Proceedings of the 2019 International Conference "ECONOMIC SCIENCE FOR RURAL DEVELOPMENT" No 52
Jelgava, LLU ESAF, 9-10 May 2019, pp. 355-362
DOI: 10.22616/ESRD.2019.142

THE CHALLENGES OF BIOECONOMY IMPLEMENTATION CONSIDERING ENVIRONMENTAL ASPECTS IN THE BALTIC STATES: AN INPUT-OUTPUT APPROACH

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Abstract. Bioeconomy is an important element of European Union political agenda. From all the three Baltic States, only Latvia has endorsed its bioeconomy strategy. However, these strategies and related discussions are mostly focused on the social and economic aspects of bioeconomy, but environmental aspects are not sufficiently addressed. One of the important elements of environmental sustainability of bioeconomy is resource efficiency. However, to the best of our knowledge, none of the researchers has analysed this aspect of bioeconomy. Therefore, in this study, we are aiming to evaluate the bio-resource usage and efficiency in the Baltic States – Estonia, Latvia and Lithuania in 2015 by applying the environmentally extended multiregional input-output analysis. The results showed that in Latvia and Lithuania half of the resources used in the production are bio-resources, meanwhile in Estonia - only one third. Considering the consumption-based resource usage only one-third of these resources (in Estonia only 19 %) were bio-resources. Referring to land footprint results, the biggest consumption and production based land footprint is associated with the forest land, followed by the cropland and the pastures. Furthermore, Estonia is a net-exporter of the land footprint, but in Lithuania the situation was inverse and the highest share of the produced land footprint was consumed nationally. The highest efficiency of the land footprint was also observed in Lithuania, meanwhile, in Estonia, the main challenge remains how to enhance the bio-resource efficiency. To improve sustainability countries should stimulate higher value-added bioeconomy activities at the national level, intensify the substitution of the non-renewable resources and improve eco-efficiency of bioeconomy.

Key words: Bioeconomy, input-output, land footprint, bio-resources, efficiency.
JEL code: Q57, R15.

Introduction

Bioeconomy is one of the main aspects of green growth and a key to sustainability (D'Amato et al, 2017; Loiseau et al., 2016). According to the conventional definition of bioeconomy, it comprises all economic activities related to the development of renewable resources and use of biological products and process (Loiseau et al., 2016; Ingrao et al., 2018; Nayha, 2019 and etc.). The development of bioeconomy contributes to food security, promotion of renewable resource, climate change mitigation, economic growth and job creation (EC, 2012; Wozniak and Twardowski, 2018; Balezentis et al., 2019; Budzinski et al., 2017; D'Amato et al., 2017; Ingrao et al., 2018 etc.).

Bioeconomy first time was mention in the document „Biotechnology for sustainable growth and development" (OECD, 2009) in 2009. Meanwhile, in the European Union (EU), the European Commission launched a strategy „Innovating for sustainable growth: A bioeconomy for Europe" (EU, 2012) in 2012. However, experts stated that the sustainable supply of biomass is not sufficiently addressed in bioeconomy strategies (European Bioeconomy Panel, 2014) and the scope of the actions of the bioeconomy strategy has to be refocused. Thus, the EU bioeconomy strategy has been renewed in 2018. Subsequently, many European countries published or are preparing a national bioeconomy strategy (Ladu and Blind, 2017). Considering the Baltic States, only Latvia accepted its bioeconomy strategy. In Lithuania and Estonia, such strategies are under development.

Taking into account the goals of Latvian bioeconomy strategy, they are divided into three main groups: „1) advancement and retention of employment in the bioeconomy sectors for 128 thousand people, 2) increasing the value added of bioeconomy products to at least EUR 3.8 billion in 2030, 3)

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increasing the value of bioeconomy production exports to at least EUR 9 billion in 2030" (Latvian Bioeconomy Strategy, 2018). These goals reveal that in the strategical level the most attention is paid for the social and economic aspects. Considering that sustainable development encompasses economic, social and environmental areas, the ignorance of environmental aspects is blasting. Despite the fact that bio-resources are renewable, biomass supplies are not endless as it takes time for supplies to regrow. The increased demand for biomass in a growing bioeconomy is expected to create biomass scarcity at the global level (Borgstrom, 2018). Particularly it concerns the EU where a local biomass supply is limited (Sleenhoff et al., 2015; Henning et al., 2016). Therefore, a steep increase in the demand for biomass and unsustainable biomass consumption could hinder the sustainability of bioeconomy (Bezama, 2018; Hildebrandt et al. 2018).

The evaluation of bioeconomy is very important because policymakers need to have baseline information representing the status of the bioeconomy at a certain time period when developing adequate policy measures. Evaluating the environmental aspects a large number of authors used land footprint approach (Hubacek and Feng, 2016; Schaffartzik et al., 2015; Bruckner et al., 2015; O'Brien et al., 2015; 2017; Kastner et al., 2014) or life cycle assessment (Sieberet al., 2018; Martin et al., 2018). Other authors as Budzinski et al. (2017) applying multi-regional input-output analysis evaluated German wood-based economy, Asada and Stern (2018) assessed the bioeconomy sectoral competitiveness. In this paper by applying both input-output and land footprint analyses, we assessed the main environmental indicators embedded in consumption, production and trade in the Baltic States.

Furthermore, seeking sustainability it is not enough to evaluate the tendencies of bio-resource usage. Schutte (2018), Scheiterle et al. (2017), Davaney and Henchion (2018) and Zabaniotou, (2018) stated that sustainable bioeconomy should focus on resource efficiency and biomass conversion must retain a high efficiency. The concept of the bio-economy has brought an objective to achieve higher efficiency in biomass usage, by maximising the value added of the produced goods (Ingrao et al., 2018). However, to the best of our knowledge, none of the researchers did analyse the bio-resource efficiency in bioeconomy sectors. Therefore, in this study we are aiming to evaluate the bio-resource usage and efficiency in the Baltic States – Estonia, Latvia and Lithuania in 2015, by calculating the main environmental indicators, coupling them with economic indicators - value-added[1] and employment.

Methodology

There are several tools available to perform a sustainability impact assessment of bioeconomy, e.g. cost-benefit analysis, input-output (IO) methods, life cycle analysis (LCA) methods, material flow analysis (MFA) and multi-criteria analysis (MCA) (Karvonen et al., 2017). In this research, we are using environmentally extended multi-regional input-output (MRIO) analysis, which is based on a globally harmonized set of input-output (IO) tables and bilateral trade data, taken from EXIOBASE 3 database (Stadler et al., 2018), covering 165 industries, 200 products, 48 countries, and regions for the years 1995–2015.

The basic linear input-output (IO) model is based on the classic Leontief demand-style modelling (Leontief, 1986) where the vector of total output x can be calculated using the following equation:

$$x = (I-A)^{-1}y = L \quad (1)$$

[1] In Exiobase 3 Gross Value Added is decompose into 3 components: i) compensation of employee, ii) operating surplus, iii) indirect tax and subsidy on products.

where, y is the final demand vector, A - the inter-industry coefficient matrix and I - the identity matrix of A, and L is the Leontief inverse or total requirements matrix ($(I-A)^{-1}$).

To calculate consumption (D_{cba}) land and material input footprints, we extend the MRIO framework with a vector of direct sectoral land and material input intensities, e, and calculated consumption-based emissions intensity matrix E:

$$E = e(I-A)^{-1} = eL \quad (2)$$

The total consumption-based footprints (D_{cba}) where calculated from the IO accounts by multiplying the consumption-based emissions intensity matrix E by the total expenditure on products that year:

$$D_{cba} = ELy \quad (3)$$

The total territorial or production land and material input footprints (D_{pba}) where calculated using the following equation:

$$D_{pba} = F+G \quad (4)$$

where F is a row vector of sectoral land and material input coefficients and G describe the impacts associated with final demand.

Research results and discussion

Here are the results of our analyses on land and material footprints in the Baltic States in 2015.

Material flows

Biological Raw Material Consumption (RMC) is one of the main indicators demonstrating environmental pressures of the industrial sectors of the bioeconomy. Our results demonstrate that bioeconomy is important resource consumer in all the Baltic States and biological resources embedded in production are generally bigger then resources embedded in the consumption, thus a big part of the biological resources are exported to other countries (Table 1).

Table 1

RMC of biological resources embedded in consumption, production and trade of the Baltic States in 2015 (volume in kt and percentage of biological resources from the total DMI)

	RMC, kt			The share of biological resources in the total RMC		
	Estonia	Latvia	Lithuania	Estonia	Latvia	Lithuania
Consumption	5 878	10 550	17 990	19 %	31 %	31 %
Imports	3 870	4 720	7 986	24 %	27 %	22 %
Production	9 562	18 725	19 469	33 %	58 %	52 %
Exports	7 553	12 894	9 465	52 %	86 %	62 %

Source: author's calculations based on EXIOBASE 3 database

For Latvia and Lithuania, biological resources account for more than 50 % of the total RMC embedded in the production, while in Estonia only 33 %. This result can be explained with the fact that in Estonia the share of agricultural land is only 23 % of all the land use, meanwhile, in Latvia and Lithuania it's 30 % and 47 % respectively. However, the forest area in Estonia and Latvia is more than 50 %, but in Lithuania only 34 %. Therefore, all the Baltic States has rather similar possibilities to develop bioeconomy and enhance bio-resource production, but the development of bioeconomy is only in the initial stage. Biological resources make also the main export flows for all the Baltic States. Forestry, logging and related service activities being the main biological resource export sector for all the Baltic States – accounting for 17 % of exported biomass in Lithuania, 32 % in Estonia and 45 % in Latvia. For Estonia and Latvia Forestry, logging and related service activities

are also the sectors with the highest land use embedded in the production. In Lithuania, Cattle farming comes out as the biggest production land use (for Estonia and Lithuania coming second).

Consumption-based RMC footprints are much more diverse in all the three Baltic States. However, non-renewable resources conversion of renewable biological resources into food, fuel, chemicals and fibre is rather vague in the Baltic States. Main biological resource consumption sectors in Estonia are *Processing of Food products nec*, *Processing of meat cattle* and *Construction* (responsible for 29 % of all the biological RMC). In Latvia 3 biggest consumption sectors are *Forestry, logging and related service activities*, *Processing of Food products nec* and *Processing of meat cattle* (responsible for 46 %), but in the Lithuania *Cattle farming*, *Processing of Food products nec* and *Forestry, logging and related service* activities are accounting for 30 % of the biological RMC.

Land footprint

Land footprint encompasses the main resources of biomass (cropland, pastures, and forests). This indicator has been defined as the land area used to produce the goods and services dedicated to satisfy the domestic final demand of a country (territory) regardless where this land was actually used (O'Brien et al., 2017). Table 2 demonstrates that production based land footprint is generally bigger than the land footprint embedded in consumption (Table 2). The smallest differences between these two are in Lithuania, which seems to be much more self-sufficient and have much smaller net-trade. In the case of Estonia production based land footprint is even bigger the whole territory of the country. It could be explained with the fact that in Estonia significant part of the land-intensive national production is meant for export. However, consumption-based land footprints are significantly smaller. Thus, Estonia instead of development of bioeconomy at the national level is a donor of bioeconomy resources to other countries.

Table 2

Land footprint embedded in consumption, production and trade of the Baltic States in 2015 (km^2)

	Estonia	**Latvia**	**Lithuania**
CONsumption	21 040	32 172	43 958
IMPorts	11 884	16 490	19 653
PROduction	52 263	61 762	56 714
EXPorts	43 107	46 081	32 410
Country territory	*45 227*	*64 589*	*65 300*

Source: author's calculations based on EXIOBASE 3 database

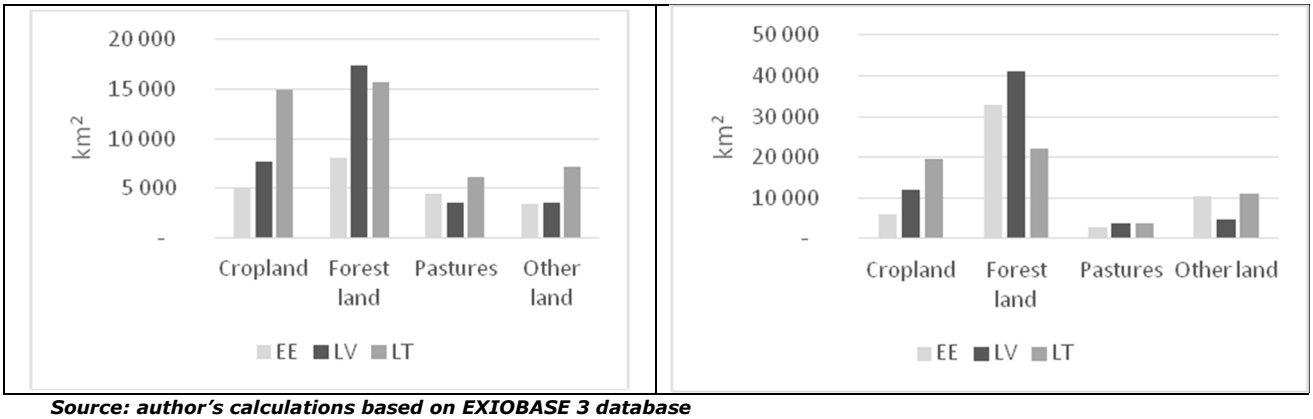
Industrial sectors accounting for 90 % of the production-based land footprint are similar to the sectors consuming most of the biological resources (Table 2) – most of the land is embedded in the forest activities, cattle farming and milk production as well as cultivation of cereals and oilseeds (Table 3).

Main production-based land footprint sectors of the Baltic States in 2015 (km^2)

Industrial sectors	Estonia	Latvia	Lithuania
Forestry, logging and related service activities	35 960	39 933	26 169
Raw milk	4 297		2 325
Manufacture of wood and of products of wood and cork, except furniture	2 531		
Cattle farming	1 908	4 603	6 095
Cultivation of wheat	1 885	5 669	6 836
Cultivation of cereal grains nec	1 700	2 599	5 376
Cultivation of oil seeds		3 073	3 854

Source: author's calculations based on EXIOBASE 3 database

The land footprint was allocated to the four land-use sectors contained in the Exiobase 3 sector classification – 'cropland, 'forest land', 'pastures' and 'other land'. If divided by these land type, the biggest consumption and production based lad footprint is associated with the forest land, followed by the cropland and the pastures (Fig. 1 left and right).



Source: author's calculations based on EXIOBASE 3 database

Fig. 1. **Consumption-based land footprint (left), production-based land footprint (right) in 2015 (km^2)**

Eco-efficiency indicators

Bio-resources are not infinite and when developing the bioeconomy policymakers should also consider planetary boundaries and the capacity of ecosystem service. Thus, seeking the sustainability bio-resources should be used more effectively and in some cases cap on the bioresource use is inevitable. To measure the eco-efficiency of the bioeconomy in the Baltic States, we looked at the following indicators:

- Material intensity per employees - kt DMC per 1000 employees;
- Land intensity per employees - km^2 land footprint per 1000 employees;
- Material productivity - Gross Value Added (GVA) in mln. EUR per kt DMC and GVA in mln. EUR per km^2 land footprint.

There are significant differences among countries in terms of DMC per persons employed. Biggest resource intensity per employee in bioeconomy sectors is in Estonia – 53.2 kt/1000 p, but the smallest is also in Lithuania - 36.45 kt/1000 p. In Latvia, material productivity per employee in bioeconomy sectors is similar as in Estonia - 51.24 kt/1000 p. Then comparing bioeconomy sectors with the highest resource consumption, *Forestry, logging and related service activities*, in Lithuania DMC intensity per employee is 240 kt/1000 p, but in Latvia and Estonia it's only 493 and 465 kt/1000 p, respectively.

Also when comparing land footprint per employee in the bioeconomy sectors situation is similar – Lithuania has the smallest land footprint intensity - 107 km^2 / 1000 p, followed by Latvia with 166.4 km^2 / 1000 p and Estonia with 3 times higher land intensity than in Lithuania - 326.1 km^2 / 1000 p. The biggest land footprint sector in all three countries is *Forestry, logging and related service activities* and land intensity per employee in this sector in Lithuania is 1 540 km^2 / 1000 p, in Latvia 2 147 km^2 / 1000 p, but in Estonia 3 179 km^2 / 1000 p.

Structure of value added shows that bioeconomy is the important economic sector in the Baltic States. In Lithuania, bioeconomy sectors contribute to 33 % of the GVA, but in Latvia and Estonia 26 % and 21 % respectively. Nevertheless, resource intensity in the Baltic States is low – In Estonia its 0.62 mln. EUR/kt, in Estonia 0.45, but in Latvia only 0.35. Similarly, GVA per production based land footprint is the highest in Lithuania – 0.21 mln. EUR/km^2; in Estonia it is 0.05 mln. EUR/km^2, but in Latvia 0.1 mln. EUR/km^2 (Table 4).

Table 4

Eco-efficiency indicators of the Baltic bio-economies

	DMC / EmplOYee	Land-Use / EmplOYee	GVA / DMC	GVA / Land-Use	BioE share in GVA
EE	53.20	435.38	0.45	0.05	21 %
LV	51.24	181.57	0.35	0.10	26 %
LT	36.45	106.17	0.62	0.21	33 %

Source: author's calculations based on EXIOBASE 3 database

Partly these differences can be explained by the fact that in all the Baltic States, but especially in Estonia and Latvia low added value sectors, e.g. *Forestry, logging and related service activities* and *Cattle farming* dominated the national bioeconomy production.

Conclusions, proposals, recommendations

1) Analysing the production, consumption and trade based bio-resources usage we observed the big differences in the Baltic States. In Latvia and Lithuania, half of the resources used in the national production are bio-resources. Meanwhile, in Estonia it's only one-third. Furthermore, considering the consumption-based resource usage in all the Baltic States only one-third of resources (in Estonia only 19 %) were bio-resources. Thus, one of the suggestions for policymakers should be to intensify the substitution of the non-renewable resources with bio-resources. But it is also important to keep the bio-resource harvesting within the sustainable levels.
2) Latvia and Lithuania in term of land footprint almost achieved the country territory capacity. In the case of Estonia production-based land footprint is even bigger than the whole territory of the country and Estonia is a donor of bioeconomy resources to other countries. Therefore, Estonia should pay more attention to the development of higher value-added bioeconomy activities at the national level. In Lithuania, the situation was inverse and the highest share of the produced land footprint was consumed domestically.
3) The agriculture and forest sectors are mostly related to bioeconomy and the biggest consumption and production based land footprint is associated with the forestland, followed by the cropland and the pastures. However, when developing the bioeconomy, policymakers should also consider other commitments e.g. sustainable development strategy and climate change policy. Furthermore, the agriculture and forestry sectors are sensitive to climate change consequences. Thus, it is crucial to anticipate the impacts of climate variability for landowners to implement strategies to adapt or respond to it by using new more sustainable agricultural practices, e.g. no-till farming, controlled drainage.

4) In the Baltic States the bio-resource efficiency differed significantly as well. In Lithuania, the land footprint efficiency was the highest, while in Estonia – the lowest. Furthermore, land intensity per employee was also highest in Estonia. Therefore, particularly in Estonia the main challenge remains how to enhance the bio-resource efficiency. One suggestion could be organic industrial waste reuse in biological processes for the generation of various bio-based products along with its remediation. O'Brien et al. (2015) emphasize the need for bioeconomy policies that support greater efficiency across the life cycle and reduce wasteful and excessive consumption practice. The investments in innovations and technologies and better adaptation to climate change are essential in order to increase the bio-resource efficiency as well.

Acknowledgement

This work was partly financed by the specific support objective activity 1.1.1.2. „Post-doctoral Research Aid" of the Republic of Latvia (Project No. 1.1.1.2/VIAA/1/16/065 „Developing New Tools for the Sustainability Assessment of the Bioeconomy"), funded by the European Regional Development Fund (project id. N. 1.1.1.2/16/I/001).

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