C10, C11, C12) to the bio-economy in terms of employment. Even if its growth has been negligible since year 2008, the absolute number of people working at the macro-sector is very high (around 50 thousand employed) and constitutes a pillar for the bioeconomic labour force of Norway.

By using, at the same time, our results about respectively value added and employment, we are able to compute sectoral labour productivities, which we show in Figure 3.9. In the middle of the figure, indicating a median labour productivity about Norwegian sectors, we find manufacture of paper and forestry and, at a slightly lower level, food, beverages and tobacco. On the left hand, with a relatively low productivity, there are wood products and furniture, textiles and plastics and rubber. At the middle-high productivity rank, instead, there are the chemical sectors, where we have here separated the 4-digit sectors 2014 and 2059 (associated by Ronzon and M'Barek (Ronzon and M'Barek 2018) to biofuels, but involving other biochemicals for the Norwegian case) from the main chemical sector. Close

to the chemical sectors, and with a high productivity, there are the pharmaceuticals. Then, if we exclude the particular case of bioelectricity which is neither a primary nor a secondary sector, the top level of productivity is occupied by fishing and aquaculture (the precise amounts of the productivity indicators are reported in Table 3 in the Appendix).² In the next section we show how this ranking, especially at the top positions, marks an important difference between Norway and other European countries.

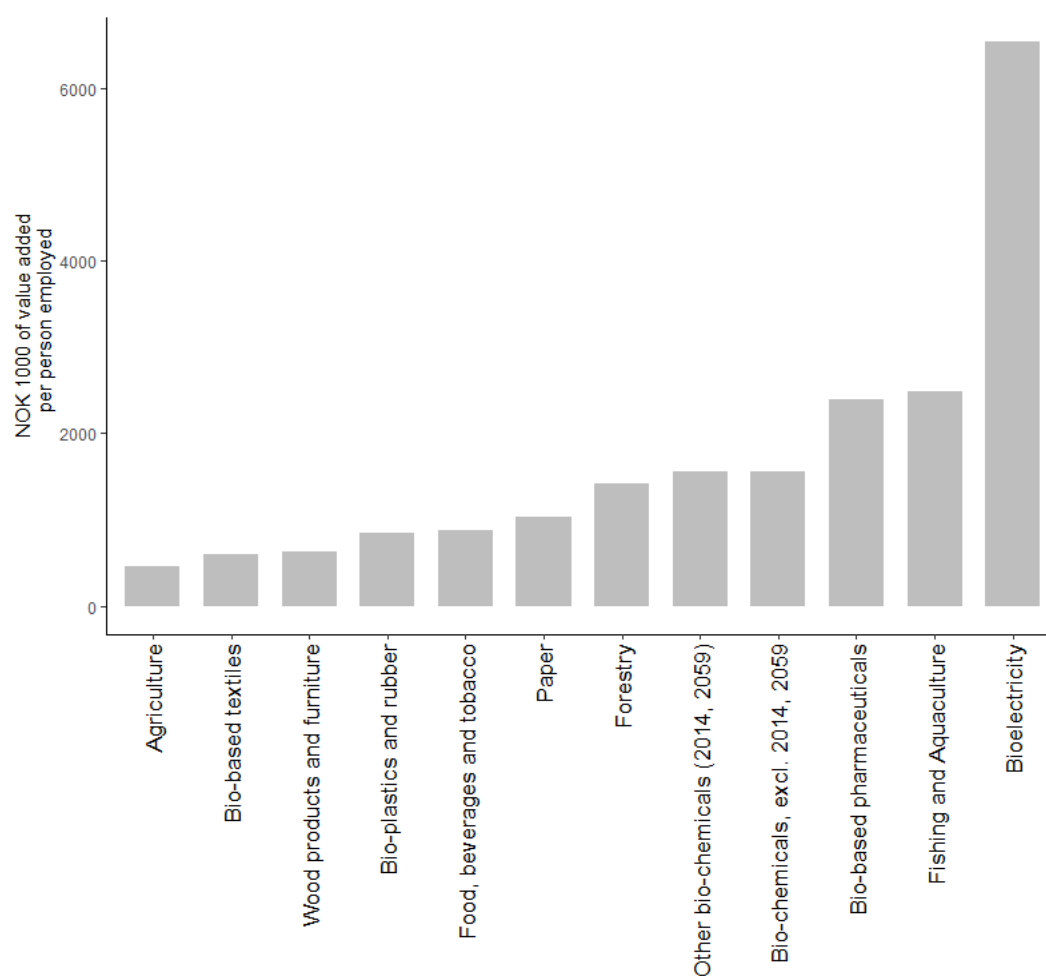


Figure 3.9. Sectoral apparent labour productivity in Norway, 2017. Source: NIFU/Statistics Norway.

² Given that bioelectricity contributes to a very low proportion of electricity production in Norway, some of our statistical assessments about the biobased part of the electricity sector (like the indication of 4 employees working on bioelectricity) must not be taken literally, but only as an indication of such a low proportion. We are still including bioelectricity among the hybrid sectors, mainly for comparisons with previous studies on other European countries. However, considering as hybrid a sector where only 0.1% of production is biobased exacerbates the approximations of the method, which was conceived for hybrid sectors with a more relevant bioshare. Also for this reason, bioelectricity will not be considered in the regional analysis of Section 3.5.

3.4 Comparison with EU countries

If we compare Figure 3.9 with the analogous figure shown by Ronzon and M'Barek (Ronzon and M'Barek 2018, Figure 1) for the EU countries, some differences are evident. First, productivity in Norway is generally higher: keeping in mind that 10 NOK (the Norwegian currency: Norwegian crowns) roughly equate 1 euro in terms of currency exchange, we can see how Norway performs much better than the EU average for what concerns apparent labour productivity. This may not be a surprising result, considering the availability of capital in Norway, which sums up with a favourable exchange rate; however, the productivity difference for some sectors is way beyond obvious. There is indeed no country in the European Union having such a high productivity in Fishing and Aquaculture: the highest country-level estimates for the EU would not reach 2 million NOK per person, while Norway is able to go above such threshold. The labour productivity for the Forestry sector is also much higher than the EU average, although it is comparable to what found in some countries like Finland. Instead, the Norwegian productivity picture resembles the EU picture when it comes to the relatively low ranking of agriculture and high ranking of electricity and pharmaceuticals.

We now turn to a dynamic analysis to check whether the differences detected about labour productivity have intensified or weakened since year 2008. To this purpose, we now provide an updated version of the double scatter plot provided for the EU countries by Ronzon and M'Barek (Ronzon and M'Barek 2018, Figure 4): in our Figure 3.10, the two axes measure respectively location quotient and apparent labour productivity, and each country is represented by the starting point of an arrow (for year 2008) and the ending point of an arrow (for year 2015). While Ronzon and M'Barek (Ronzon and M'Barek 2018, Figure 4) considered only EU countries, we here also include Norway (to allow an easier comparison between figures, we consider the times span 2008-2015, as for the original figure); notice that all location quotients for the EU countries have been recomputed by considering, as a benchmark, an enlarged set of countries consisting of all EU countries plus Norway. A location quotient greater than 1 in a country thus means that the labour market of the country is more 'concentrated' in the bioeconomy than the whole labour market composed by the EU-28 countries plus Norway.

The resulting Figure 3.10 does not show strong differences from the one by Ronzon and M'Barek (Ronzon and M'Barek 2018, Figure 4) for what concerns the EU countries, which means that the different benchmark did not change qualitatively what was previously observed about the European Union; instead, our anal-

ysis can focus on Norway (identified through the code NO) and its position in Figure 3.10, where clusters of EU countries have been highlighted as in Ronzon and M'Barek (Ronzon and M'Barek 2018). The arrow depicting Norway's dynamics (its starting point, in blue colour, refers to the values in year 2008) shows that Norway clearly belongs to the cluster (circled in red) of European countries with a low specialisation, but a high productivity in the bioeconomy: the "Northern states" cluster previously identified by Ronzon and M'Barek (Ronzon and M'Barek 2018). Moreover, the arrow associated to Norway shows that the country has slightly decreased its bioeconomic location quotient and strongly increased its bioeconomy's labour productivity. In other words, Norway's labour market is, relative to the EU, stayed specialised in non-bio sectors, but the value added per worker in the Norwegian bioeconomy has increased dramatically.

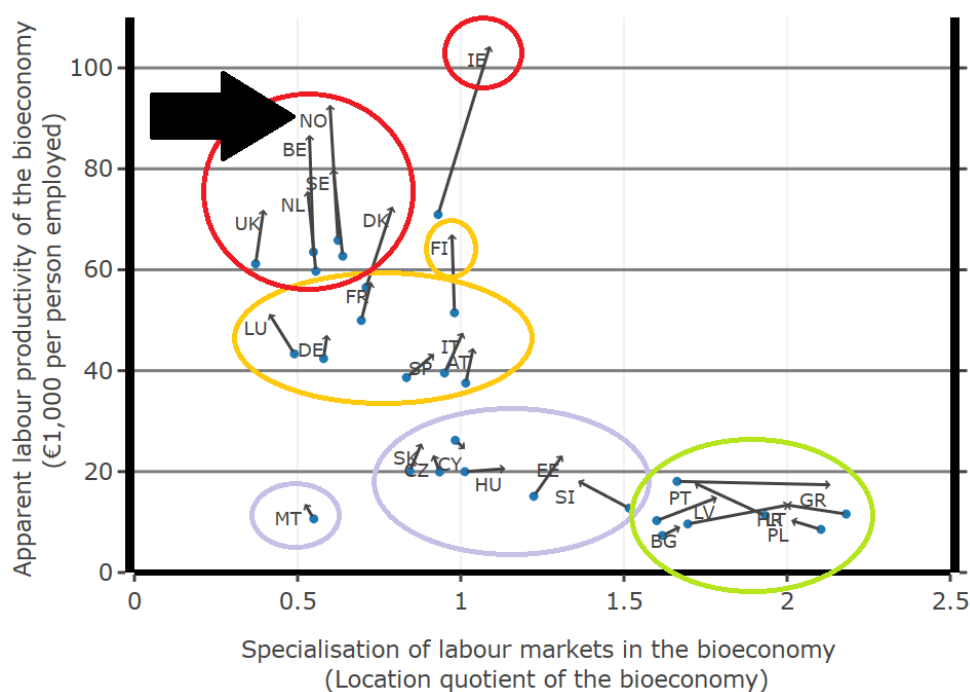


Figure 3.10. Evolution of the location quotient and apparent labour productivity in the bioeconomy of Norway and of the 28 EU Member States, 2008–2015. Note that Romania is missing since it is out of scale (location quotient of 3.77). Source: NIFU/Statistics Norway.

To have an intuitive idea of where the low level of the Norwegian bioeconomic location quotient originates from, we need to mention that the biosectors employ altogether a low share of the Norwegian labour force (around 5%). The bioeconomy's employment is also decreasing over time (see Figure 3.11, employment measured on the right axis). Instead, the value added of the Norwegian bioeconomy, as resulting from all bioeconomic sectors, has experienced a steep increase (in Figure 3.11, the value added is measured on the left axis; for "hybrid" sectors,

the values have been split between bioeconomy and “other” non-biosectors according to their respective bioshares). The value added of the Norwegian bioeconomy appears to account for 4% of the total value added in the whole economy, as of year 2017. However, a precise interpretation of the relation between bioeconomy and rest of the economy requires additional reflections, which we report in Section 4.

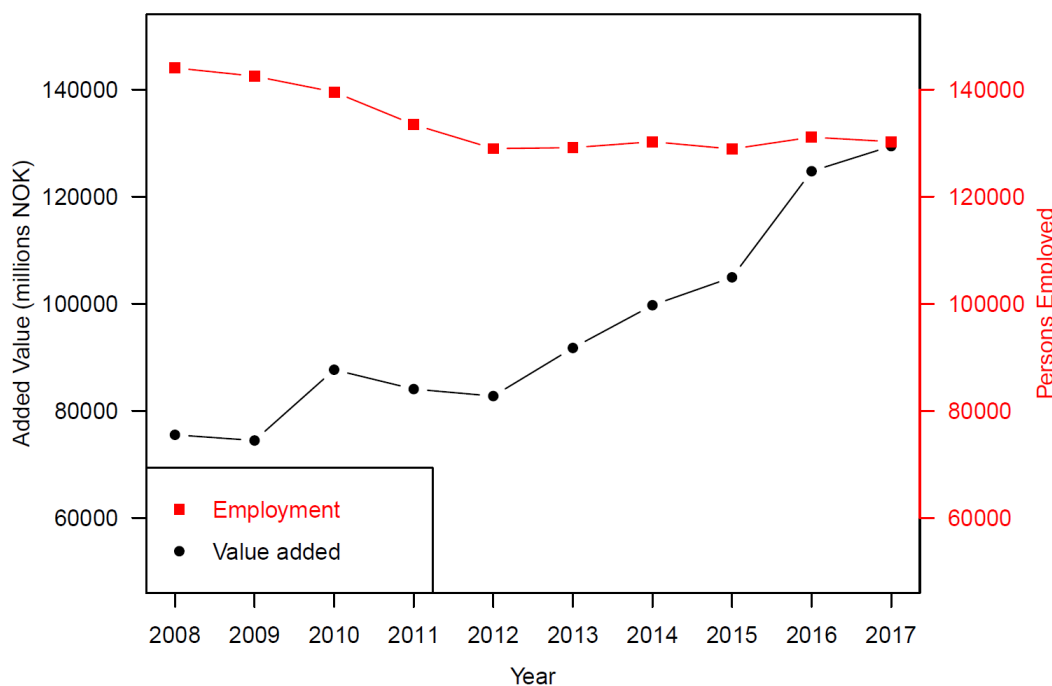


Figure 3.11. Evolution of employment and value added in the Norwegian bioeconomy. Source: NIFU/Statistics Norway.

3.5 Regional analysis

Following the methodology outlined in Section 2.1, we restrict now the geographic scale of our analysis to examine the development of the bioeconomy in the different Norwegian counties. As previously explained, the main difficulty here lies in reconstructing figures for value added in each county in each 2-digit sector, since the value-added figures made available at county-level by Statistics Norway follow a higher sectoral aggregation. Our algorithm for disentangling 2-digit sectoral information seems to work properly, with the exception of chemicals and pharmaceuticals, which pay the toll of being aggregated together with “refined petroleum products” in the official regional statistics. Such aggregation creates additional difficulties for our algorithm, and therefore chemicals and pharmaceuticals will be shown together in our regional analysis of value added. All the other numbers we obtain from our algorithm, assigning a specific value added to each bioeconomic

2-digit sector in each county, will be used to reconstruct macrosectoral value added for each county, where we consider the same bioeconomic macrosectors as in Figure 3.9. We are then able to show, in Table 1, the most productive counties in each bioeconomic macrosector where productivity is proxied by value added per worker (average across years 2015, 2016 and 2017).³

Table 1. Most productive Norwegian counties in each bioeconomic macrosector, according to value added per employee (estimates based on regional accounts; average across years 2015, 2016 and 2017). Source: NIFU/Statistics Norway.

Agriculture	Forestry	Fishing and Aquaculture	Food, beverages and tobacco	Bio-based textiles	Wood products and furniture	Paper	Bio-plastics and rubber	Bio-chemicals and pharmaceuticals
Østfold	Finnmark	Sør-Trøndelag	Oslo	Østfold	Vestfold	Oppland	Telemark	Hordaland
Nord-Trøndelag	Møre og Romsdal	Sogn og Fjordane	Nordland	Møre og Romsdal	Akershus	Vestfold	Nordland	Nord-Trøndelag
Akershus	Hedmark	Troms - Romsa	Møre og Romsdal	Nordland	Oppland	Østfold	Akershus	Møre og Romsdal
Hedmark	Sør-Trøndelag	Hordaland	Akershus	Sør-Trøndelag	Nord-Trøndelag	Nord-Trøndelag	Vestfold	Oslo
Sogn og Fjordane	Østfold	Nordland	Sogn og Fjordane	Sogn og Fjordane	Østfold	Akershus	Oslo	Akershus

We pair the information from Table 1 with additional information, shown in Table 2, about turnover per employee in the Norwegian counties (in year 2017, latest year available in our microdata). Turnover per employee is not a proper measure of productivity, since firms with high turnover might have high input costs, and also since a high total turnover in a region may derive from goods moving along different firms co-located in the same region without strong value adding activities. However, it provides important information about the levels of bioeconomic activity in the counties, in comparison with the number of workers employed for the same activities; moreover, we build this measure by aggregating establishment-level statistics without any additional estimation passage. By pairing the information on value added in Table 1, from regional accounts, with the information on turnover in Table 2, from establishment register data, we are able to give a precise picture of how the bioeconomy differs across Norwegian counties.

³ The bioshares for the 2-digit «hybrid» sectors have been assumed to be constant across different geo-graphic regions, and equal to the country-level bioshares, in order to avoid arbitrary assignments based on partial information. For higher aggregations of sectors, as shown in Table 1 (e.g., “Wood products and furniture”), the bioshares can still differ across regions, depending on the relative contribution from different 2-digit sectors (e.g., “Wood products” and “Furniture”) in each different region.

Table 2. Most active Norwegian counties in each bioeconomic macrosector, according to turnover sum per employee (total turnover is computed as the sum of establishment-level turnover across all establishments located in the county). Source: NIFU/Statistics Norway.

Agriculture	Forestry	Fishing and Aquaculture	Food, beverages and tobacco	Bio-based textiles	Wood products and furniture	Paper	Bio-plastics and rubber	Bio-chemicals	Bio-based pharmaceuticals
Oslo	Møre og Romsdal	Hordaland	Møre og Romsdal	Buskerud	Oslo	Buskerud	Akershus	Telemark	Aust-Agder
Hedmark	Buskerud	Sogn og Fjordane	Sør-Trøndelag	Akershus	Østfold	Nord-Trøndelag	Oppland	Møre og Romsdal	Hordaland
Østfold	Hedmark	Møre og Romsdal	Nordland	Østfold	Buskerud	Østfold	Finnmark	Rogaland	Nord-Trøndelag
Rogaland	Nordland	Nord-Trøndelag	Rogaland	Møre og Romsdal	Vest-Agder	Møre og Romsdal	Nordland	Akershus	Vest-Agder
Vestfold	Østfold	Sør-Trøndelag	Sogn og Fjordane	Sør-Trøndelag	Hedmark	Telemark	Telemark	Vestfold	Sør-Trøndelag

In Agriculture, Østfold appears to be the most productive county; its first position in the first column of Table 1 signals indeed the highest value added per employee, according to our estimations. Given the third position in terms of total turnover per employee (first column of Table 2), we can safely say that the productivity measured for Østfold does not result from a technical artifact. Analogously, we can see Hedmark reaching top positions in the first column of both Tables 1 and 2. Akershus, Sogn og Fjordane and Nord-Trøndelag seem to have a very high productivity, but lower numbers for what concern turnover per employee might signal that the high value added is measured across few firms and we cannot thus be completely sure of the result. On the other hand, the case of Oslo in top position in the first column of Table 2 seems to indicate the existence, in the capital of activities connected to the sector but not adding most of the value in the sector.

When moving to second column of Tables 1 and 2, and thus to the Forestry and Logging sector, we find again a consistently high position of Hedmark and Østfold, this time accompanied by Møre og Romsdal: these three counties are confirmed to be among the most productive in the Forestry sector. Notice that the presence of Finnmark in top position, for value added for employee in forestry, derives from a very low presence of employees in the county (we are applying to counties the same types of indicators that we use at country-level, and their application may bring strong variations in measurements among low-population counties). On the other hand, the high value added per employee recorded in Sør-Trøndelag is highly relevant, since it signals a high productivity reached in a county where the sector has a strong presence. In Fishing and Aquaculture (third column), Hordaland and Sogn og Fjordane appear to have both a high value added and high turnover per employee. More in general, all the counties along the Western coast present a high productivity in the sector, even if Rogaland appears a bit lower in the ranking (possibly due to a diversion of investments toward the oil and gas sectors). For what concerns Food, Beverages and Tobacco, two counties appear in top positions for both value-added and turnover per employee: Nordland and Møre og

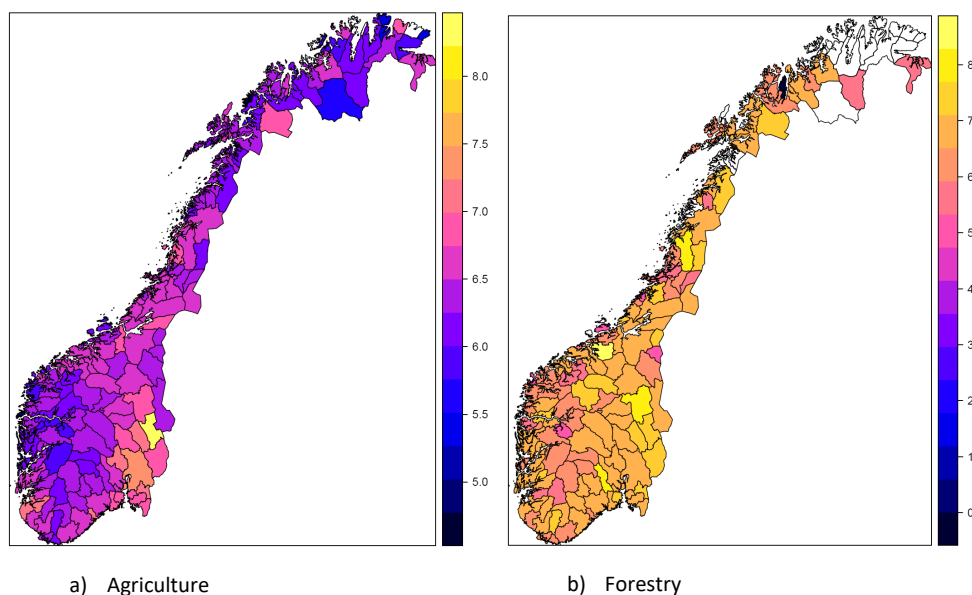
Romsdal (Oslo and Akershus have a high value added, but lower turnover per employee). Møre og Romsdal appears to be important also in Textiles, Wearing Apparel and Leather (column 5), together with Østfold and Sør-Trøndelag.

Østfold dominates the ranking also in Wood products and Furniture (column 6) and Paper (column 7, together with Nord-Trøndelag); Møre og Romsdal is highly productive in the manufacture of furniture, but does not appear in the ranking given our aggregation of wood products and the bio-based furniture in the same macrosector. For bio-Plastic and Rubber (column 8), the three counties Akershus, Nordland and Telemark appear in top positions for both Tables 1 and 2. Finally, to distinguish Chemicals and Pharmaceuticals, whose rankings appear in a unique column of Table 1 due to difficulties in disentangling the two sectors from the regional accounts, we need to look at the rankings of turnover per employee in the last column of Table 2. It emerges then that Møre og Romsdal and Akershus are highly productive in manufacturing chemicals, while Hordaland and Nord-Trøndelag reach the top positions for the production of pharmaceuticals. It is important to point out that, while counties differ in productivity within each macrosector, the productivity differences across macrosectors are often higher. Therefore, counties with a comparative advantage in agriculture or forestry (i.e. that are in top positions in Table 1 in the corresponding columns) might find more profitable to invest in chemicals or pharmaceuticals. In other words, the comparative advantages suggested by Tables 1 and 2 summarise the current situation, but do not exclude policies aimed at restructuring the economy of particular counties.

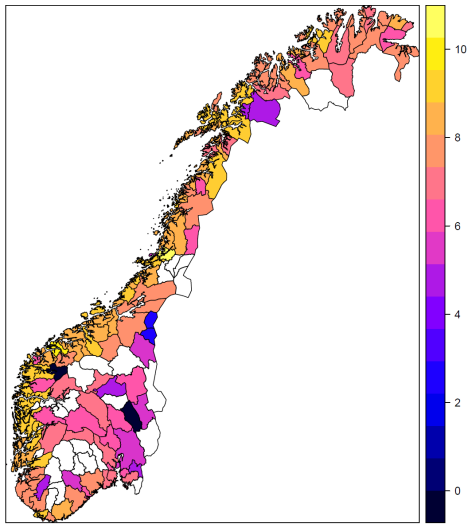
Given that turnover and number of employees are available at establishment-level, it is possible to use an even lower geographic scale for our analysis and look into turnover per employee at the level of labour market areas.⁴ There are 160 labour market areas in Norway, according to Juvkam, 2002; this fine disaggregation allows us to check whether differences in turnover per employee, as detected previously at the level of county, derive from activity peaks within each county or are instead part of a geographically extended pattern, not reconducted to a city-countryside dichotomy. Each panel of Figure 3.12 shows a map of Norway for a particular bioeconomic macrosector, where the labour market areas have been coloured according to their turnover per employee in the same macrosector. The total macrosector turnover and number of employees have been computed by

⁴ We have considered the bioshare of NACE sector 20 (Manufacture of chemicals and chemical products) as a whole, by computing a weighted average of the bioshares of: sector 2014, sector 2059, sector 20 excl. 2014 and 2059. The average was weighted according to the respective contributions of the three components to the total country-level value added of sector 20. This decision has been taken only for the regional analysis at the level of labour market areas, to avoid a high disaggregation at both geographic and industrial level, which could lead to artificially high values in some areas and sectors.

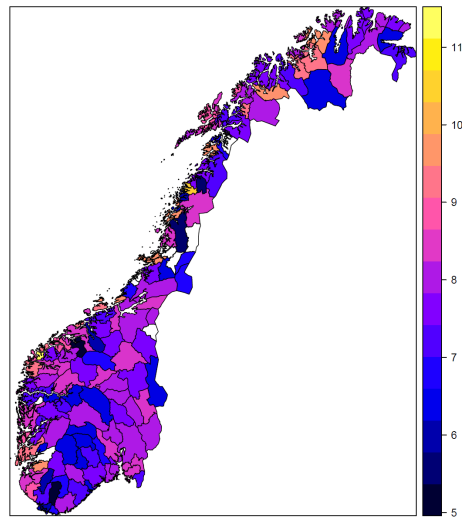
weighing, according to their respective bioshares, the turnover and number of employees of the macrosector's 2-digit components (the country-level 2-digit sector bioshares have been used). For graphic purposes, a logarithm has been applied to the turnover per employee (expressed in 1000 NOK per person; so, for instance, a number of 7 in the map legend indicates a turnover of $e^7 = 1\,096$ thousands NOK per employee).⁵



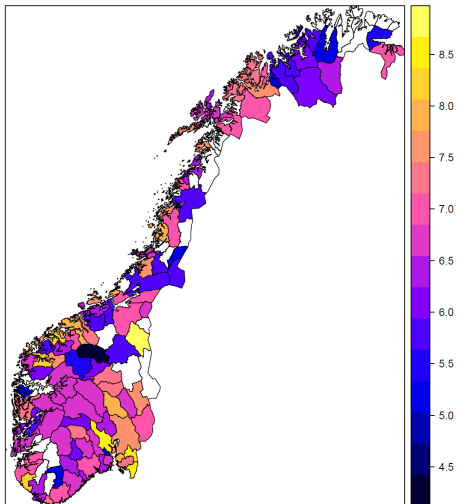
⁵ The use of logarithms to transform variables like regional population or value added must not surprise, since power laws are an empirical recurrence for geographic and economic variables. In many countries, few very populated regions coexist with many scarcely populated areas, and in many economies there are few very large firms as well as many microfirms. Therefore, mapping a variable across different regions could often translate into a map with many "dark" areas and few "bright" areas (i.e. areas with a very large population), without utilizing the full range of intermediate colour shades and without providing sufficient visual information on intermediate cases. By using logarithms, we are able to visualize better such intermediate cases. For instance, the bioeconomic employment depicted in Figure 3.15 decreases fast when moving from the labour market area of Oslo ($16078 = e^{10}$) to Hamar ($5178 = e^9$) to Elverum ($1563 = e^7$) to Trysil/Engerdal ($481 = e^6$). Using a logarithmic transformation, we assign a number 10 to Oslo, 9 to Hamar, 7 to Elverum and 6 to Trysil/Engerdal, and visualize the decrease more smoothly.



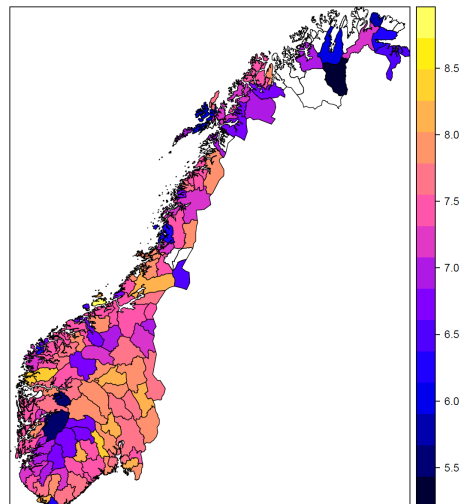
c) Fishing & aquaculture



d) Food, beverages & tobacco



e) Bio-based textiles



f) Wood products & furniture

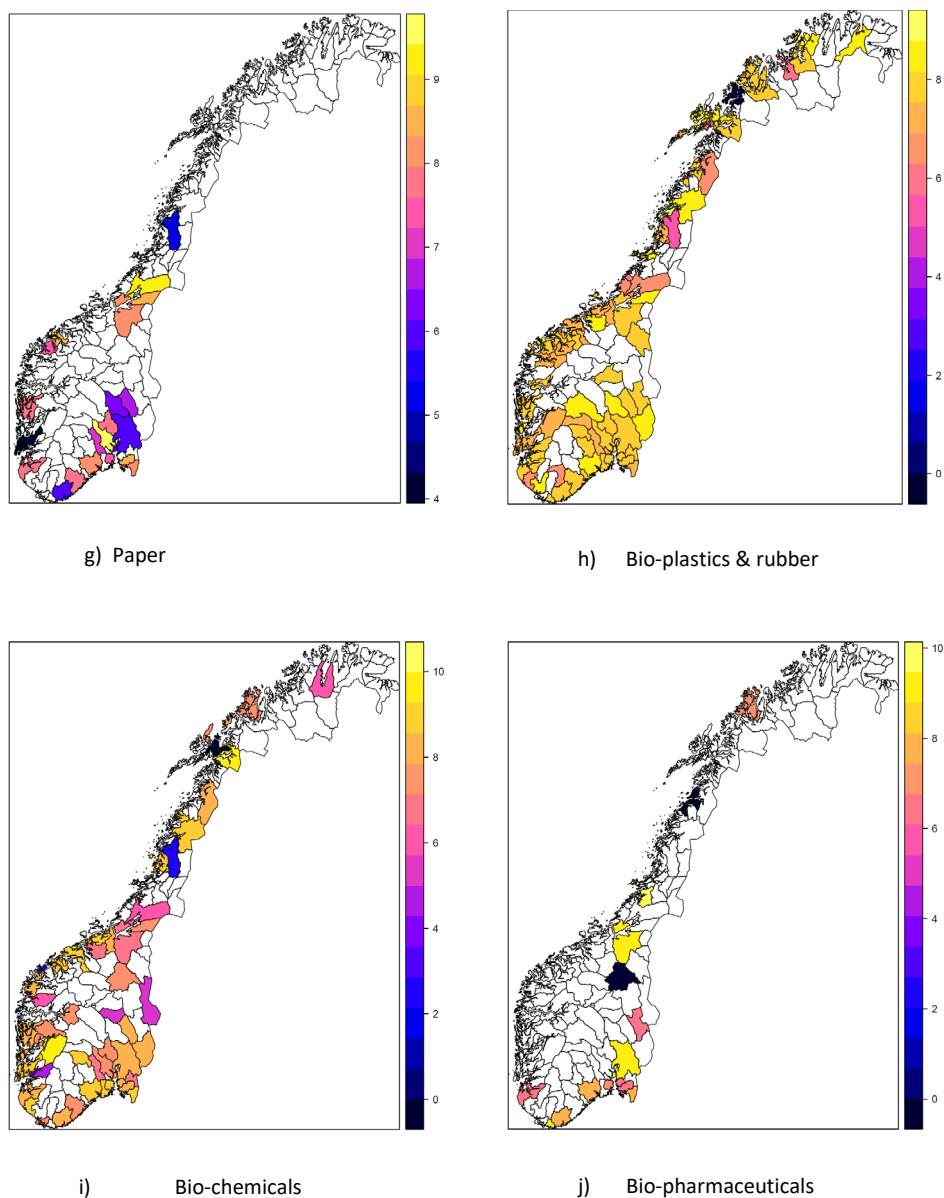


Figure 3.12. Turnover per employee (thousands NOK, in logarithm) measured across the labour market areas of Norway; each panel shows a different bioeconomic macrosector. Source: NIFU/Statistics Norway.

Looking at Panels a and b of Figure 3.12, referring respectively to Agriculture and Forestry, we can see that, apart from a few exceptions, the turnover per employee varies smoothly across the country, with a higher agricultural activity registered in South-Eastern Norway. A different picture comes from Fishing and Aquaculture, having a very high turnover per employee along the West Coast, but still a relevant presence in the Southern and Eastern parts of Norway. Wood products and furniture (Panel f) still display regular variations across the country, even if the variance of turnover per employee looks higher than in the previous cases. A much

higher heterogeneity, and a less clear geographic pattern, appears for Food, beverages and tobacco (Panel d) and for Textiles (Panel e). Manufacture of paper (Panel g) and Pharmaceuticals (Panel j) look scattered around the country with a high variance in turnover per employee, while the turnover per employee in Bioplastics and rubber (Panel h) and chemicals (Panel i) seem to display a lower variance, despite the lack of activity in some parts of the country.

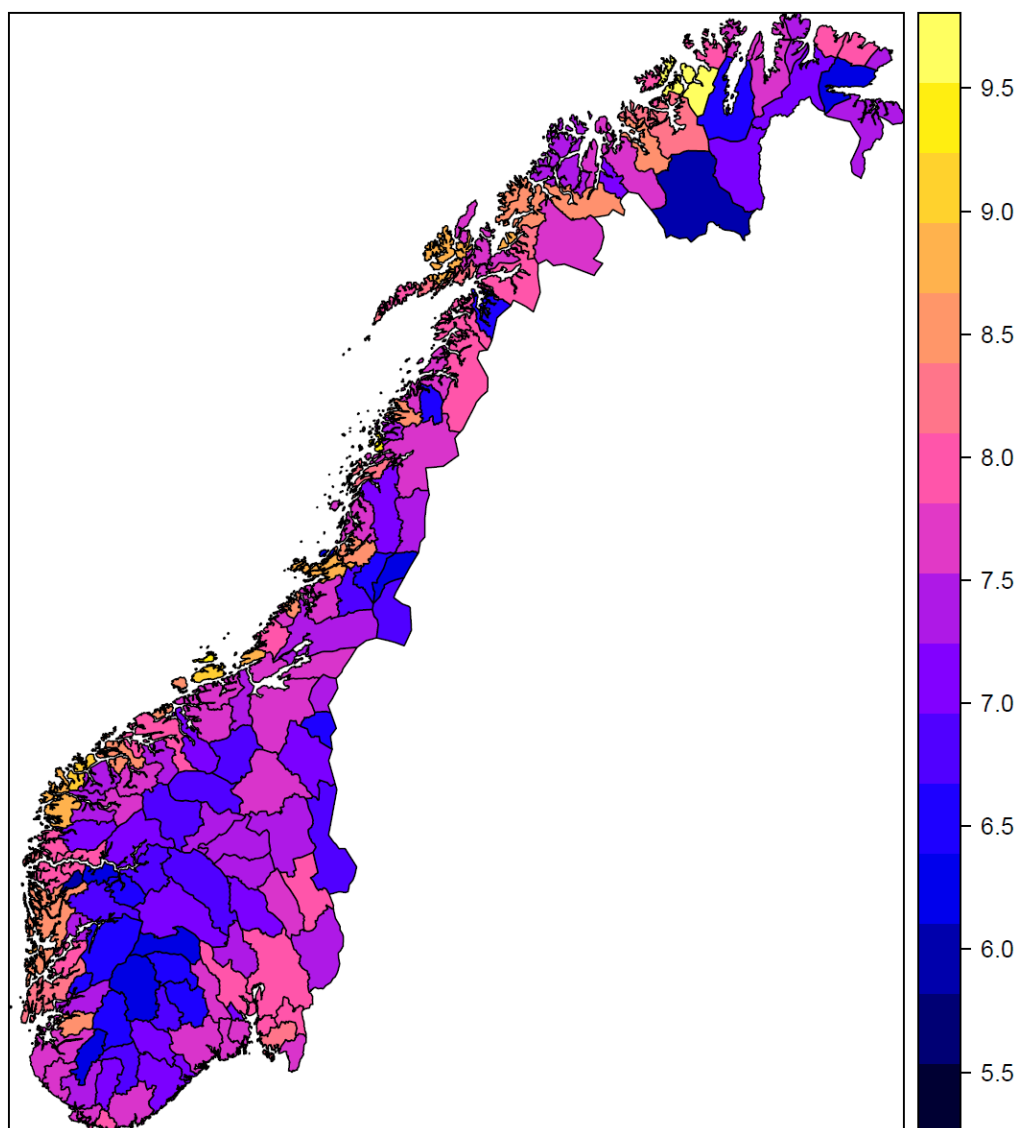


Figure 3.13. Turnover per employee (thousands NOK, in logarithm) measured across the labour market areas of Norway; summing up all bioeconomic macro-sectors (year 2017). Source: NIFU/Statistics Norway.

Finally, Figure 3.13 shows the same map when considering all bioeconomic macro-sectors together (their sum weighed by the respective bioshares): the Western coast appears as producing the highest turnover per employee, followed by the

South-Eastern Norway and the Southern coast. Figures 3.14 and 3.15 show respectively turnover and persons employed, summed across all bioeconomic sectors: it is then possible to observe that coastal regions in the North are associated to a relatively high bioeconomic turnover with a low number of employees.

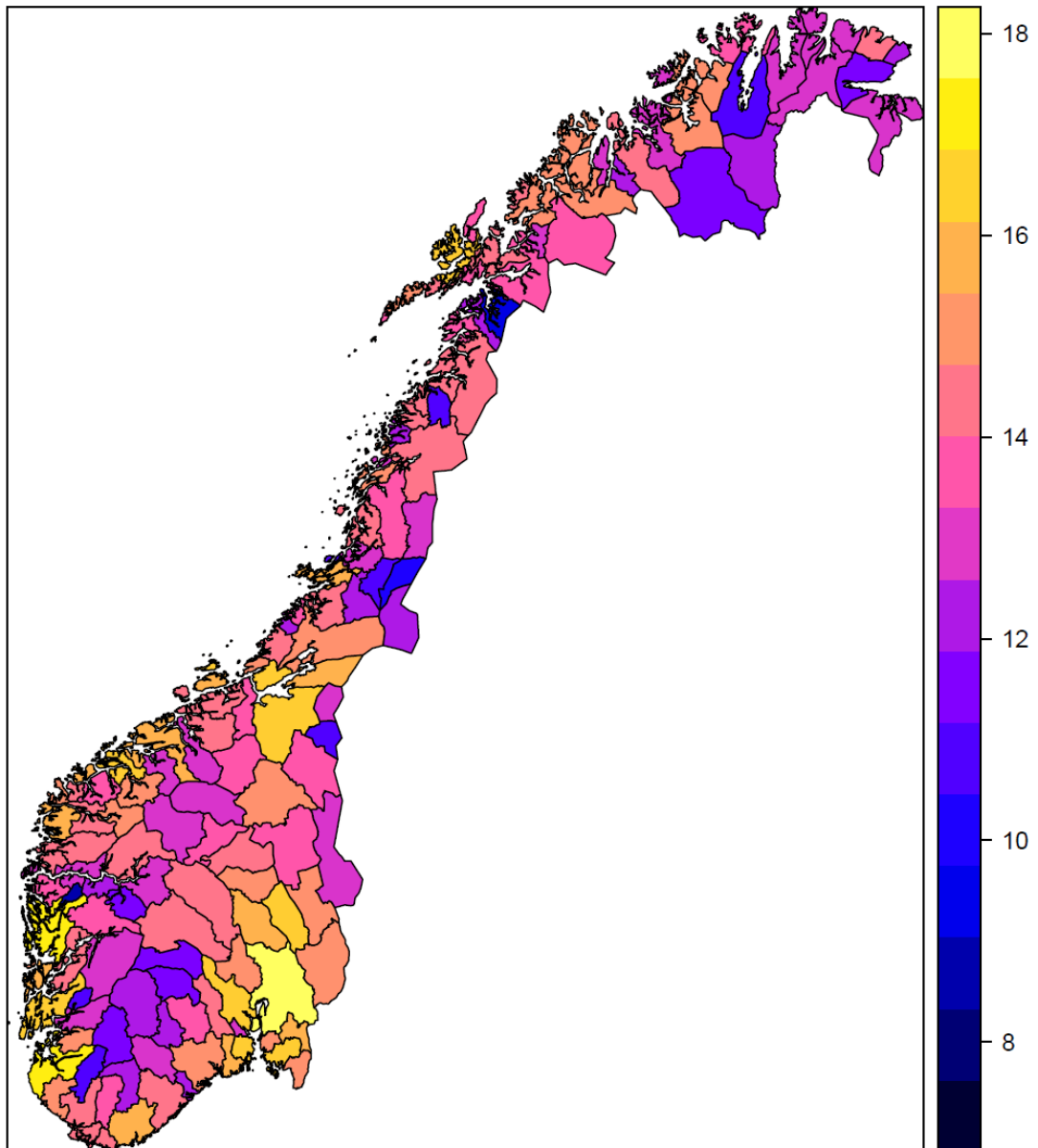


Figure 3.14. Turnover (thousands NOK, in logarithm) measured across the labour market areas of Norway; summing up all bioeconomic macrosectors (year 2017). Source: NIFU/Statistics Norway.

On the other hand, there may be areas where bioeconomic productivity is low even if the bioeconomy holds a strong position in the local economy. This can happen, for instance, in regions specialised in bioeconomic activities which do not generate

a high turnover, possibly in spite of occupying a remarkable share of the local workforce.

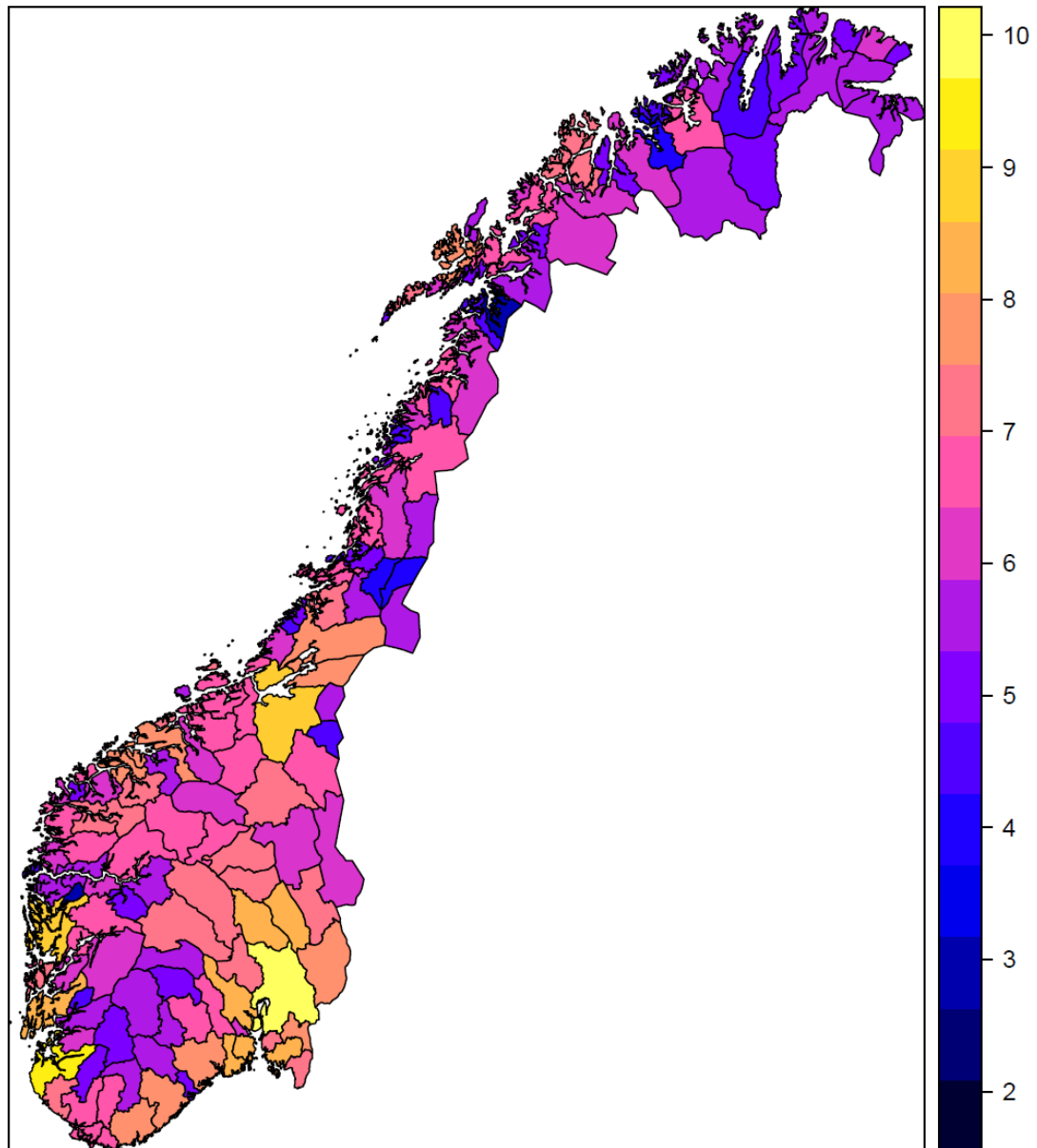


Figure 3.15. Employment (logarithm), measured across the labour market areas of Norway; summing up all bioeconomic macrosectors (year 2017). Source: NIFU/Statistics Norway.

Figure 3.16 shows the employment in the local bioeconomy as percentage (in logarithm) of the total local employment, for each labour market area of Norway (year 2017). Some of the internal regions of Norway appear, then, as having a high specialisation in the bioeconomy. However, this is not the case for all the regions where we would expect the bioeconomy to flourish. Indeed, there may be areas

where the local employment is absorbed mainly by services or by public administration, with no apparent economic exploitation of bioresources. Moreover, there may be areas where the local employment is economically exploiting bioresources in ways that have not been contemplated by our methodology: nature-based tourism can be a clear example of bioeconomic value creation not conforming to the canon of bioresource buying and selling. A discussion of our method and results is therefore due; we present it in the next section.

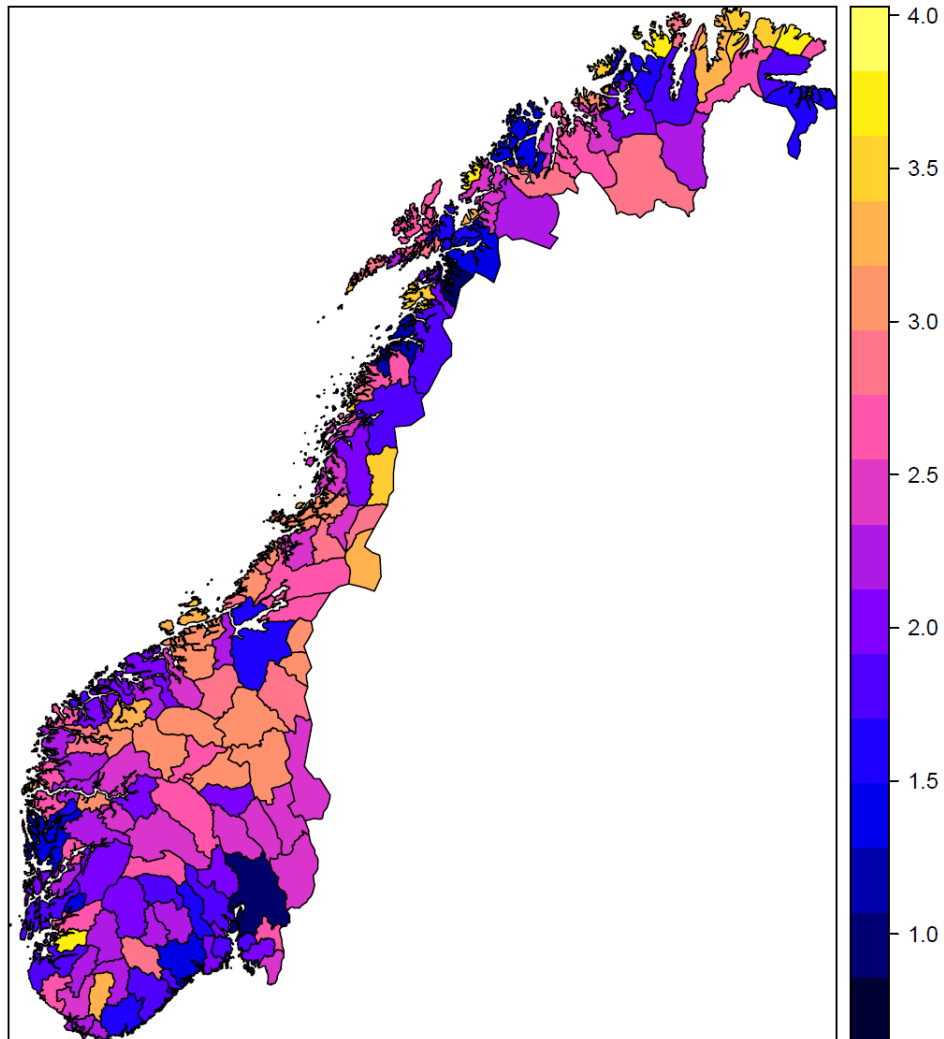


Figure 3.16. Employment in the bioeconomy as percentage (in logarithm) of the total local employment, for each labour market area of Norway (year 2017). Source: NIFU/Statistics Norway.

4 Discussion

4.1 Bioshare of products

When considering the proportion between the whole economy of a country and that part of it which depends on the utilization of biomass, that is the “bioeconomy”, it is important to find a definition of the term “bioeconomy” in a way that can simplify the interpretation of such comparison. Traditionally, when it comes to define the bioeconomy in quantitative terms, and to estimate its value in monetary terms, researchers tend to focus only on the sectors which constitute the “green” economy (agriculture and forestry) and the “blue” economy (fishing and aquaculture). The articles by Ronzon et al. (2017) and by Ronzon and M’Barek (2018), instead, have extended the boundaries of the bioeconomy from the primary sectors to include secondary sectors which are connected to bio-mass, even if less directly. Of course, when including manufacturing sectors in the analysis, an estimation problem arises because some of those sectors (think for instance about textile-related sectors), present only a share of activity and of output which depend on a bioresource input. This estimation problem has already been dealt with in the previous sections of this study; however, we need to point out specifically here that, however we estimate the “bioshare” of a particular “hybrid” industrial sector, we indirectly provide also an estimation of the share of industrial sector that is not “bio”, in the sense that does not depend on biomass. Such “non-bioshare” of an industrial sector will characterize those economic activities which we would altogether consider as the rest of the economy, or “non-bioeconomy”, which in turn constitutes our term of comparison when inferring the economic importance of the bioeconomy within a country. We argue that the relative weight of the bioeconomy in a country could be assessed more precisely by considering “bio-shares” for all the economic sectors of the country and not only for primary sectors, where the bioshare approximates 100%, and secondary sectors, which have been considered in our study, following Ronzon and M’Barek (Ronzon & M’Barek, 2018).

Let us consider the estimation problem from a value chain perspective. Primary sectors may have biomass as input or as output, but in any case, their connection

to biomass is direct and pervasive. Manufacturing sectors can lay on the second layer, or on lower layers, of the same value chain of the primary sectors; the biomass coming from the primary sectors constitutes the inputs, or part of the inputs, of the manufacturing sectors. In this sense, the manufacturing sectors have a “bio-share”. Why not going further down the value chain? The output of the manufacturing sectors may still contain plant or animal materials; which will be used as input by other sectors of the economy. The only sector that is not primary nor secondary, and still is considered in our study of the bioeconomy following Ronzon and M’Barek (Ronzon & M’Barek, 2018), is the production of Bioelectricity. We think that many more sectors could, in the future and after further elaborations on the problem, be included in the analysis. A first example can be the construction sector. Suppose that some activities in the construction sector of a country are devoted to the production of wooden houses. Would such activities represent a “bio-share” of the construction sector? Probably so, if we use the same criteria, we have used for manufacturing sectors: the wooden houses produced by the construction sector would indeed utilize construction elements which are outputs of secondary sectors (to be precise, of the “bioshares” of some secondary sectors) and would still comprise bioelements. Therefore, part of the value added of the construction sector could be considered as resulting from bioeconomic processes, and as such contribute to the estimate of the overall value-added of a country’s bioeconomy.

4.2 Bioeconomic activities

Notably, Ronzon and M’Barek (Ronzon & M’Barek, 2018) have considered also production of bioelectricity as a bioeconomic sector (the only sector they consider which is not primary not secondary). This sector is totally different from all the other bioeconomic sector, in that biomass is here used as an input, but does not constitute any part of the output. This peculiarity has lead first Ronzon and M’Barek (2018), and then us, to adopt a totally different way of measuring its contribution to a country’s bioeconomy: we cannot measure a percentage of the product which is made of biomaterials, but we must estimate how much of the product (electricity) has been produced by using biomass (or derivatives) as a main input.

We agree with the inclusion of bioelectricity in the analysis; four possible implications follow. First, other forms of energy production could be considered; a major example comes from biogas production, which pertains to NACE code D3821 (“[...]disposal of non-hazardous waste by combustion or incineration or other methods, with or without the resulting production of electricity or steam, compost, substitute fuels, biogas, ashes or other by-products for further use etc.”) and has therefore not been included in the analysis by Ronzon and M’Barek (Ronzon & M’Barek, 2018), nor by ours. Notice, moreover, that the NACE code

D3821 is a subcategory of the NACE sector D38 (“Waste collection, treatment and disposal activities; materials recovery”). Can waste collection and treatment be considered, at least partially, as a bioeconomic sector? We suppose so, especially because biomaterials often constitute an important input and sometimes even an output (think, for instance, of recycling activities).

If we think that energy from biomass is not only the output of a specific sector, but can be also used by the same sector that produces it, we can approach our second implication, focused on processes rather than products. There have been cases, also in Norway, where manufacturing sectors have employed energy from biomass, and specifically sludge and leftovers from other biosectors, to produce cement. This is not a marginal event for a cement-producing company, given that the share of its budget devoted to energy utilization is typically far from irrelevant. Therefore, we believe that the analysis of a bioeconomy could encompass also a study of the changes in the processes behind the economic activities of a country. It is important to point out that such encompassing might extend the area of the bioeconomy to some sectors, but downsize the bioshare of sectors which we already consider: for instance, an intensive application of synthetic chemicals in the processing of wood might be accounted for by lowering the bioshare of a wood-related sector.

A third implication about possible extensions of the definition of the bioeconomy can be suggested by a more challenging, but not less meaningful, example. Consider a research institute that has bought wooden chairs. The wooden chairs are acknowledged as inputs by the accounting division of the research institute: a value-added tax will either not be paid upon the purchase of those chairs or will be paid but reimbursed at a later time. This is because those chairs will contribute to the value of the output of the research institute. Given that such output is intangible, it is not intuitive for us to determine a “bioshare” of it and, therefore, a “bioshare” of the research activities connected to it. However, a parallel with the case of bioelectricity production can be established, even if far-fetched: both the power company and the research institute perform tasks leading to a product which does not contain biomaterials, and both utilize biomaterials as an input. The obvious objection is: the biomaterial input has a major role for the power company while it is scarcely relevant for the research institute. Suppose now that, instead of the research institute, we consider a major distribution company buying and selling paper products. In this case, the objection would not hold: even if the value-added by the distribution company does not involve the production or transformation of biomaterials, its formation clearly bases upon bio-materials. As a consequence, that value-added could as well be defined as bioeconomic, even if it would stem from a sector which, as all trade sectors, has not been considered as bioeconomic.

We could go on mentioning other sectors, for instance in transportation, where biomaterials enter the sector as inputs but not as outputs; instead, for sake of space, we prefer to turn now our attention toward activities which sell their outputs to sectors producing bioproducts. All sectors that have been considered as bioeconomic in our study, no matter whether primary or secondary, use also inputs and infrastructures which do not have a physical “bioshare”. Sometimes the inputs and infrastructures are purchased directly by the firms belonging to the bio-economic sector: a biopharmaceutical company may, for instance, acquire a patent from a private research firm. In other cases, they are purchased indirectly: a forest-related company may employ new roads and skilled workers, where the infrastructure and education have at least partially been provided by the state or the county, that is, indirectly, by the same forest-related company through taxes. How much of the services, of the public administration, of the education system of a country are financed by, and contribute to, the sectors which we are traditionally considered as bioeconomic? In other words, does a “bioshare” exist for their value-added as well? If so, such bioshare could be extremely high in some countries, especially in the developing world, where the whole economy rests upon the production of bio-goods. In Norway, such bioshare would be lower and difficult to quantify, but placing it at zero, by excluding almost all services and all the public administration from the accounting of the Norwegian bioeconomy, still feels like a methodological stretch.

4.3 Cross-border bioeconomies

An analysis of socioeconomic indicators of the bioeconomy for a country like Norway, whose economy is characterized by openness and internationality, poses additional methodological questions. In an open economy, goods and capitals flow across country borders by means of international trade and foreign investments. The indicators of an open economy include distinctions between national property and national place of production; an exemplary distinction in this sense is between Gross Domestic Product and Gross National Product, which derive from different points of view on a country's economy, and possibly at different definitions of a country's economy. Should similar distinctions be in place when defining indicators for an "open bioeconomy"? Consider the case of wearing apparel: as pointed out previously in Section 3, the production of wearing apparel in Norway often employs wool as a material. The utilization of wool is grounded in the Norwegian history, marks the Norwegian society in that wool is still considered the champion material to protect from the cold, and constitutes one of the traditional prides of the "made in Norway" apparel. On the other hand, the use of synthetic materials is

far from negligible among Norwegian clothing brands; however, most of the production based on synthetic materials for the same brands occurs abroad. This does not mean that value adding processes for these products only happen abroad: many value adding activities still happen in Norway even if not directly involving physical activities of production. A first order of technical problems, therefore, comes from the fact that some of the value adding activities in a sector in a country may derive from a production abroad with synthetic materials, even if the production within the country is mainly based on biomaterials.

Unfortunately, a second and more difficult set of problems comes from the international division of demand, which we can illustrate again through the example of wearing apparel. The Norwegian domestic market is much more oriented towards biomaterials in clothing than many foreign markets, including other Nordic markets. This means that an assessment of the sectoral bioshare based on export statistics could differ strongly from an assessment based on production statistics. For our analysis, we have related to production rather than to exports, but a different decision would have led to different quantifications of the Norwegian textile-related bioshares. Notice that the bioshares considered by Ronzon and M'Barek (Ronzon & M'Barek, 2018) for the sectors C20 and C21 were based on production value (from the EUROSTAT-Prodcom database) while the bioshares for the other sectors were based on export value (from the EUROSTAT-Comext database); for an open economy like the one of Norway, a decision had to be made between the two methodological approaches.

A third comment can be brought forward about the international features of the bioeconomy, and specifically about the role of imports. If a country shifts its manufacturing toward a higher use of biomaterials, and those biomaterials are imported, an analysis like ours would translate this shift in an increase of bioeconomic value-added for the manufacturing sectors, because of an increased bioshare in its products. Figures for primary sectors like agriculture and forestry would not be altered, since the analysis is restricted to sectors within a country and ignores repercussions on a global scale. Therefore, changes in the world's bioeconomy, following a country's shift like the one described above, could go well beyond the changes in the same country's bioeconomy, both in terms of value added and in terms of employment.

4.4 Complementary visions

In the current analysis, we have used a definition of the bioeconomy which focuses mostly on the resources used by firms in order to produce. We do not forget that the existing visions of the bioeconomy are not only based on bio-resources, but

also on bio-technology and bio-ecology (Bugge, Hansen, & Klitkou, 2016); therefore, a goal for future studies on value creation in the bio-economy could be aimed at disentangling between the value creation occurred within the existing production patterns and within the existing national economic structure, and the value creation which results from systemic changes in the country's production patterns. Such systemic changes may signal a restructuring process for the country, as well as global economic reactions to environmental and political pushes towards sustainability development goals. Radical innovations from the supply side, and changes on the consumption side in the way human beings satisfy their needs, translate into money flows which we measure through value-added measures. Our analysis of value creation in the bioeconomy in Norway represents an occasion for hinting towards future analyses, which would look at the overall structural variations in the Norwegian economy, and at the innovation patterns followed by firms at micro-level to respond to macro-level global challenges.

Possible alterations of existing ecosystems should also be taken into account more explicitly. For instance, the high value added for fishery and aquaculture found in this report has to be seen on the background of the IPBES-report on biodiversity and ecosystem services (IPBES, 2019). While the draft IPBES-report highlights that fishery, aquaculture and mariculture play an increasing role in food security, livelihoods and the global economy, the report also points out that these bioeconomic activities affect nature directly and indirectly. Industrial fishing can lead to the depletion or overexploitation of marine fish stocks, while growth of aquaculture and mariculture affects nature in several ways, such as through the production of aquafeed - by harvesting stocks of small, fast reproducing or by producing plant-based fish feed - or through the degradation of coastal habitats by different waste streams (nutrients, feces, antibiotics) (IPBES, 2019). On the other hand, the specific context of Norway can provide examples of a sustainable management of fishery resources, as well as of ecologically sound aquaculture and marine spatial planning systems. Cross-sectoral cooperation between fishery, aquaculture and mariculture could then be important for addressing the potential damages caused by fishery, aquaculture and mariculture, especially in terms of losses in biodiversity. And technology can help to address some of the mentioned challenges.

For future research it would also be important to highlight changes in the Norwegian technology and supplier industries towards the evolving bioeconomy. While the main focus of economists, regarding technology and supplier industries, has often been on the provision of knowledge-based services, equipment and machinery for the oil and gas industry, the evolving bioeconomy brings the need for turning the technology and supplier industries towards different needs. The bioeconomy can indeed become a new platform for value creation and employment,

involving not only primary industries, but many other industries of the Norwegian economy, and to produce not only material goods, but also immaterial goods and services. Value creation examples can include: technology and services for aquaculture and mariculture, digitalisation and artificial intelligence in the bioeconomy, new equipment for processing organic biomass in biorefineries.

5 Conclusions

Environmental challenges at global scale are forcing countries to re-examine their economic structure and adopt new economic concepts. The bioeconomy is a concept increasingly used to circumscribe that part of the economy which depends on the utilization of biomass.

Our study has replicated recent analyses of the European bioeconomies, to assess the features and evolution of the Norwegian bio-economy. Norway appears to belong to the Nordic bioeconomy cluster, in the sense that the Norwegian bioeconomy is characterised, as for other Nordic countries, by a relatively low share of workers in bioeconomic sectors and by a very high labour productivity in the same sectors. In other words, while not many workers are employed in the Norwegian bioeconomy, their socioeconomic impact is high. This is due not only to a high productivity across all bioeconomic sectors, as expected given the level of development of the Norwegian economy, but also to astonishingly high peak in productivity in fishing and aquaculture, whose value added has evolved massively during the last ten years. Also as a whole, the Norwegian bioeconomy has strongly increased its productivity in recent years. Sectors connected to food and beverages, which already had a high weight within the Norwegian bioeconomy, are still increasing their contributing to the Norwegian value added; at the same time, pharmaceuticals are experiencing a dramatic shift toward bio-based production and thus contributing to qualitative changes in the Norwegian bioeconomy. We need to point out that stable measures of value added detected in some sectors, for instance in forestry and in paper manufacturing, may hide strong internal dynamics aimed at curbing pressures from foreign competition.

As a note for future research, deriving from our reflections throughout the present study, we advise a further evolution of socioeconomic indicators to parallel more extensive definitions of the bioeconomy concept. Moreover, we suggest that data from firm-level innovation surveys could uncover innovation patterns behind the observed bioeconomic dynamics.

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Appendix

Quantified Socioeconomic Indicators

Table 3. Quantified Socioeconomic Indicators of Norway's Bioeconomy in 2017 (number of persons employed, value added and apparent labour productivity).

Source: NIFU/Statistics Norway.

Sector	Workers	Value Added	Apparent Labour Productivity
	Number of persons employed	(NOK million)	(NOK000 per person employed)
Agriculture	34700	16112	464
Forestry	3800	5419	1426
Fishing and aquaculture	17501	43601	2491
Manufacture of food, beverages and tobacco	51625	45573	883
Manufacture of bio-based textiles	1289	771	598
Manufacture of wood products and furniture	16016	10190	636
Manufacture of paper	2899	2981	1028
Manufacture of bio-based chemicals, pharmaceuticals, plastics and rubber	2423	4743	1923
Production of bioelectricity	4	28	7000
Bioeconomy	130257	129418	994

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