BAE
Bio-based and Applied Economics

AIEAA
ASSOCIAZIONE ITALIANA DI ECONOMIA AGRARIA E APPLICATA

OPEN ACCESS

Citation: Lasarte-López, J., Grassano, N., M'barek, R., Ronzon, T. (2023). Bioeconomy and resilience to economic shocks: insights from the COVID-19 pandemic in 2020. *Bio-based and Applied Economics* 12(4): 367-377. doi: 10.36253/bae-14827

Received: June 20, 2023
Accepted: September 26, 2023
Published: December 31, 2023

Data Availability Statement: All relevant data are within the paper and its Supporting Information files.

Competing Interests: The Author(s) declare(s) no conflict of interest.

Editor: Silvia Coderoni

ORCID
JLL: 0000-0002-3627-5466
NG: 0000-0003-1507-7476
RM: 0000-0002-3205-3938
TR: 0000-0001-8554-627X

Bioeconomy and resilience to economic shocks: insights from the COVID-19 pandemic in 2020

Jesús Lasarte-López[1,*], Nicola Grassano[2], Robert M'barek[1], Tévécia Ronzon[1]

[1] *European Commission, Joint Research Centre (JRC), Edificio Expo, Calle Inca Garcilaso, 3, 41092 Sevilla, Spain*
[2] *Department of Economics, Universidad Loyola Andalucía, Avda. de las Universidades s/n, 41704 Dos Hermanas, Spain*
*Corresponding author. E-mail: Jesus.LASARTE-LOPEZ@ec.europa.eu

Abstract. Using the latest release of employment and value added numbers in the bioeconomy sectors, we conducted an analysis on the performance of the EU bioeconomy during the COVID-19 pandemic in 2020. Our findings point to a possibly higher level of resilience of the bioeconomy sectors compared to the overall economy. While employment in the bioeconomy registered a similar (but slightly sharper) decrease to the total EU average (-1.7% vs. -1.4%), the value added fell substantially below average (-0.4% vs. -4.0%). The more contemporary biomass-processing sectors (chemicals and pharmaceuticals, as well as bioelectricity) performed better than the more traditional sectors (such as food or textiles). At the Member State level, we observe a high degree of heterogeneity in sectoral performance. By discussing these estimates alongside previous qualitative insights from the related literature, we emphasize the relevance of the bioeconomy not only for environmental sustainability but also for socioeconomic resilience.

Keywords: COVID-19 shock, bioeconomy, socioeconomic indicators, European Union, green transition, resilience.
JEL Codes: Q57, O44.

1. INTRODUCTION

The bioeconomy is composed by all those economic activities that depend on the use of biological resources. This definition includes not only all biomass-producing and processing sectors, but also related services (European Commission, 2018). The launch of the EU's Bioeconomy Strategy in 2012[1], along with its update in 2018[2], positioned the bioeconomy as both a

---

[1] Innovating for sustainable growth: A bioeconomy for Europe. https://op.europa.eu/en/publication-detail/-/publication/1f0d8515-8dc0-4435-ba53-9570e47dbd51
[2] A sustainable bioeconomy for Europe: Strengthening the connection between economy, society and the environment: updated bioeconomy strategy. https://op.europa.eu/en/publication-detail/-/publication/edace3e3-e189-11e8-b690-01aa75ed71a1/language-en/format-PDF/source-149755478

Firenze University Press | www.fupress.com/bae

key enabler and a result of transitioning to a green and fair economy in the EU. As a result, synergies have been identified with the overarching European Green Deal strategy, which aims to address climate and environmental challenges. Specifically, the Bioeconomy Strategy can help evaluate and address trade-offs between policy objectives and competing resource uses, promoting both environmental sustainability and socioeconomic gains and resilience (European Commission, 2022).

The significance of the bioeconomy in enhancing resilience to external economic shocks has gained considerable attention in both academic and policy debates, particularly in light of recent major events. In 2020, the COVID-19 pandemic strained global supply chains under stress, due to shifts in demand and labour shortages (OECD, 2020; Ozdemir et al., 2022; Galanakis et al., 2022). More recently, the Russian invasion of Ukraine led to price increases in basic resources like food and energy products (Ramanauske et al., 2022). In this context, the strategic importance of the bioeconomy has become evident in its potential to create shorter and more circular bio-based value chains, thus reducing dependence on imported basic resources (Farcas et al., 2020; Galanakis et al. 2022; European Commission, 2022). An additional step in this direction is the Council of the European Union's Conclusions on the opportunities of the bioeconomy, approved on April 25, 2023. These conclusions emphasize the potential of the bioeconomy to address challenges such as climate change, fossil fuel dependency and food security, as well as contributing to increased resilience[3].

Despite its recognized strategic importance, the literature examining the role and economic performance of the bioeconomy under the aforementioned events is still scarce and inconclusive. Some studies provided qualitative insights into the economic impact of these events on the bioeconomy (see Fritsche et al., 2021; Galanakis et al., 2022; Kulisic et al, 2021 or Woźniak & Tyczewska, 2021). An ex-ante quantitative assessment was also provided by González-Martínez et al. (2020). However, to the extent of our knowledge, an ex-post analysis on the impact of these events on the bioeconomy is still missing in the academic literature.

In June 2023, the EU-Bioeconomy Monitoring System[4] (EU-BMS, hereinafter) was updated with data on employment and value added in the bioeconomy sector for 2020. This fact opens the possibility of analysing the performance of the bioeconomy during the pandemic. Therefore, this article aims to fill the gap in the literature by using the latest release of the EU-BMS to answer the following research questions:

- What was the impact of the pandemic on the bioeconomy in the EU and its Member States?
- Did the bioeconomy sectors exhibit greater resilience compared to the overall economy and other sectors?
- Are there any drivers or common sectoral patterns explaining the performance of the bioeconomy across countries in 2020?

This short article is structured as follows. Section 2 describes the methodology to estimate jobs and value added in the EU bioeconomy. Section 3 presents and discusses the main results. Section 4 concludes.

2. DATA AND METHODOLOGY

The sectoral scope of this study comprises all biomass producing and transforming activities, namely the primary sectors and the bio-based manufacturing and electricity ones presents the selected sectors in this study and their contributions to the bioeconomy.

The indicators on employment and value added in these sectors from the EU-BMS are computed following the methodology proposed by Ronzon et al. (2018, 2020, 2022) and Lasarte-López et al. (2023a). The process involves two main steps. In the first step, data from Eurostat is collected and cleaned for sectors falling within the bioeconomy scope defined by the EU's Bioeconomy Strategy (European Commission, 2018). National Accounts data is used for primary sectors (nama_10_a64_e for employment and nama_10_a64 for value added), while Structural Business Statistics (sbs_na_ind_r2) is used for bio-based manufacturing and electricity.

In the second step, output bio-based shares are applied to those sectors considered as 'hybrid' (their output can contain biomass but also other non-bio-based materials). These shares inform about the proportion of final production by sector made of biomass. Therefore, this approach assumes that the quantity of jobs and value added from each sector allocated to the bioeconomy is proportional to its bio-based output.

The bio-based shares are initially prepared at the product level (for each item in the PRODCOM product classification). The proportion of biomass incorporated by all products is estimated using expert knowledge and scientific literature review. This information is then aggregated to determine sectoral bio-based shares at

[3] Access to the press release and related documents: https://www.consilium.europa.eu/en/press/press-releases/2023/04/25/promoting-a-more-sustainable-competitive-and-resilient-europe-and-boosting-rural-areas-council-approves-conclusions-on-the-opportunities-of-the-bioeconomy/
[4] Access to the EU- Bioeconomy Monitoring System: https://knowledge4policy.ec.europa.eu/bioeconomy/monitoring_en

Table 1. Sectoral scope and bio-based share by sector.

	Sectors	NACE codes	Aggregated bio-based share for the EU27
Primary sectors	Agriculture, forestry and fishing	A01, A02, A03	100
	Food, beverages and tobacco	C10, C11, C12	100
	Bio-based textiles	C13, C14, C15	42.0
Bio-based manufacturing and electricity	Wood products and furniture	C16, C31	72.4
	Paper	C17	99.5
	Bio-based chemicals, pharmaceuticals and rubber	C20, C21, C22	13.7
	Bio-based electricity	D3511	5.8

Own elaboration from Lasarte-López et al. (2023b).

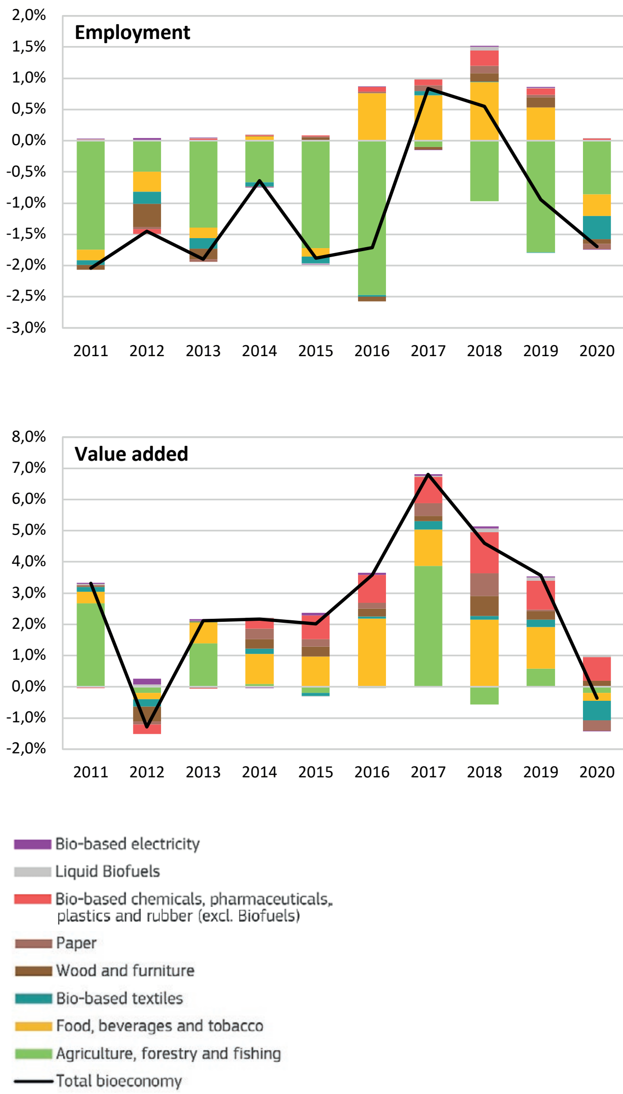

Figure 1. Growth rate of employment and value added in the EU bioeconomy, and decomposition by sector. Source: Own elaboration from Lasarte-López et al. (2023b).

the 2- and 4- digit levels of the NACE classification (see Ronzon et al., 2017, for details).

The latest release of the EU-BMS indicators was conducted with a different data pre-processing than previous releases. This new pre-processing incorporates additional economic information (when available) to estimate missing values. Specifically, National Accounts estimates on employment and value added by sectors are used as auxiliary variables to compute missing values in Structural Business Statistics (see Lasarte-López et al., 2023a, for details).

3. RESULTS

3.1. General trends in the EU

The EU bioeconomy provided 17.16 million jobs in 2020 (8.3% of total employment) and contributed with 664.82 billion euro value added (4.9% of total GDP). These figures reflect a decline in employment above the EU average in comparison to 2019 (-1.7% vs. -1.4%), and a slight decline in the value added with regard to GDP (-0.4% vs. -4.0%).

The decline in employment and value added are explained by differences in behaviours by sector. Figure 1 illustrates the growth rates of employment and value added and their breakdown by sector. As for employment, most sectors registered negative growth in 2020, with the primary and the traditional biomass-transforming sectors (particularly, food and textiles) explaining a large portion of the total decline. Regarding value added, the impacts are mixed; while more traditional bio-based sectors exhibited a negative impact (excluding wood and furniture manufacturing sectors), the bio-based chemicals and pharmaceuticals, plastics, and rubber sectors continued to grow in 2020.

3.2. Analysis by Member States

The heterogeneous behaviour is also manifested in the evolution of the bioeconomy for the 27 EU Member States (MS). Section 3.2.1 describes the employment dynamics in the bioeconomy sectors by MS, while Section 3.2.2 focuses on value added by MS.

3.2.1. Employment in the bioeconomy by MS

Table 2 shows the growth rate of employment in 2020 for the bioeconomy, the total economy, primary sectors, the bio-based manufacturing and electricity sectors, and the total manufacturing sector. Despite bio-based employment registering a slightly higher decrease than total EU employment, there were 15 MS where employment in the bioeconomy sectors overperformed that of their respective aggregated economies. This is particularly true for Finland, France, Latvia, Poland and Slovakia, where employment in the bioeconomy grew while decreasing (or remaining stable) in the overall economy. Conversely, Luxembourg and Malta registered notably better employment growth in the total economy compared to the bioeconomy.

Splitting the bioeconomy employment into agriculture and bio-based manufacturing and electricity, we see that both subsectors registered a decrease in employment in 9 MS. The consequent overall negative employment performance of the bioeconomy is aligned with the total economy (besides the already mentioned Luxembourg). Conversely, only Finland and Latvia registered growth in employment for both subsectors. In the remaining 16 MS, the two subsectors registered variations of opposite signs. In 10 cases, the overall performance of the bioeconomy was driven by the primary sector (4 decreases and 6 increases). In the other 6 cases, the bio-based manufacturing conditioned the sign of the overall bioeconomy (3 increases and 3 decreases).

Within the EU manufacturing sector, the decrease of bio-based employment in 2020 was less pronounced compared to the overall manufacturing sector. Bio-based employment outperformed total manufacturing employment in 17 MS, with 8 MS even experiencing growth in bio-based employment while the overall manufacturing sector witnessed a decrease. However, the remaining 9 MS registered greater declines in bio-based employment than the total manufacturing. Only Ireland recorded growth in both categories, although the growth rate was lower for bio-based employment.

Figure 2 decomposes the aggregate growth rate of bio-based manufacturing and electricity sectors. The figure reveals that there are no clear patterns observed across MS. However, two sectors appear to explain most of the growth in the top-performing MS: (1) wood products and furniture (Eastern and Northern countries such as Latvia, Slovakia, Estonia, Finland and Slovenia, with the exception of Spain) and (2) the manufacturing of food, beverages and tobacco (France, Denmark and, to a lesser extent, Finland and Spain). In contrast, for countries experiencing negative growth in employment, the main drivers are the food, beverages and tobacco sectors, as well as the bio-based textiles sector. Notably, Bulgaria, Portugal and Romania show a significant impact from both sectors. Food, beverages and tobacco explains most of the negative growth in Germany, Sweden, and Luxembourg, while the bio-based textiles manufacturing sector experienced particularly poor performance in Italy.

3.2.2. Value added in the bioeconomy by MS

The analysis of value added draws a slightly different picture (see Table 3). As for the EU, the value added growth of the bioeconomy outperformed that of the overall economy in 22 of the 27 MS. Within these countries, the added value of the bioeconomy grew while the total economy decreased in 12 of them; both magnitudes increased in Lithuania, Bulgaria and Denmark and decreased in the remaining 7 MS. In the other 5 MS, the bioeconomy performed worse than the total economy: in Luxembourg and Ireland by growing less than the total economy; in Finland and Romania by decreasing more. Only in Sweden value added in the bioeconomy decrease while it slightly increased in the total economy.

The growth of value added in the two main subsectors of the bioeconomy (agriculture and bio-based manufacturing and electricity) exhibited the same sign in 15 MS, with 11 of them experiencing positive growth and being negative in the other 4. In other 4 cases, the value added in primary sectors grew while it decreased in the bio-based manufacturing, resulting in all cases in a negative overall decrease of the bioeconomy, except for Spain. As for the remaining 8 MS, the bio-based manufacturing sector recorded growth in valued added while there was a decrease in agriculture. The combined effect of these trends resulted in an overall growth for the bioeconomy, except in Hungary, Portugal, and Sweden.

When comparing the evolution of value added between both bio-based and total manufacturing, the direction of value added growth for the two sectors was the same in 11 MS (7 negative and 4 positive). In 15 of the remaining 16 MS, the bio-based sector grew while the total manufacturing decreased. The only exception was Greece.

It is worth noting that, according to Table 3, countries with a more positive or less negative GDP trend tend to be positioned in the upper half of the table when ranked by the overall growth of bioeconomy sectors, particularly in terms of value added. Assuming that the decline in a country's GDP is related with the pandemic's impact (including lockdown implementation and the effectiveness of measures taken to mitigate the shock), this national

Table 2. Employment change (%) in the bioeconomy sectors and in the overall economy by MS (2020).

	Total bioeconomy	Total economy	Agriculture, forestry and fishing	Total biobased manufacturing and electricity	Total Manufacturing
LV	3.4	-2.3	0.5	6.9	-3.4
PL	2.2	0.0	4.5	-1.5	-4.0
FI	2.1	-1.9	2.2	2.1	-1.7
FR	1.8	-0.7	-0.4	3.6	-1.2
SK	1.0	-1.9	-2.6	3.9	-4.3
HU	0.8	-1.1	1.8	-0.2	-3.8
MT	0.6	2.8	2.4	-0.2	-1.1
NL	0.6	-0.5	1.5	-0.3	-0.2
AT	0.5	-1.6	1.9	-0.7	-1.3
CY	0.3	-1.1	0.8	-0.2	-0.8
IE	0.2	-2.8	-0.2	0.8	2.7
DK	0.0	-1.1	-2.9	2.1	-3.0
CZ	-0.3	-1.7	0.8	-1.0	-3.7
BE	-0.5	0.1	0.8	-1.0	-1.1
SE	-1.2	-1.3	1.0	-2.5	-1.8
HR	-1.2	-1.2	-1.3	-1.2	-1.3
EE	-1.4	-0.4	-8.6	2.2	-1.7
SI	-1.4	-0.7	-3.0	1.1	-1.9
LU	-1.5	1.7	0.0	-2.3	-1.7
BG	-1.5	-2.3	-0.2	-6.1	-4.8
EU27_2020	-1.7	-1.4	-1.6	-1.8	-2.8
PT	-2.5	-1.8	-0.4	-5.5	-3.0
IT	-2.5	-2.2	-2.5	-2.5	-2.1
EL	-2.7	-1.8	-2.9	-2.1	-0.1
ES	-2.9	-4.2	-6.5	1.3	-4.4
DE	-3.4	-0.8	-3.0	-3.5	-2.5
RO	-5.2	-2.1	-5.2	-4.8	-6.4
LT	-6.4	-1.6	-11.7	-1.5	-1.3

Note: The categories identified by each typology of arrow are defined following the same classification than Mubareka et al. (2023), where a negative performance in 2020 (below -1.0%) is flagged with a red arrow, a stable one (between -1.0% and 1.0%) is remarked with a yellow arrow, and a good performance (above 1.0%) is assigned a green arrow.
Source: Own elaboration from Lasarte-López et al. (2023b).

effect on the performance of the bioeconomy partially explains the observed heterogeneity across countries.

The dynamics of value added within the bio-based manufacturing and electricity subsectors also present a high degree of heterogeneity. Figure 3 shows the contribution by sector to the growth rate of value added. Similar to employment, two sectors play a substantial role in driving positive growth in bio-based manufacturing for the top-performing MS: (1) wood products and furniture (Latvia, Lithuania, Estonia, Slovakia, Slovenia and Luxembourg) and food, beverages and tobacco (Lithuania, Slovakia, Bulgaria and The Netherlands). Among the countries with a lower (negative) growth in value added, the food beverages and tobacco sectors were also important drivers. These countries are located in Southern and Eastern Europe, i.e., Croatia, Italy, Romania, Spain and Greece. Within them, Croatia experienced the poorest performance in these sectors, which explain most of the decline in value added within its bioeconomy. In contrast to employment, there is a generalized positive impact across countries from the bio-based chemicals and pharmaceuticals, plastics and rubber, as well as the bio-based electricity sectors.

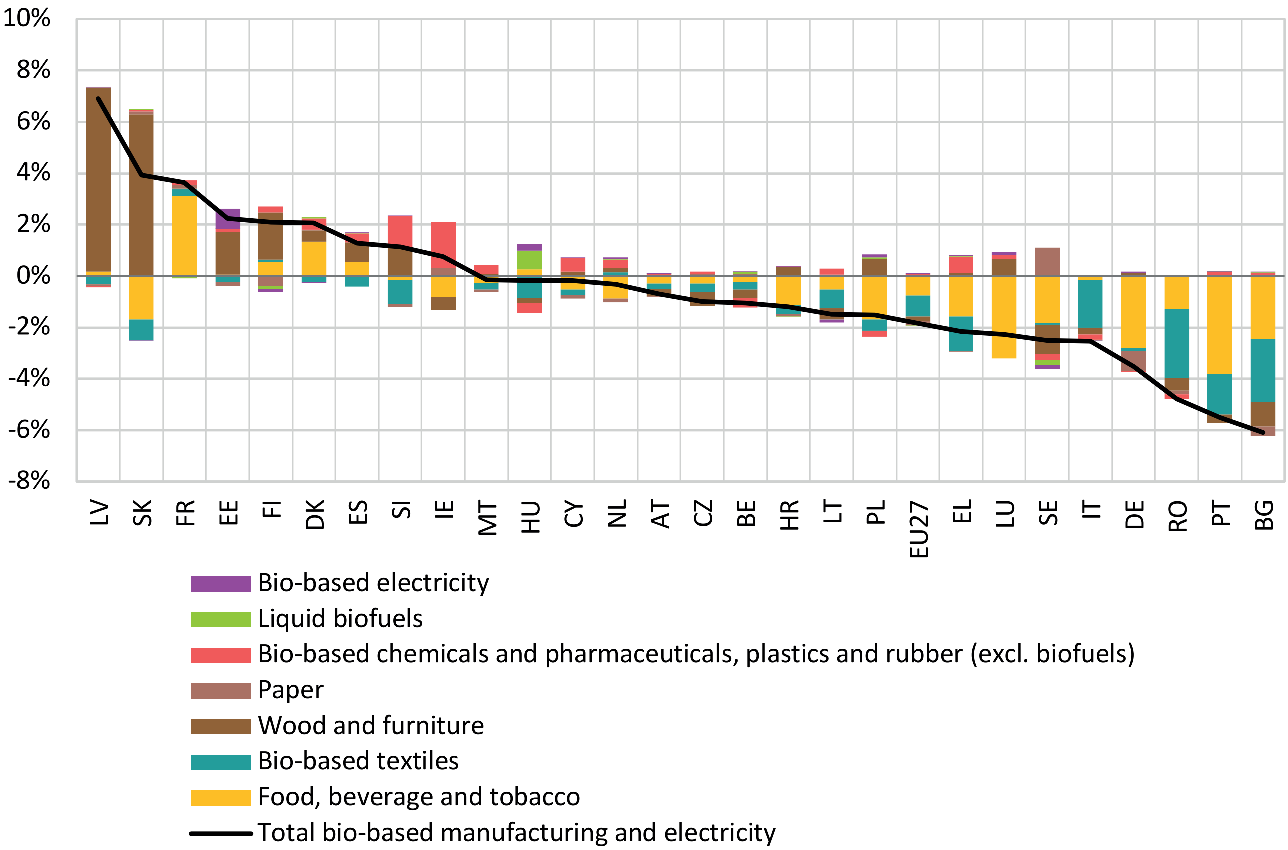

Figure 2. Decomposition of growth in employment in the bio-based manufacturing and electricity sectors (2020). Source: Own elaboration from Lasarte-López et al. (2023b).

3.3. Sectoral trends across the pandemic

The next step is to identify if there were common break in sectoral across countries due to the disruption of the pandemic. For this purpose, we conducted a paired sample t-Test to determine whether the growth of bioeconomy sectors by country in 2020 differed significantly from the average growth during the period 2014-2019, which covers the last expansionary phase of the business cycle in the EU27 before the COVID-19 shock. The results are shown in Table 4.

For the overall bioeconomy, there are no significant breaks in employment trends, which contrast, with the statistically significant negative difference observed in the total employment variation. However, for value added, we identify a statistically significant difference in the growth rate of 2020 compared to the 2014-2019 average, although this difference is of lesser magnitude than the observed for total value added.

In the two big sectors of the bioeconomy, a common break in trends is identified for both employment and value added in the bio-based manufacturing and electricity sectors, but not for Agriculture, Forestry and Fishing. The greater relative weight of employment in the primary sector in the bioeconomy can explain the absence of a statistically significant break in total employment within the bioeconomy. As for value added, the lower relative contribution of primary sectors would not offset the negative impact of bio-based industries, therefore explaining the statistically significant break in the total bioeconomy.

From a sectoral point of view, the differences in the growth rate of 2020 across countries are statistically significant for the more traditional biomass-processing sectors, namely, the manufacturing of food, beverages and tobacco, bio-based textiles and, only for employment, the paper industry.

Regarding bio-based chemicals and pharmaceuticals, plastics and rubber, we find no statistically significant differences in the growth trends of this sector across the EU countries. As spotted in Section 3.2.2, the contribution of this sector was positive for most coun-

Table 3. Value added change (%) in the bioeconomy sectors and in the overall economy by MS (2020).

	Total bioeconomy	Total economy	Agriculture, forestry and fishing	Total biobased manufacturing and electricity	Total Manufacturing
LT	↑ 14.4	↑ 1.6	↑ 15.4	↑ 13.7	↓ -1.4
MT	↑ 13.7	↓ -5.8	↑ 53.6	↑ 1.1	→ 0.7
LV	↑ 9.2	↓ -1.1	↑ 2.8	↑ 15.6	↑ 2.4
BG	↑ 6.1	→ 0.6	↑ 7.8	↑ 4.7	↓ -4.6
SI	↑ 5.2	↓ -1.9	→ 0.9	↑ 7.4	↓ -3.5
SK	↑ 4.4	→ -0.8	↑ 2.4	↑ 6.2	↓ -9.3
PL	↑ 3.8	→ -1.0	↑ 7.1	↑ 2.1	↓ -3.8
DK	↑ 3.8	→ 0.5	↑ 8.3	↑ 2.5	→ -0.9
EE	↑ 2.8	→ 0.0	↓ -14.7	↑ 12.2	↓ -3.1
LU	↑ 2.8	↑ 4.3	→ 0.0	↑ 3.9	↑ 4.6
BE	↑ 2.8	↓ -3.4	↑ 7.6	↑ 2.0	↓ -4.4
IE	↑ 1.9	↑ 5.2	↑ 7.6	→ 0.6	↑ 12.7
ES	↑ 1.1	↓ -9.7	↑ 4.4	↓ -1.5	↓ -9.4
AT	→ 0.5	↓ -3.6	↓ -1.0	→ 0.9	↓ -5.1
CZ	→ 0.3	↓ -3.6	→ 0.8	→ 0.0	↓ -9.7
NL	→ 0.3	↓ -2.1	↓ -4.2	↑ 3.4	↓ -1.6
DE	→ 0.2	↓ -1.3	↓ -4.9	↑ 1.6	↓ -6.2
EL	→ -0.2	↓ -8.7	→ 0.4	↓ -1.2	→ 0.7
EU27_2020	→ -0.4	↓ -3.5	→ -0.6	→ -0.2	↓ -5.9
CY	→ -0.5	↓ -4.2	→ 0.4	↓ -1.1	↓ -1.8
PT	→ -1.0	↓ -5.8	↓ -2.6	→ 0.0	↓ -5.5
SE	↓ -1.1	→ 0.7	↓ -3.8	→ 0.1	↓ -2.7
HU	↓ -1.2	↓ -6.0	↓ -4.3	↑ 1.9	↓ -6.6
FR	↓ -1.3	↓ -5.0	↓ -2.3	→ -0.8	↓ -12.2
FI	↓ -2.6	→ -0.5	↑ 3.6	↓ -6.7	↓ -1.8
RO	↓ -5.3	↓ -1.4	↓ -7.0	↓ -2.2	↓ -9.1
IT	↓ -5.8	↓ -6.8	↓ -2.6	↓ -7.6	↓ -9.5
HR	↓ -6.3	↓ -8.0	↓ -2.5	↓ -8.8	↓ -8.1

Note: The criteria that define the orientation of each arrow is the same as in Table 2 (see note).
Source: Own elaboration from Lasarte-López et al. (2023b).

tries in terms of value added. This is probably explained by the crucial role of the bio-based pharmaceuticals sector during the COVID-19 pandemic, which was reflected in the economic performance of this sector.

The existence of similar breaks in certain sectors suggests that the observed heterogeneity in the overall performance of the bioeconomy across MS could also be partially explained by their sectoral composition. Thus, the specialization of some countries in traditional biomass-processing sectors (particularly food and textiles) could have had a negative effect on the aggregate performance of their bioeconomies (e.g., the cases of Hungary, Italy, France or Spain).

3.4. Comparison of results with previous studies

The COVID-19 pandemic and the measures taken to contain it had strong economic consequences in most countries worldwide. In the EU MS, there were widespread falls in production and employment levels (OECD, 2020). Besides the effects of restrictions, the collapse of oil prices also hindered the development of the bio-based economy (Chulok, 2021). According to Fritsche et al. (2021) and Galanakis et al. (2022), the effects of the pandemic on the production and distribution of biomass value chains were primarily explained by changes in the demand structure by sector and labour shortages in the supply side, due to mobil-

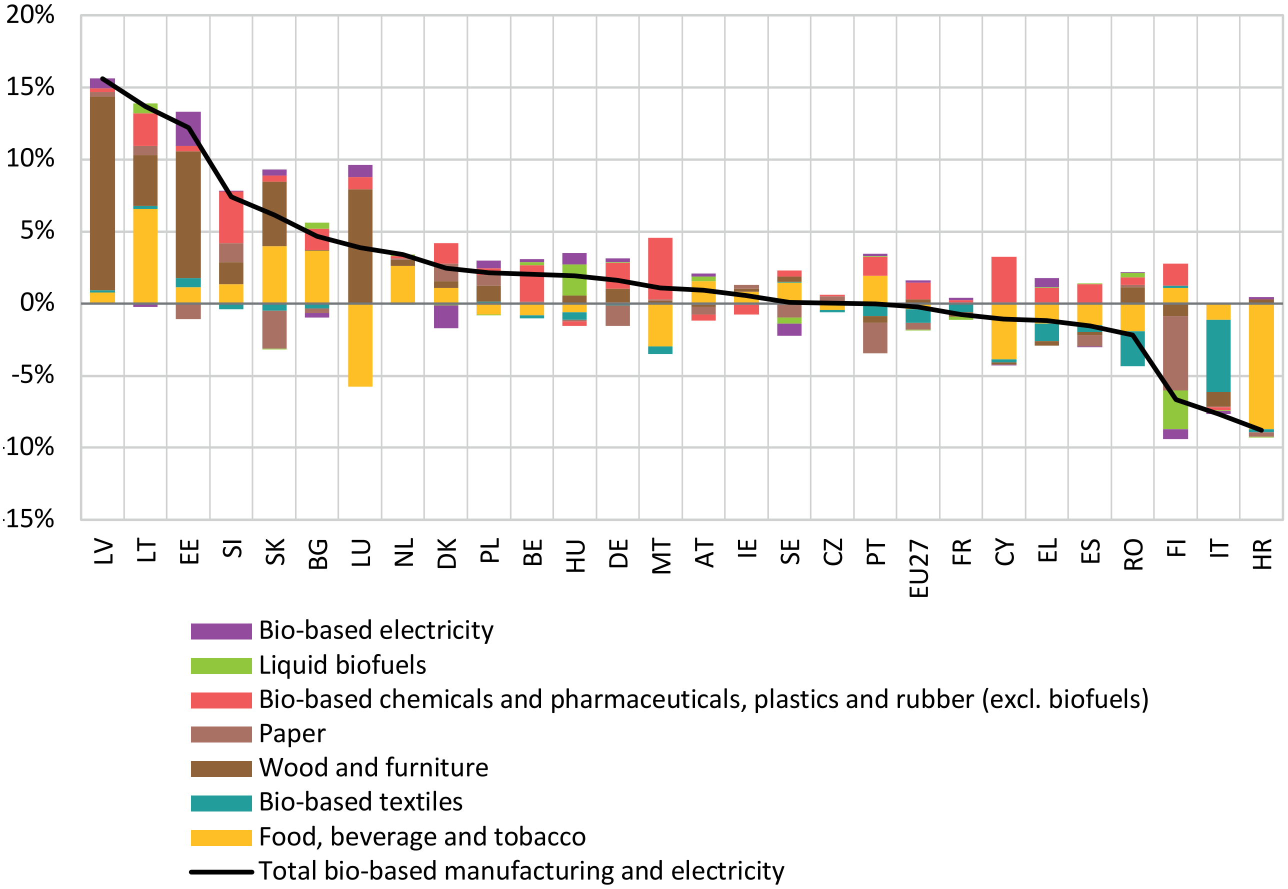

Figure 3. Decomposition of growth in value added in the bio-based manufacturing and electricity sectors (2020). Source: Own elaboration from Lasarte-López et al. (2023b).

ity restrictions. However, an expert survey conducted by Kulisic et al. (2021) revealed that biomass supply chains demonstrated overall resilience to the pandemic shock: no significant changes in the level of aggregated production were identified for the bio-based industries, and potential productivity gains were anticipated. These findings align with the results in Section 3. The decline in value added was less pronounced than that of employment within the bioeconomy, as well as in comparison to GDP.

Galanakis et al. (2022) highlight that the primary and food manufacturing sectors (NACE codes A01, A03, C10 and C11) experienced labour shortages and sharp decreases in demand from food services, which led to income decreases. González-Martinez et al. (2020) anticipated a higher resilience in the agriculture sector, and limited impacts on the agri-food sectors overall. These findings are also consistent with our own analysis, as no breaks in trends are found for the primary sectors across MS, and the decline in employment and value added in the agri-food sectors generally remained below the EU average for the total manufacturing sector.

The textiles industries (C13, C14 and C15) experienced an increase in demand for protective clothing (e.g., masks) (Galanakis et al., 2022). However, according to our analysis, this foreseeable increase did not have a positive impact on the demand of bio-based products, which is affected by the general decline of the sector. This decrease was more pronounced in those countries most affected by the pandemic in the first stage (therefore, implementing stronger restrictions). For instance, the textile sector in Italy registered an important decrease in jobs and value added.

Galanakis et al. (2022) also identified the paper, wood products and furniture industries (C16, C17 and C31) as mainly affected by changes in demand (decrease in wood demand for construction, increase in wood products for home and pallets for distribution). Based on our estimates, the net effect on employment and value added was positive, especially in the main wood-

Table 4. Mean and variance of sector growth by period, and results of the t-Test for Paired Two Sample for Means.

	Employment			Value added		
	Average growth 2014-2019 (Variance)	Change 2020 (Variance)	P-value	Average growth 2014-2019 (Variance)	Change 2020 (Variance)	P-value
Total Bioeconomy	-0.0030 (0.0003)	-0.0078 (0.0005)	0.3277	0.0384 (0.0002)	0.0179 (0.0025)	0.0335**
Agriculture, forestry and fishing	-0.0142 (0.0004)	-0.0123 (0.0013)	0.8012	0.0282 (0.0008)	0.0271 (0.0139)	0.9633
Bio-based manufacturing and electricity	0.0125 (0.0004)	-0.0049 (0.0009)	0.0231**	0.0480 (0.0003)	0.0185 (0.0032)	0.0070***
Food, beverage and tobacco	0.0157 (0.0004)	-0.0133 (0.0006)	0.0001***	0.0417 (0.0005)	0.0066 (0.0029)	0.0044***
Bio-based textiles	-0.0133 (0.0004)	-0.0635 (0.0035)	0.0004***	0.0267 (0.0009)	-0.0806 (0.0179)	0.0008***
Wood and furniture	0.0094 (0.0015)	0.0193 (0.0036)	0.5213	0.0601 (0.0010)	0.0698 (0.0313)	0.8012
Paper	0.0136 (0.0006)	-0.0060 (0.0011)	0.0189**	0.0521 (0.0009)	0.0014 (0.0147)	0.0546*
Bio-based chemicals and pharmaceuticals, plastics and rubber	0.0318 (0.0009)	0.0376 (0.0040)	0.6077	0.0736 (0.0030)	0.1059 (0.0157)	0.1528
Bio-based chemicals and pharmaceuticals, plastics and rubber (excl. biofuels)	0.0339 (0.0009)	0.0379 (0.0050)	0.7581	0.0854 (0.0129)	0.1151 (0.0174)	0.1928
Liquid biofuels	0.0457 (0.0454)	0.4952 (3.2358)	0.2420	0.1477 (0.0793)	0.5688 (3.1269)	0.2406
Bio-based electricity	0.1429 (0.0300)	0.1352 (0.0866)	0.9169	0.1324 (0.0351)	-0.1690 (2.0624)	0.3203
Total economy	0.0168 (0.0001)	-0.0120 (0.0002)	<0.0001***	0.0466 (0.0008)	-0.0251 (0.0014)	<0.0001***
Total manufacturing and electricity sectors	0.0119 (0.0001)	-0.0216 (0.0003)	≤0.0001***	0.0539 (0.0026)	-0.0368 (0.0027)	<0.0001***

Note: The null hypothesis is rejected with a significance level of 10% (*), 5% (**) or 1% (***).
Source: Own elaboration from Lasarte-López et al. (2023b).

producing economies (Nordic and Baltic countries). The increase in the price level of wood as commodity is behind this growth, which conditioned the performance of their overall bioeconomies.

The bio-based chemicals and pharmaceuticals, plastics and rubber industries sectors (C20, C21 and C22) witnessed a generalised increase in demand for products such as ethanol and alcohols (for disinfectants). An increased demand for bio-based plastics is also identified, given the higher usage of one-single use plastics products (Galanakis et al., 2022, Fritsche et al., 2021, Woźniak and Tyczewska, 2021). These facts, besides the crucial role of the pharmaceuticals sector during the pandemic, are consistent with the superior performance of these sectors in the EU and most MS in 2020.

4. CONCLUDING REMARKS

The economic consequences of the major events occurring since 2020 (the COVID-19 pandemic and, more recently, the Russian invasion of Ukraine war) underlined the potential role of the bioeconomy not only to achieve environmental sustainability but also socio-economic stability. Our results shows a higher level of resilience of the EU bioeconomy compared to the overall economy in the initial stage of the pandemic. While employment in the bioeconomy declined similarly to the EU average in 2020 (-1.7% vs -1.4%), value added fell substantially below (-0.4% vs -4.0%). As the primary sectors remained stable, this greater resilience was driven by some bio-based sectors such as chemicals, pharmaceuticals, bioelectricity and wood products, which partially offset the negative impact on more traditional biomass-processing sectors (mainly food, beverages, tobacco, and bio-based textiles).

At the MS level, the bioeconomy performance was quite heterogeneous, although a potential effect of the country overall economic performance was identified. Furthermore, the disruptions observed in traditional biomass-transforming sectors (food, textiles and paper) were generalised across countries, while bio-based chemicals and bioelectricity kept their positive growth trends in most countries. These findings suggest that the sectoral composition of the bioeconomy could also have an impact on its overall performance at the country level, negatively affecting those countries with higher specialization in the aforementioned traditional biomass-transforming sectors.

The lower relative impact of the pandemic shock on the bioeconomy provides empirical evidence for the academic literature and the policy documents supporting the need for the EU to reinforce the bio-based value chains (e.g. Farcas et al. 2020, Galanakis et al. 2022; European Commission, 2018, 2022), so as to fulfil sustainability goals while enhancing socioeconomic resilience to economic shocks and disruptions in the global value chains.

These insights are subject to some limitations, caused by the data availability. For 2021 onward, the available information is still scarce, due to long publication delays of some of the required data sources (14 months in the case of the PRODCOM survey, needed for the product-level bio-based shares; and 21 months for Structural Business Statistics, the main data source for employment and value added in the bio-based manufacturing and electricity sectors). As the year 2020 is the most recent data point available in our dataset, it is still not possible to analyse the full impact of the pandemic on the bioeconomy (i.e., including the recovery in 2021) nor of the Russian invasion of Ukraine starting in 2022. An additional limitation is that the current composition on the jobs and growth indicators for the bioeconomy only considers biomass-producing and transforming sectors. The bioeconomy services are foreseen to be integrated in the future, following the methodology from Ronzon et al. (2022b).

These limitations also pave the way for future research. The in-depth analysis of the aforementioned events in 2021 and 2022 would be useful to further support (or not) the hypothesis of a stronger resilience of at least some bioeconomy sectors to economic shocks. The integration of services into the said indicators would also provide an opportunity to analyse the performance of the tertiary sector in comparison to biomass-producing and transforming sectors, as well as their non-bio-based counterparts.

FUNDING

This project received funding from an administrative arrangement between the Directorate-General for Research and Innovation (DG RTD) and the Joint Research Centre (JRC).

ACKNOWLEDGEMENTS

The authors would like to thank Adrian Leip (DG RTD) and the colleagues from the Knowledge Centre of the Bioeconomy for their feedback on the manuscript, and Saulius Tamosiunas for technical support.

REFERENCES

Chulok, A. (2021). Bioeconomy in the Twenty-First Century: Global Trends Analysis Perspective. Koukios, E., Sacio- Szymańska, A. (eds). Bio# Futures: Foreseeing and Exploring the Bioeconomy. Cham: Springer International Publishing. https://doi.org/10.1007/978-3-030-64969-2_25

European Commission. (2018). Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the committee of the Regions. A sustainable bioeconomy for Europe: strengthening the connection between economy, society and the environment. Updated Bioeconomy Strategy. COM(2018) 673 final. Publications Office of the European Union, 2018. https://doi.org/10.2777/792130 .

European Commission (2022). Report from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. European bioeconomy policy – Stocktaking and future developments. COM(2022) 283 final. Publications Office of the European Union, 2022. https://doi.org/10.2777/997651

Farcas, A. C., Galanakis, C. M., Socaciu, C., Pop, O. L., Tibulca, D., Paucean, A., … & Socaci, S. A. (2020). Food Security during the Pandemic and the Importance of the Bioeconomy in the New Era. Sustainability, 13(1): 150. https://doi.org/10.3390/su13010150

Fritsche, U., Brunori, G., Chiaramonti, D., Galanakis, C.M., Matthews, R. & Panoutsou, C. (2021). Future transitions for the Bioeconomy towards Sustainable Development and a Climate-Neutral Economy – Bioeconomy Opportunities for a green recovery and enhanced system resilience. Borzacchiello, M. T., Sanchez Lopez, J. & Avraamides, M. (eds). Publications Office of the European Union, Luxembourg. https://doi.org/10.2760/831176,

Galanakis, C. M., Brunori, G., Chiaramonti, D., Matthews, R., Panoutsou, C., & Fritsche, U. R. (2022). Bioeconomy and green recovery in a post-COVID-19 era. Science of The Total Environment, 808: 152180. https://doi.org/10.1016/j.scitotenv.2021.152180

González-Martinez, A. R., Jongeneel, R., Salamon, P., Zezza, A., De Maria, F., & Potori, N. (2021). The COVID-19 pandemic and the EU agri-food sector: Member State impacts and recovery pathways. Studies in Agricultural Economics, 123(3): 153-158. https://doi.org/ 10.7896/j.2215

Kulisic, B., Gagnon, B., Schweinle, J., Van Holsbeeck, S., Brown, M., Simurina, J., … & McDonald, H. (2021). The Contributions of Biomass Supply for Bioenergy in the Post-COVID-19 Recovery. Energies, 14(24): 8415. https://doi.org/10.3390/en14248415

Lasarte-Lopez, J., M`barek, R., Ronzon, T. & Tamosiunas, S., (2023a). EU Bioeconomy Monitoring System indicators update. Jobs and value added in the bioeconomy 2020, Publications Office of the European Union, Luxembourg, 2023. https://doi.org/10.2760/761583

Lasarte-López, J., Ronzon, T., M'barek, R., Carus, M., & Tamošiūnas, S. (2023b). Jobs and wealth in the EU bioeconomy - JRC - Bioeconomics. European Commission, Joint Research Centre (JRC) [Dataset] PID: http://data.europa.eu/89h/7d7d5481-2d02-4b36-8e79-697b04fa4278

Mubareka, S., Giuntoli, J., Sanchez Lopez, J., Lasarte Lopez, J., M'barek, R., Ronzon, T., … & Avraamides, M. (2023). Trends in the EU bioeconomy. Publications Office of the European Union, Luxembourg, 2023. doi10.2760/835046.

OECD. (2020). Building back better: a sustainable, resilient recovery after COVID-19. OECD Publishing. https://www.oecd.org/coronavirus/policy-responses/building-back-better-a-sustainable-resilient-recovery-after-covid-19-52b869f5/#biblio-d1e973

Ozdemir, D., Sharma, M., Dhir, A., & Daim, T. (2022). Supply chain resilience during the COVID-19 pandemic. Technology in Society, 68: 101847. https://doi.org/10.1016/j.techsoc.2021.101847

Ramanauske, N., Balezentis, T., & Streimikiene, D. (2023). Biomass use and its implications for bioeconomy development: A resource efficiency perspective for the European countries. Technological Forecasting and Social Change, 193: 122628. https://doi.org/10.1016/j.techfore.2023.122628

Ronzon, T., Piotrowski, S., M'Barek, R., & Carus, M. (2017). A systematic approach to understanding and quantifying the EU's bioeconomy. Bio-based and Applied Economics Journal, 6(1): 1-17. https://doi.org/10.22004/ag.econ.276283

Ronzon, T., & M'Barek, R. (2018). Socioeconomic indicators to monitor the EU's bioeconomy in transition. Sustainability, 10(6): 1745. https://doi.org/10.3390/su10061745

Ronzon, T., Piotrowski, S., Tamosiunas, S., Dammer, L., Carus, M., & M'barek, R. (2020). Developments of economic growth and employment in bioeconomy sectors across the EU. Sustainability, 12(11): 4507. https://doi.org/10.3390/su12114507

Ronzon, T., Iost, S., & Philippidis, G. (2022). An output-based measurement of EU bioeconomy services: Marrying statistics with policy insight. Structural Change and Economic Dynamics, 60: 290-301. https://doi.org/10.1016/j.strueco.2021.10.005

Woźniak, E., & Tyczewska, A. (2021). Bioeconomy during the COVID-19 and perspectives for the post-pandemic world: Example from EU. EFB Bioeconomy Journal, 1: 100013. https://doi.org/10.1016/j.bioeco.2021.100013