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Decomposition analysis of bioresources: Implementing a competitive and sustainable bioeconomy strategy in the Baltic Sea Region

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ABSTRACT

Bioeconomy development has become one of the new trends in policy design and research. This study looks at biotic resource extraction in the Baltic Sea region countries providing detailed country by country analyses of factors affecting changes in resource extraction. The study is based on the index decomposition analysis including factors related to bioeconomy strategies such as the population, share of people employed in bioeconomy, labour intensity, biotic resource extraction productivity, share of bioeconomy, export intensity, and share of bioresource export. The main factors increasing biotic resource extraction were the growth in labour material intensity, biotic extraction productivity and export intensity. However, changes in these factors differed significantly among the countries studied and had different trajectories over time depending on overall performance of the economy. These differences should be taken into account when developing national bioeconomy strategies.

1. Introduction

Bioeconomy is one of the main strategies implemented by the European Union (EU) (Sanz-Hernández et al., 2019). The bioeconomy development in the EU begun in 2012 when “Innovating for Sustainable Growth: A Bioeconomy for Europe” was launched (Commission, 2012). In the renewed EU bioeconomy strategy presented in 2018 (EU, 2018) the concepts of sustainable and circular bioeconomy were highlighted. This strategy has contributed to the implementation of the Sustainable Development Goals and the Paris Climate Agreement targets (Grossauer and Stoeglehner, 2020; Hamelin et al., 2019; Ronzon and Sanjuán, 2020; Wohlfahrt et al., 2019). In recent literature, the role bioeconomy in ensuring sustainable development has been discussed comprehensively (D’Amato et al., 2017, 2019; Koukios et al., 2018; Liobikiene et al., 2019; Loiseau et al., 2016; Ramcilovic-Suominen and Pülzl, 2018). Other authors have highlighted the bioeconomy role in circular economy (D’Amato et al., 2020; Giampietro, 2019; Hamelin et al., 2019; Karan et al., 2019; Näyhä, 2019; Stegmann et al., 2020; Ubando et al., 2020). Furthermore, implementation of bioeconomy is important in seeking green growth and climate change mitigation (Aguilar et al., 2018; Baležentis et al., 2019; Bell et al., 2018; Budzinski et al., 2017; de Besi and McCormick, 2015; Devaney and Henchion, 2018; Ingrao et al., 2018; Loiseau et al., 2016; Pitkänen et al., 2016).

Bioeconomy is also closely related to the questions of land use and land-use policy (Choi and Entenmann, 2019; Fradj et al., 2020). Bioeconomy growth and decarbonisation can increase the global demand and competition for productive land to satisfy the increasing supply of food, energy and materials from biotic resources (Bringezu et al., 2014). To minimise these negative impacts systemic bioeconomy monitoring system is necessary (O’Brien et al., 2017) which would cover different social, economic environmental aspects of bioeconomy (D’Adamo et al., 2020).

Authors analyzing the trends of bioeconomy sector usually considered economic and social indicators such as the size or value-added (Efken et al., 2016; Heijman, 2016; Scarlat et al., 2015; Schütte, 2018), investments in research and patents (Arujanan and Singaram, 2018; M’barek et al., 2014; Philp, 2018; Scarlat et al., 2015; Woźniak and Twardowski, 2018), employment rate (Arujanan and Singaram, 2018; Efken et al., 2016; Guo and Song, 2019; Robert et al., 2020; Scarlat et al., 2015; Schütte, 2018), and labour productivity (Muizniece et al., 2016). From environmental indicators, environmental footprints were studied comprehensively as well (Brizga et al., 2019a; Bruckner et al., 2019; Egenolf and Bringezu, 2019; Hubacek and Feng, 2016; Liobikiene et al., 2020; O’Brien et al., 2015, 2014, 2017). Other authors analysed bioresource (biomass) trends (Brizga et al., 2019a; Budzinski et al., 2017; Hamelin et al., 2019; Kalt et al., 2016; Scarlat et al., 2015).

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Sustainable use of bioresource is the main principle of sustainable bioeconomy (Blumberga et al., 2017; Brizga et al., 2019a; Cristóbal et al., 2016; Juerges and Hansjürgens, 2018; Muizniece et al., 2016; Sasson and Malpica, 2018; Scarlat et al., 2015). Bioresources are renewable resources, however, the supply is not endless. In the EU, bioresources are limited, and the growth of this resource consumption could create biomass scarcity (Aguilar et al., 2018; Borgström, 2018; Sleenhoff et al., 2015). Therefore, implementation of the bioeconomy strategy could be expected to ensure the sustainability of bioresource extraction.

Brizga (2019a) in the recent analysis analyzed the trends of bioresource use in the Baltic Sea Region (BSR), which is one of the leaders in the implementation of the bioeconomy strategy. However, to the best of our knowledge, none of the previous researchers analysed the drivers behind the bioresource extraction. Even though bioeconomy strategies significantly differ among the countries of BSR, the following aspects are common: the increase of competitiveness, value-added, export, employment rate and sustainable production of biomass. Therefore, in this paper by encompassing bioeconomy strategy components and applying decomposition analysis, the main drivers of changes in bioresource extraction in BSR countries were evaluated. This paper has revealed how the growth of value-added, the employment rate in the bioeconomy sector and bioresource productivity influenced bioresource extraction and bioeconomy development. It is a new topic in bioeconomy studies. Furthermore, in this paper the results of the decomposition analyses were studied in several time-periods depending on the bioeconomy policy development: growth period (period of economic growth and before preparation of bioeconomy strategy), transition period (the period of bioeconomy strategy preparation) and strategy period (the period during bioeconomy strategy implementation and until its renewal). This analysis revealed whether the changes in the extraction of bioresource and main determinants differed before and after the launch of bioeconomy strategy.

2. Literature review

2.1. The components of bioeconomy strategies and changes in bioresources in BSR

Referring to the definition of bioeconomy, namely, that it encompasses all economic activities related to the biological products and process (Cristóbal et al., 2016; Loiseau et al., 2016; Sasson and Malpica, 2018), the usage of bioresource is the driving force of bioeconomy. However, according to the strong sustainability approach, the development of bioeconomy should be considered without exceeding the planetary boundaries and ecological thresholds (Liobikiene et al., 2019). Therefore, bioresource production is the main aspects of bioeconomy. In the literature, the authors usually analysed the impact of technologies or climatic conditions on bioresource (biomass) production (Ledger et al., 2011; Zhang et al., 2019a, 2019b, 2019c). Meanwhile, considering economic and social indicators, authors showed that biomass usage stimulated economic growth (Aydin, 2019; Bilgili et al., 2017; Bilgili and Ozturk, 2015; Ozturk and Bilgili, 2015). Silalertruksa et al. (2012) found that the development of bioresources contributed to the growth of employment rate. However, to the best of our knowledge, none of the researchers analysed the impact of bioeconomy development on changes in bioresource extraction.

BSR bioeconomy programme (2018) was presented in the same year as a revision of the EU bioeconomy strategy, i.e. in 2018. The compatibility between economy and environment is the main aspect of the BSR bioeconomy strategy which is based on 4 main pillars: i) competitive bio-based industries, ii) inclusive economic development, iii) sustainable resource management, and iv) resilient and diverse ecosystems. Considering individual BSR countries, Lithuania and Estonia have not adopted this strategy yet. In the remaining countries, the strategy has been adopted in national bioeconomy strategies (Germany, Finland, Latvia) or integrated into other policy documents (Sweden, Poland and Denmark).

Brizga et al. (2019a) analyzing the environmental aspects of bioeconomy implementation showed a great difference among BSR in terms of production-based bioresource. It could depend on the bioeconomy development level, the share of agriculture and forest land. Furthermore, different changes were observed in bioresource from 2011 to 2015. However, the factors which influenced these changes were not analysed, particularly analyzing the different periods - before, during and after the development of the bioeconomy strategy. Therefore, by applying the decomposition analysis in this paper the impact of bioeconomy strategy components (growth of value-added, the employment rate in the bioeconomy sector and bioresource productivity) on bioresource extraction in BSR countries were analysed.

2.2. Decomposition analysis approach

Decomposition analysis is vastly applied to analyse the factors of energy consumption or carbon emissions (Huang et al., 2019). Considering the natural resource, decomposition analysis has been applied to explore the determinants of raw material consumption (Plank et al., 2018), water resources (Feng et al., 2017; Sun and Hsu, 2019; Zhang et al., 2019a, 2019b, 2019c; Yang and Lahr, 2019), material use (Wang et al., 2017a, 2017b; Baninla et al., 2020), metal consumption (Song et al., 2019). However, to the best of our knowledge, none of the researchers applied this method to the analysis of the factors of bioresource extraction.

There are two prevailing methods used for time series decomposition, namely, structural decomposition analysis (SDA) and index decomposition analysis (IDA) (Wang et al., 2017a, 2017b). Comparison between the two can be found in Hoekstra and van den Bergh (2003) and Wang et al. (2017a, 2017b). SDA is based on the input-output model and is mostly used to analyze energy savings or emission abatements and aggregate intensity (Brizga et al., 2014; Yang and Lahr, 2019; Wang et al., 2017a, 2017b). Rose and Casler (1996) provided a review on its theoretical basis and main features.

The IDA employs the index number theory to decomposition, and its advantage is that it can be used to study any available data at any level of aggregation (Ma and Stern, 2008) and is less data-intensive, but also less detailed since indirect inter-industry effects cannot be reported (Wood and Lenzen, 2009).

One of the simplest IDA decompositions is the so-called Kaya identity, which quantifies the drivers behind changes in energy use or emissions - energy intensity (energy use per unit of GDP), per capita GDP and population (Kaya, 1989). Other authors expanded these theories by including other determinants as the fuel mix, industrialisation (Brizga et al., 2013; Zhang et al., 2019a, 2019b, 2019c; Zheng et al., 2019). Liobikienė et al. (2016) used the IDA to analyze the components of the EU 2020 strategy to determine the carbon emissions in the Baltic States. Therefore, these analyses reveal that the decomposition analysis method could be applied to evaluate the determinants of extraction of bioresource in BSR countries.

3. Methods and materials

The purpose of the present decomposition analysis is to identify and analyze how the changes in biotic resource extraction (BRE) have been brought about by the changes in several independent factors. In this study, we use additive and multiplicative forms of the IDA to generate results from different perspectives and enrich the analysis and discussions. The multiplicative form illustrates the relative aspect for each factor in driving the changes in biotic resource extraction, but the additive form provides the measure of magnitude of emissions changes driven by decomposed factors.

In this paper, by applying the decomposition analysis, we expressed national BRE as an extended Kaya identity (Kaya, 1989) by using the following equation Eqn 1:

$$BRE = POPx\frac{BEE}{POP}x\frac{BRE}{BEE}x\frac{GDP}{BRE}x\frac{TVAbio}{GDP}x\frac{BREx}{TVAbio}x\frac{BRE}{BREx} \quad (1)$$

where *BRE* is total national biotic resource extraction in thousand tons, *POP* represents the total national population, BEE stands for the number of people employed in bioeconomy, GDP is the total national gross domestic product in the given year in euros, TVA_{agro} is the total value-added by bioeconomy in EUR, but *BREx* is national export of biotic resources.

In multiplicative decomposition, the relative change of aggregate BRE between year *0* and *t* can be decomposed by the ratio of each factor, as shown in Eqn 2:

$$BRE = BRE_t / BRE_0 = P \times E \times R \times I \times A \times X \times S \quad (2)$$

where changes in BRE between base year 0 and target year t can be represented by quantifying the contributions from changes in seven different factors:

- P – the population effect;
- E = BEE/POP (%) - the share of people employed in the bioeconomy;
- R = BRE/BEE (labour material intensity – t/cap) – biotic resource extraction per bio-economy employee;
- I = GDP/BRE (biotic resource extraction productivity – €/t) – national GDP per ton of biotic resources extracted;
- A = TVA_{bio}/GDP (share of bioeconomy - €/€) – TVA of bioeconomy per unit of total national GDP;
- X = BREx/TVA_{bio} (export intensity – t/€) – the amount of bio-resources exported per unit of TVA of bioeconomy;
- S = BRE/BREx (inverted share of biotic resource export – t/t) – inverted the share of biotic resource export in BRE.

The multiple of the relative changes in each variable should equal the total relative change of the aggregate.

In additive decomposition, the absolute change of BRE between year *0* and *t* can be decomposed by the difference of each factor, as shown in Eq. (3):

$$\Delta BRE = BRE_t - BRE_0 = \Delta P + \Delta E + \Delta I + \Delta R + \Delta A + \Delta X + \Delta S \quad (3)$$

The sum of the absolute changes of each variable should equal the total absolute change of the aggregate.

This research is based on data extracted from Eurostat databases (Eurostat online data codes provided in square brackets):

- BRE – the total amount of biotic resources extracted by resident units from the natural environment for further processing in the economy [env_ac_mfa] (Accessed on 04 February 2020);
- Population – the number of persons having their usual residence in the respective country on 1 January of the respective year [TPS00001] (Accessed on 04 February 2020);
- BEE – annual employment by bio-economy sectors (A01, A02, and A03) [lfsa_egan22d] (Accessed on 04 February 2020);
- GDP - chain-linked volumes (2015) of GDP in million euro [nama_10_gdp] (Accessed on 04 February 2020);
- GVA_{bio} – gross value-added of agriculture, forestry and fishing in current prices, million euro [naida_10_a10] (Accessed on 04 February 2020);
- BREx – exports of biotic resources in their simple mass weight [env_ac_mfa] (Accessed on 04 February 2020).

In this paper, we define the scope of the bioeconomy covering the time period of 2000–2018 and the following sectors: crop and animal production, hunting and related service activities (A01), forestry and logging (A02), and fishing and aquaculture (A03). Therefore, evaluating the changes in biotic resource extraction the traditional land-use sectors were covered. Nevertheless, it should be recognised that bioresources are also used by other industrial sectors, e.g. manufacture of food, beverages and tobacco bioenergy (C10, C11, C12), biochemicals (C20, C21, C22) (M'barek et al., 2018), but the land-use footprint for these sectors is marginal (Brizga et al., 2019b) and thus excluded from this study. However, it is expected these sectors will grow with the development of bioeconomy and thus should be included in further research analyzing the impacts of bioeconomy.

We also performed decomposition analysis dividing this period as follows: 2000–2007 – growth period (period of economic growth and before bioeconomy strategy preparation), 2008–2012 – transition period (the period of bioeconomy strategy preparation) and 2013–2018 – strategy period (the period after bioeconomy strategy implementation and until its renewal). These periods encompass durations before, during and after the preparation of bioenergy strategy.

4. Results and discussion

4.1. Changes in biotic resource extraction and main determinants in all the periods analysed

Results of the additive decomposition analysis in Fig. 1 have shown an increase in the biotic resource extraction in BSR countries by 101.4 million tons, or 17%, from 2000 to 2018. The main driving forces behind the increase was growth in labour material intensity (R). Other factors positively driving biotic resource extraction were biotic resource extraction productivity (I) and export intensity (X). These results revealed that factors related to extraction intensity, which, in turn, is related to the export contributed to the growth of biotic resource extraction the most. Therefore, the decrease in export intensity is the main aim when seeking a decrease in the growth of bioresource extraction in BSR countries.

Table 1 shows that changes in biotic resource extraction between 2000 and 2018 varied strongly among the BSR countries. The results have shown 3 groups of countries (see Fig. 2): 1) Estonia and Latvia experienced moderate increase in biotic resource extraction, but the strongest increase in biotic resource extraction productivity (I) and inverse share of bioeconomy (A); 2) Lithuania and Poland, on the other hand, demonstrated the highest increase in BRE, as well as the highest increase in labour (R) and export intensity (X) and decreasing share of people employed in bioeconomy (E) as well as the inverse share of biotic resources exported (S); 3) Scandinavian countries and Germany had the slowest increase in BRE and were the only countries where the population (P) was increasing, demonstrating the slowest increase in labour intensity (R) and biotic extraction productivity (I).

The decomposition analysis and analysis of the main determinants of changes in biotic resource extraction during all the periods analysed have shown that the extraction increased the most in Lithuania and Poland. In these countries, labour (R) and bioresource export (X) intensity contributed to the increase in biotic resource extraction the most. This could be linked to the fact that the extraction of bioresource in these countries grew faster than the rate of employment and bioresource extraction prevailed over production or recycling. The intensity rate of exported bioresources (X) was also driving biotic resource extraction upwards. This suggests that the most attention should be paid not only to the way of enhancement of the export of biotic resources but also to the way of increase of resource productivity. Meanwhile, the decrease in the share of people employed in the bioeconomy (E) and the decreasing share of biotic resource export (S) were the main forces driving biotic resource extraction downwards. The higher the share of bioresources exported, the greater the bioresource extraction ($R^2 = 0.54$). Therefore, promotion of export could have a negative impact on the sustainability of bioeconomy. The major focus should be placed on the productivity increase of export and enhancement of the price for the bioresource to be competitive in all the EU countries. Meanwhile, the increased employment rate in bioeconomy sector, particularly in production and recycling sector of bioeconomy, had positive influence on the sustainability

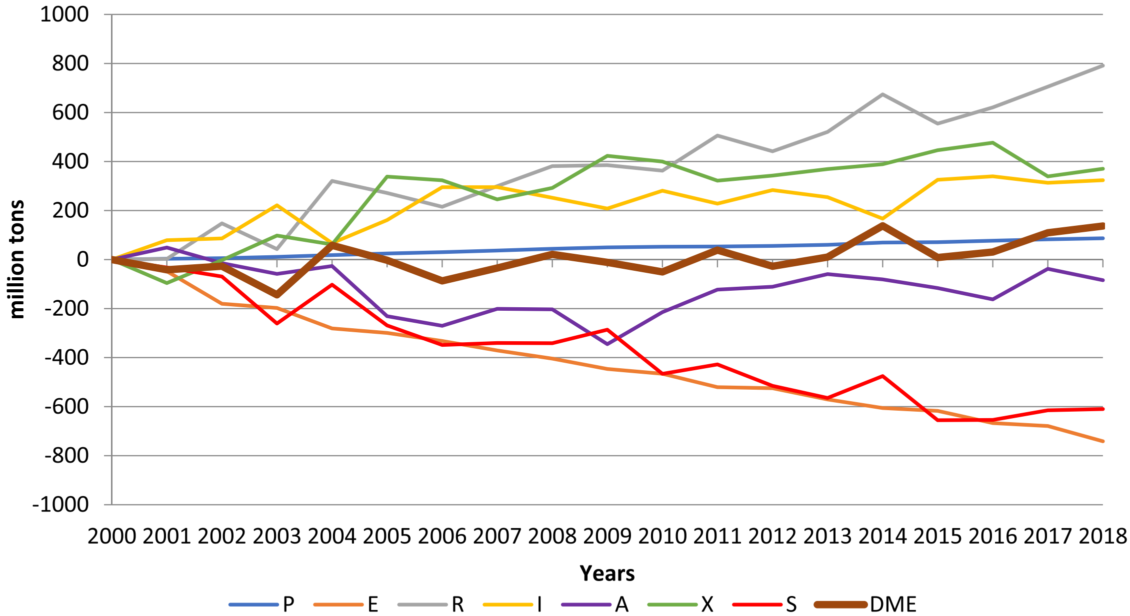

Fig. 1. Additive decomposition analysis of biotic resource extraction (in million tons) in the BSR countries in the period 2000–2018.

Table 1
Changes in biotic resource extraction and driving forces in the BSR countries in the period 2000–2018.

Country	P	E	R	I	A	X	S	BRE
Denmark	1.08	0.66	1.30	0.86	0.65	1.54	0.75	0.93
Germany	1.01	0.91	1.27	1.05	0.97	1.04	0.92	1.16
Estonia	0.94	0.61	1.95	2.58	1.54	0.49	0.80	1.12
Latvia	0.81	0.65	2.06	2.52	1.45	0.75	0.53	1.09
Lithuania	0.80	0.55	3.13	1.36	0.93	2.14	0.34	1.38
Poland	0.99	0.62	2.04	1.45	0.93	2.40	0.29	1.25
Finland	1.07	0.67	1.58	1.26	1.11	0.75	1.06	1.13
Sweden	1.14	0.73	1.38	1.01	0.79	0.96	1.03	1.16
Average	0.98	0.68	1.84	1.51	1.05	1.26	0.71	1.15
Standard deviation	0.12	0.11	0.62	0.67	0.31	0.70	0.30	0.13
Coeficient of Variation	0.13	0.16	0.33	0.44	0.30	0.55	0.42	0.11

Note: Green colour represents the decreasing, and red colour – the increasing factors; colour intensity increases gradually as the value of the factor moves away from 1.

of bioeconomy.

In Estonia and Latvia, weaker increase of bioresource extraction was observed, and the productivity growth of bioresource extraction (I) was the main factor driving bioresource extraction upwards. Therefore, despite biotic resource productivity growth (I), bioresource extraction continued to increase rapidly. It is not a positive pattern, as the EU bioeconomy strategy mainly focused on the promotion of productivity. Therefore, it shows that in the countries considered, productivity did not achieve the level at which the decrease in bioresource production begins. Furthermore, along with labour intensity (R), the increased share of the bioeconomy sector (A) also contributed to the growth of bioresource extraction, and the impact was positive only in Estonia and Latvia. Therefore, in these countries, the greatest attention should be paid to the ways of development of the bioeconomy with less bioresource extraction by increasing the value-added and implementing circular economy principles by creating closed-loop systems, minimising the use of bioresources, and eliminating waste generation (D'Amato et al., 2020; Giampietro, 2019; Hamelin et al., 2019; Karan et al., 2019; Näyhä, 2019; Stegmann et al., 2020; Ubando et al., 2020). Meanwhile, the reduction of export intensity (X) did not offset the growth of extraction for production level and share of exported resources.

In Germany and Finland, the growth in labour intensity (R) was the main contributor to the increase in bioresource extraction. The impact of other factors was less significant. Meanwhile, in Denmark, a decrease in bioresource extraction was observed. The increase of export intensity (X), labour intensity (R) and the population (P) was offset by other factors. The decrease in bioresource extraction was linked to the decrease in the share of people employed in bioeconomy (E), the share of bioeconomy sector (A), and share of export (S). Furthermore, the decrease in bioresource productivity (I) also contributed to the decrease of biotic resource extraction. It shows the problem that the fast growth of bioresource extraction could emerge in Denmark in the case of a more developed bioeconomy sector.

However, the main factors driving the biotic resource extraction downwards were the decreasing share of people employed in the bioeconomy (E) and decreasing share of bioresources exported (S). 3 groups of countries can be identified here as well (Fig. 3). Latvia, Lithuania and Poland experienced the strongest decrease in both parameters; Estonia and Denmark were above the regional average for the share of bioresource export; for Finland, Sweden and Germany, these parameters

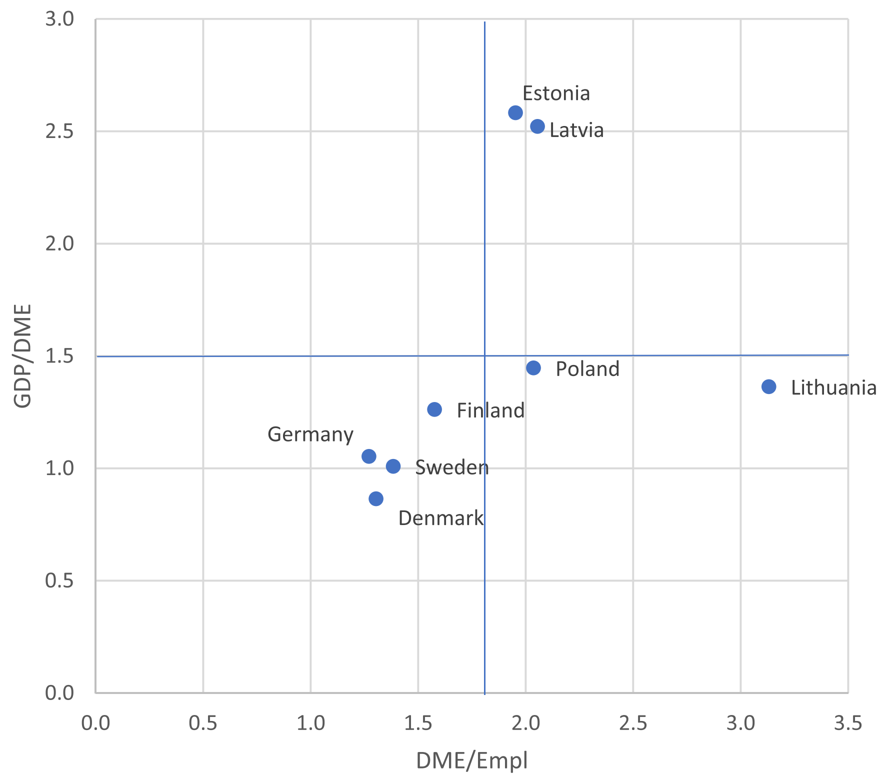

Fig. 2. Changes in material labour intensity (R) and biotic resource extraction productivity (I) in the BSR countries in the period 2000–2018.

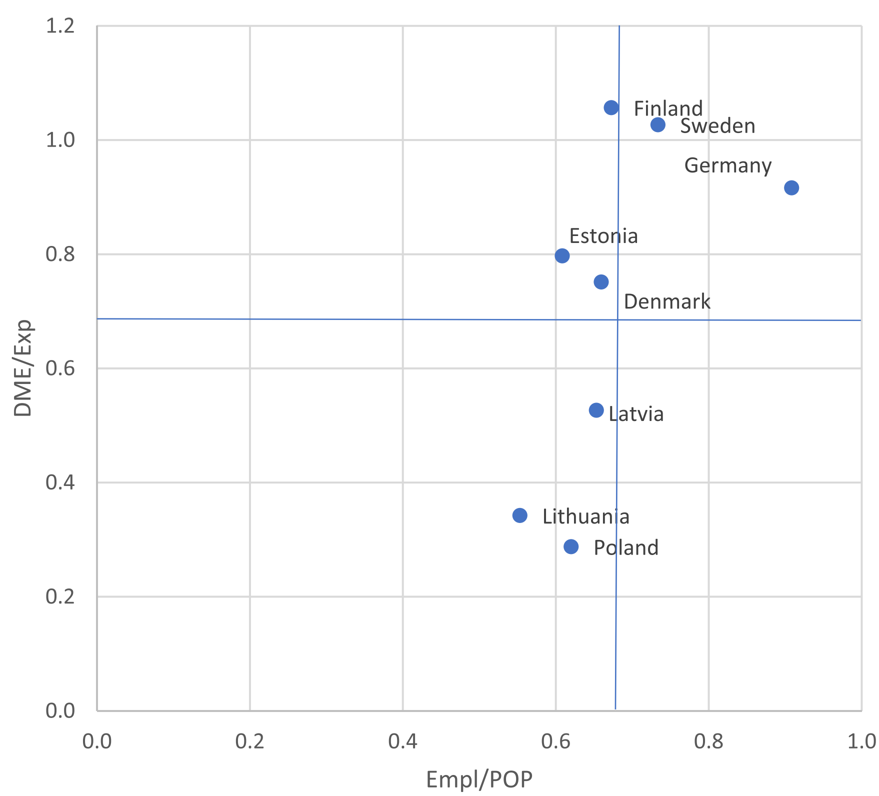

Fig. 3. Changes in the share of people employed in the bioeconomy (E) and share of bioresources exported (S) in the BSR countries in the period 2000–2018.

played a minor role in affecting bioresource extraction: for Finland and Sweden, the share of bioresources exported (S) did not decrease, but in case of Finland, export intensity (X) and, for Sweden, decreasing share of bioeconomy (A) were driving the bioresource extraction down.

4.2. Changes in biotic resource extraction and main determinants in the growth period (2000–2007)

Considering the changes in biotic resource extraction and the main determinants during economic growth period before the preparation of the EU bioeconomy strategy, a decrease in bioresource extraction was observed in Estonia, Denmark, and Latvia. The biggest decrease in biotic resource extraction (by 35%) was in Estonia. The growth of bioresource productivity (I), decrease in export intensity (X), and the share of exported bioresource (S) were the main drivers behind the decrease in extraction in Estonia and Latvia. The share of bioeconomy growth (A) was offset by the effectively used bioresource. In Denmark, to the contrary, the biotic resource extraction decrease was largely due to the decrease of the bioeconomy share in the economy despite the increase in export intensity (X) Table 2. The decrease in the bioresource productivity level and the influence of the reduction of extraction are considered to be negative developments. It could be a limiting factor for further development of bioeconomy sector in Denmark if the circle bioeconomy principles are not considered.

In the remaining BSR countries, increase in bioresource extraction was observed. The most significant increase was registered in Lithuania and Sweden, 13% and 16% respectively. The increase in biotic resource extraction was largely caused by an increase in labour (R) and export intensity (X). Therefore, it shows that, in these countries, the problem was the growth of exported bioresources. The employment rate seems to not have been centred on production. Meanwhile, the biotic resource extraction per bio-economy employee increased (R), but the largest share was exported to other countries. The decrease in the bioeconomy share was not offset by other factors. Furthermore, the growth of bioresource productivity also did not influence the decrease in biotic resource extraction in Lithuania and was assessed negatively. Meanwhile, in Sweden, the decrease in bioresource productivity (I) led to increase in the extraction level.

In Finland, Poland and Germany, bioresource extraction increased slower during the period of economic growth. The main determinants of these changes were the increase in labour intensity (R), bioresource productivity (I) and export intensity (X) in Finland and Poland. Meanwhile, in Germany, only the growth of export intensity (X) and labour intensity (R) contributed to the increased extraction. However, the decrease in the share of the bioeconomy sector and bioresource productivity (I) did not offset the impact of other factors, in particular, the growth of bioresource export share (S).

4.3. Changes in biotic resource extraction and main determinants in the transition period (2008–2012)

During the period of development of bioeconomy strategies, almost all BSR countries (except for Finland) demonstrated an increase in bioresource extraction. At the beginning of this period, all of the BSR economies (except for Poland) experienced economic recession followed by the economic restructuring period which increased biotic resource extraction in the region. The highest increase was in the Baltic States – Estonia, Latvia and Lithuania, where biotic resource extraction increased by 32%, 29% and 18%, respectively. The main drivers behind the increase were increasing labour (R) and export (X) intensity and increasing share of bioeconomy (A). During this period, Estonia and Latvia intensified the export of bioresources, and the decrease in bioresource productivity (I) also influenced the increase in bioresource extraction. Meanwhile in Lithuania, the increase in bioresource productivity did not offset other factors, in particular, the growth of bioeconomy sector share in the economy.

In Germany, Poland, Denmark and Sweden, the rate of increase in biotic resource extraction was slower during this period. However, the drivers of these changes were different among these countries. As suggested by previous results, in Denmark, during the economic growth, extraction decreased particularly due to the decreased bioeconomy share in the economy. Meanwhile, in this period, the growth of the share of bioeconomy (A) particularly contributed to the growth of biotic extraction. A significant decrease in export intensity (X) did not offset the growth of bioeconomy sector. Furthermore, the increase in bioresource productivity (I) also contributed to the increase in extraction. Thus, the productivity increase could not halt the growth of bioresource extraction. In Germany and Sweden, despite the decrease in the share of export (S) and export intensity (X), the increase of bioeconomy sector (A) and bioresource productivity (I) slightly contribute to the increase in extraction level. Meanwhile, in Poland, the increase in extraction was driven by the increase in export intensity (X) and share of bioresource export (S) Table 3.

In Finland, during the period of preparation of the EU bioeconomy, a slight decrease in biotic resource extraction was observed. The decrease in export intensity (X) and share of export (S) contributed to this change the most. This country could be viewed as an example for other countries where, despite the growth of the bioeconomy sector (A), the growth of bioresources productivity (I) ensured a slight decrease in bioresource extraction.

Table 2
Changes in biotic resource extraction and driving forces in the BSR countries in the period 2000–2007.

Country	P	E	R	I	A	X	S	BRE
Denmark	1.02	0.81	1.08	0.80	0.64	1.50	0.83	**0.89**
Germany	1.00	0.92	1.16	0.87	0.85	1.30	0.89	**1.07**
Estonia	0.96	0.76	0.90	4.12	1.60	0.28	0.86	**0.65**
Latvia	0.93	0.76	1.37	1.99	1.05	0.69	0.73	**0.96**
Lithuania	0.93	0.68	1.80	1.29	0.84	1.44	0.54	**1.13**
Poland	1.00	0.81	1.30	1.56	1.24	1.22	0.53	**1.05**
Finland	1.02	0.86	1.20	1.05	0.89	1.00	0.95	**1.05**
Sweden	1.03	0.78	1.46	0.88	0.83	1.24	0.92	**1.16**
Average	**0.99**	**0.79**	**1.28**	**1.57**	**0.99**	**1.08**	**0.78**	**0.99**
Standard deviation	0.04	0.07	0.27	1.11	0.30	0.41	0.17	**0.16**
CV	0.04	0.09	0.21	0.70	0.30	0.38	0.21	**0.16**

Note: Green colour represents the decreasing, and red colour – the increasing factors; colour intensity increases gradually as the value of the factor moves away from 1.

Table 3
Changes in biotic resource extraction and driving forces in the BSR countries in the period 2008–2012.

Country	P	E	R	I	A	X	S	BRE
Denmark	1.02	0.86	1.20	1.94	2.07	0.52	1.00	1.05
Germany	0.98	1.02	1.08	1.02	1.06	0.89	1.10	1.07
Estonia	0.99	0.94	1.42	0.80	1.08	1.35	0.93	1.32
Latvia	0.93	0.91	1.52	0.78	1.11	1.37	0.93	1.29
Lithuania	0.93	1.03	1.23	1.05	1.30	1.12	0.85	1.18
Poland	1.00	0.89	1.18	1.06	0.98	1.23	0.76	1.05
Finland	1.02	0.94	1.04	1.09	1.13	0.86	1.07	0.99
Sweden	1.03	1.05	0.95	1.16	1.15	0.78	1.11	1.03
Average	**0.99**	**0.95**	**1.20**	**1.11**	**1.24**	**1.02**	**0.97**	**1.12**
Standard deviation	0.04	0.07	0.19	0.36	0.35	0.30	0.12	0.12
CV	0.04	0.07	0.16	0.32	0.28	0.30	0.13	0.11

Note: Green colour represents the decreasing, and red colour – the increasing factors; colour intensity increases gradually as the value of the factor moves away from 1.

4.4. Changes in biotic resource extraction and main determinants in the strategy period (2013–2018)

Increasing biotic resource extraction continued in almost all the countries of the region and labour productivity (R) and export intensity (X) were the main drivers for this increase. However, similarities between countries that had adopted the national bioeconomy strategies (Denmark, Germany, Latvia, and Finland) were observed. It has been revealed that the principles of bioeconomy development by increasing the export, employment rate and value-added in bioeconomy strategy led to slow growth of bioresource extraction. Meanwhile, Estonia and Lithuania, where the bioeconomy strategy had not been adopted, experienced different extremes. In Estonia, the biggest growth, while in Lithuania – the biggest reduction in bioresource extraction was observed.

By applying decomposition, the decrease in BRE (−11%) in Lithuania was influenced by the decreasing share of biotic resource exports (S), which decreased by 19% in this period. However, the share of bioeconomy (A), people employed by bioeconomy (E) and total population (P) were also decreasing. Therefore, in Lithuania, the development of bioeconomy sectors has been abandoned. The policymakers should faster tackle the preparation and implementation of sustainable bioeconomy ensuring growth of the bioeconomy sector and stabilise changes in bioresource extraction. Meanwhile, Estonia experienced an increase in biotic resource extraction by 24%. This increase was mostly driven by an increase in labour intensity (R) and share of bioresource export (S). However, the decrease in the bioresource productivity level and the share of bioeconomy sector reveals that the Estonian policymakers preparing the bioeconomy strategy should pay particular attention to the ways to enhance bioresource productivity.

In Poland, biotic resource extraction increased by 17%. This increase was mostly driven by the increase in labour intensity (R) and a significant increase in export intensity (X). Furthermore, the comparison of all the remaining BSR countries showed the largest decrease in bioresource productivity and share of bioeconomy sector during the strategy period (2013–2018). The problem of ineffective bioeconomy sector could be linked to the fact that Poland did not have a single document dedicated to bioeconomy and the concept of bioeconomy was not well known, opportunities were not fully identified (Woźniak and Twardowski, 2018). Therefore, considering the context of sustainable bioeconomy, policymakers should focus more on increasing the bioresource productivity level and decreasing the export intensity by developing the biotechnologies.

In Denmark, negligible reduction of BRE was observed. The growth of export intensity (X) and share (S) were offset by the decrease in the share of the bioeconomy sector (A). A decrease in bioresource productivity in Denmark was also assessed negatively. Throughout the period, population change (P) contributed the least to the change in biotic resource extraction. Denmark did not have a single national bioeconomy strategy but has chosen integrated approach, emphasising the need for sustainable economy. However, policymakers should revise the strategies related to bioeconomy in order to continue improving the bioresource productivity. In Sweden, negligible increase in BRE was observed. Despite the decrease in the share of the bioeconomy sector (A), increase in BRE was mostly driven by an increase in labour intensity (R). The Swedish Research and Innovation Strategy for a Bio-based Economy aimed to increase the use of biomass by increasing added value for these materials. As a result, the decrease in bioresource productivity (I) in Sweden was the lowest among all BSR countries Table 4. However, identifying the way of improvement of the productivity of bioresource use also remained a challenge for Sweden.

In Germany, Finland, and Latvia, where the bioeconomy strategies had been adopted in the national document, minor increase in bioresource extraction was observed. However, the drivers for this increase varied from country to country. In Latvia and Finland, the extraction was mostly stimulated by an increase in the bioresource extraction productivity (I) and increasing share of bioeconomy (A). Therefore, unfortunately, growth of the bioresource productivity level did not offset the growing bioeconomy sector. However, the increase in bioresource productivity in these countries is assessed very positively. Furthermore, in Finland, a decrease in export intensity was observed. Therefore, strong bioeconomy competence and sustainability of bioresources in the Finnish Bioeconomy strategy, which focused on the competitive environment for the bioeconomy, demonstrated positive results in the pursuit of sustainable bioeconomy principles. In Latvia, despite the main focus of the bioeconomy strategy placed on social and economic aspects, the increase in bioresource extraction was one of the biggest among all the BSR. However, Latvia would face a potential challenge in the case of the increasing bioresource export as planned by the Latvian bioeconomy strategy. Thus, policymakers should also stabilise the rapid growth of BRE enhancing export efficiency. In Germany, the main drivers of BRE were the increasing export intensity (X) and share of bioresource exports (S). However, although Germany mostly emphasised the environmental aspects and vision of sustainable and

Table 4
Changes in biotic resource extraction and driving forces in the BSR countries in the period 2013–2018.

Country	P	E	R	I	A	X	S	BRE
Denmark	1.03	0.96	1.04	0.92	0.82	1.19	0.91	**0.99**
Germany	1.03	0.97	1.00	0.89	0.88	1.07	1.05	**1.09**
Estonia	1.00	0.91	1.10	0.96	0.99	0.99	1.06	**1.24**
Latvia	0.96	1.00	0.96	1.33	1.26	0.83	0.90	**1.10**
Lithuania	0.95	0.96	1.16	1.19	0.91	1.03	0.81	**0.89**
Poland	1.00	0.89	1.19	0.79	0.76	1.41	0.90	**1.17**
Finland	1.02	0.87	1.06	1.12	1.10	0.94	0.96	**1.07**
Sweden	1.06	0.91	1.21	0.98	0.87	1.01	1.00	**1.01**
Average	**1.00**	**0.93**	**1.09**	**1.02**	**0.95**	**1.06**	**0.95**	**1.07**
Standard deviation	0.04	0.05	0.09	0.18	0.17	0.17	0.08	0.11
CV	0.04	0.05	0.08	0.17	0.17	0.16	0.09	0.10

Note: Green colour represents the decreasing, and red colour – the increasing factors; colour intensity increases gradually as the value of the factor moves away from 1

circular bioeconomy in its strategy, a decrease in bioresource productivity was observed during the bioeconomy strategy period. Thus, although not sufficient enough, mere declaration of the willingness still is very important in terms of following the published principles and monitoring the trends and drivers.

5. Conclusions and future directions

In the renewed EU bioeconomy strategy and almost in all BSR countries, pursuit of sustainable bioeconomy is emphasised. However, none of the previous researchers have analysed the drivers behind the bioresource extraction. Therefore, the aim of this paper is, by encompassing bioeconomy strategy components (the growth of value-added, employment rate in the bioeconomy sector, and bioresource productivity) and applying decomposition analysis, to evaluate the main determinants of bioresource extraction in all the BSR countries by following periods: 2000–2007 – growth period, 2008–2012 – transition period, and 2013–2018 – strategy period. In this paper, we define the scope of the bioeconomy covering the traditional land-use sectors: crop and animal production, hunting and related service activities, forestry and logging, and fishing and aquaculture. For more detailed analyses in the future researchers also could perform product or bioeconomy subsector-specific decomposition analyses, as well as including other bioeconomy sectors not covered in this study, e.g. biochemistry and bioenergy.

Bioresource extraction during all periods varied significantly for all the BSR countries. During the entire period analysed (2000–2018), the extraction decreased in Denmark only. Meanwhile, in Lithuania and Poland, the biggest increase in BRE was observed. The main driving forces behind the increase were the growth in labour material intensity (R), biotic extraction productivity (I), and export intensity (X). It should be also noted that changes in these factors differed significantly from country to country studied and had different trajectories over time depending on the overall performance of the economy. Therefore, complex tools should be implemented, focusing not only on the efficiency of bioresource production but also on stimulation of the decrease in intensity of bioresource export as well as increase in the value-added of biotic resource use. Such tools should illustrate possible transition pathways away from a linear resource-intensive economy to bioeconomy with a cluster of inter-related activities having a major regional or local impact on employment, local value-added and the environment (Refsgaard et al., 2021). Such tools would also require qualitative and quantitative information on the sustainability of bioeconomy and on the tradeoffs between environmental, economic and social goals (Lewandowski, 2018).

During the economic growth (2000–2007), when the bioeconomy was not considered at the policy level, the average level of bioresource extraction decreased in the BSR, in particular, in Lithuania, Latvia and Denmark. The growth of bioresource productivity (I), decrease in export intensity (X) and the share of exported bioresources (S) were the main drivers behind the decrease in extraction in Estonia and Latvia. However, the most significant increase during this period was in Lithuania and Sweden, 13% and 16%, respectively. This increase in biotic resource extraction was largely caused by an increase in labour (R) and export intensity (X). This suggests that, in these countries, the problem was the growth of bioresource export, and the employment rate does not seem to have been related to production.

During the transition period (2008–2012), when the BSR countries experienced economic recession followed by the economic restructuring period, the countries (except for Finland) saw an increase in biotic resource extraction. The highest increase was in the Baltic States. The main drivers behind this increase were increasing labour (R) and export (X) intensity and increasing share of bioeconomy (A). Therefore, in these countries, one of the economic crisis curbs was the promotion of the agricultural sector. However, the bioresource productivity level, in particular, in Estonia and Latvia, decreased the most and increased in Denmark only.

In the strategy period (2012–2018), in Estonia, bioresource extraction increased the most, while Lithuania experienced the steepest decrease. These countries have not yet adopted the bioeconomy strategy at the national level. Meanwhile, in the countries, which had adopted the bioeconomy strategies at the national level (Denmark, Germany, Latvia and Finland), similarities were observed. Furthermore, almost in all the BSR countries (except for Lithuania and Denmark), the BRE increased. In Poland, biotic resource extraction increased by 17%. The increase was mostly driven by an increase in labour intensity (R) and significantly increasing export intensity (X). Furthermore, a comparison of all the BSR countries has shown that the decrease in bioresource productivity and share of bioeconomy sector during the strategy period was the greatest for most countries, and it could be related to the fact that Poland had no single policy document dedicated to bioeconomy. The same problem remained in Denmark. In Sweden, the promotion of bioresource productivity also remained a challenge. In countries (Germany, Finland, and Latvia), where the bioeconomy strategies have been adopted at the national level, a minor increase in bioresource extraction was observed. In Latvia and Finland, the extraction was mostly stimulated by an increase in the bioresource extraction productivity (I) and increasing share of bioeconomy (A). Furthermore, in Finland, a decrease in export intensity was observed. Therefore, implementation of the Finnish Bioeconomy strategy encompassed the sustainable bioeconomy principles the most successfully. Meanwhile, in Germany, despite the fact that their strategy mostly emphasised the vision of sustainable and circular bioeconomy, a decrease in bioresource productivity was observed. Therefore, all the BSR countries should seek ways to implementa more sustainable bioeconomy strategy. However, the real challenge is the achievement of the long-term sustainability of bioresource extraction ensuring that the use of renewable resources remains within sustainable limits. Looking into ways of ensuring this remains a prospective area for further research.

Considering the fact that this paper dealt with only 2000–2018 period, further research should also focus on changes in bioresource extraction and productivity level analyzing the period of the revised EU sustainable bioeconomy strategy implementation. These studies might help refine the bioeconomy strategies and propose the tools for improvement of the sustainable bioeconomy implementation.

CRedit authorship contribution statement

Genovaitė Liobikienė: Conceptualization, Writing - review & editing; **Astrida Miceikienė**: Writing - review & editing; **Janis Brizga**: Conceptualization, Methodology, Formal analysis, Writing - review & editing.

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