Assessing the transition towards bioeconomy through a socio-economic indicator

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This study presents a consolidated methodology, based on national statistics data analysis and participatory approach, in order to propose an indicator able to measure the socio-economic performance of bioeconomy sectors (Socio-economic indicator for Bioeconomy - SEIB). This is done through a Multi-Criteria Decision Analysis (MCDA) that, using Eurostat data and the Analytic Hierarchy Process (AHP), allows a direct comparison of European Member State in terms of their bioeconomy socio-economic performance. The final goal is to propose a socio-economic indicator, based on employment, turnover and value-added, for each Member State in order to show a picture of the current development of the bioeconomy in Europe. Results show as three groups (i.e. virtuous, in-between and lagger) can be defined considering the European average as value of reference. Ireland, Denmark and Netherlands occupy the first three positions of this ranking.

Keywords: AHP, bioeconomy, Europe, indicators, MCDA, sustainability

1. Introduction

The European Bioeconomy Strategy supports the production of renewable biological resources and their conversion into vital products and bio-energy in order to satisfy the 2030 Agenda and its Sustainable Development Goals (European Commission, 2018). The development of bioeconomy represents a great chance to revive productivity and growth (Purkus et al., 2018) and reduce the dependence on imported feedstocks (Hurmekoski et al., 2019).

There is a clear lack of research on the bioeconomy in term of definition and monitoring (Falcone and Imbert, 2018). Little work has been carried out to monitor, model and appraise the development of bioeconomy (Schütte, 2018). Indeed, the transition out of a fossil-based economy towards a bioeconomy should be assessed against the three main pillars of sustainability: environmental, techno-economic and social. Albeit relevant, the social pillar of sustainability has been often neglected in sustainability assessment, who rather concentrate on environmental and techno-economic aspects. In a recent paper, Ronzon and M'Barek (2018) discuss and propose socio-economic indicators for the analysis of EU Member States' bioeconomies so as to provide some insights into the situation of individual countries, in terms of bioeconomy disparities, and suggest measures to promote the EU bioeconomy development.

In this article, we complement such recent work by aggregating the proposed indicators, through a consolidated methodology based upon a participatory approach, in order to propose a new indicator, namely the "Socio-economic indicator for Bioeconomy" (SEIB), able to measure the socio-economic performance of bioeconomy sectors. In doing so, this research proposes a Multi-Criteria Decision Analysis (MCDA) that, starting from both Eurostat data and the Analytic Hierarchy Process (AHP), allows a direct comparison of European countries (Cucchiella et al., 2017). This could help to fill the gap concerning the little attention towards the monitoring of bioeconomy by employing a participatory approach to weight relevant indicators capable of directly providing reliable information on effective transition towards bioeconomy targets in EU.

The remainder of the paper is organized in the following way: Section 2 introduces materials and methods, whereas Section 3 presents the results, along with a brief picture of the bioeconomy in the European Union. Section 4 discusses the findings, while Section 5 ends with some concluding remarks.

2. Materials and methods

Multi-Criteria Decision Analysis (MCDA) offers a consistent framework for supporting decision-makers evaluating multiple and also conflicting goals (Vogdrup-Schmidt et al., 2019). This work proposes a new indicator (SEIB) measuring the socio-economic performance of bioeconomy sectors.

SEIB is a dimensionless indicator coming from the interaction among three variables: i) the value of socio-economic parameters for each sector (VP), ii) the weight of socio-economic parameters for each sector (WP) and the weight of bio-based sectors (WS). It is based on a twofold approach:

1. The first concerns the assessment of the indicator calculated for each bio-based sector ($SEIB_{SK-(MS)}$) – equation (1).
2. The second regards the aggregation of $SEIB_{SK-(MS)}$ considering all bio-based sectors – equation (2).

$$SEIB_{SK-(MS)} = VP_{SK-(MS)-P1} * \wp_{SK-P1} * WS_{SK-P1} + VP_{SK-(MS)-P2} * \wp_{SK-P2} * WS_{SK-P2} + VP_{SK-(} \qquad (1)$$

$$SEIB_{(MS)} = \sum_{K=1}^{N} SEIB_{SK-(MS)} \qquad (2)$$

in which $VP_{SK-(MS)-PJ}$ = is the value of parameters calculated for the following combinations: i) bio-based sector SK with K = 1 … N, in which N = number of bio-based sectors; ii) country MS, that represents the alternative to analyse, in which its total number is equal to 28, or number of current European MSs and iii) socio-economic parameter with X = 1 … J, in which J = number of socio-economic parameters. Additionally, $\wp_{SK-PX}$ is defined according to the following combinations: i) bio-based sector SK with K = 1 … N and ii) socio-economic parameter with X = 1 … J. Finally, WS_{SK-PX} is proposed considering the following combinations: i) bio-based sector SK with K = 1 … N and ii) socio-economic parameter with X = 1 … J. The value of $VP_{SK-(MS)-PJ}$ is specific for each MS, while one of both $\wp_{SK-PJ}$ and WS_{SK-PJ} is independent.

Our methodology framework builts upon the following steps: i) selecting bioeconomy sectors according to the NACE classification; ii) choosing parameters useful to measure the socio-economic performance according to the literature review (Ronzon and M'Barek, 2018); iii) assigning values to the parameters for each bioeconomy sector based mainly on Eurostat data; iv) gathering of data for the definition of indicators priority through a pairwise comparison provided by experts (Khalil et al., 2016) and v) defining weights to the bio-based sectors based mainly on Eurostat data.

Concerning the first step, ten macro-sectors are selected according to the official statistical classification of economic activities of the European Community (NACE rev. 2) (Ronzon and M'Barek, 2018): K = 1) Agriculture (A01); K = 2) Forestry (A02); K = 3) Fishing and aquaculture (A03); K = 4) Manufacture of food, beverages and tobacco composed by manufacture of food (C10), manufacture of beverages (C11) and manufacture of tobacco (C12); K = 5) Manufacture of bio-based textiles composed by manufacture of textiles (C13), manufacture of wearing apparel (C14) and manufacture of leather (C15); K = 6) Manufacture of wood products and furniture composed by manufacture of wood products (C16) and manufacture of furniture (C31); K = 7) Manufacture of paper (C17); K = 8) Manufacture of bio-based chemicals, pharmaceuticals, plastics and rubber (excluding biofuels) composed by manufacture of chemicals (excluding biofuels) (C20), manufacture of pharmaceuticals (C21) and manufacture of bio-based plastics and rubber (C22); K = 9) Manufacture of liquid biofuels composed by manufacture of bioethanol (C2014) and manufacture of biodiesel (C2059) and K = 10) Production of bioelectricity (D3511). NACE classification does not distinguish bio-based and non-bio-based activities. Nine of micro-sectors exclusively use biomass as a feedstock (e.g. A01, A02, A03, C10, C11, C12, C15, C16 and C17), while the other nine are hybrid because they use either biomass feedstock or carbon fossil-based one (e.g. C13, C14, C31, C20, C21, C22, C2014, C2059 and D3511). For this reason, it is necessary to estimate their bio-based share.

Regarding the second step, the choice of parameters is based on literature (Ronzon and M'Barek, 2018). Specifically, three parameters are selected: i) Turnover; ii) Value added at factor costs and iii) Workers.

Concerning the third step, Eurostat provides statistical information to the institutions of the EU and last data available are referred to 2017. In the case of hybrid sectors, a sectoral bio-based share is applied following the approach used by (Ronzon et al., 2017). These values are divided by the population in order to have homogeneous data among several MSs.

Regarding the fourth step, the Analytic Hierarchy Process (AHP) methodology, developed by (Saaty, 1980), allows producing a list of priorities through pairwise comparisons based upon the judgements of experts. The questionnaire used in our empirical investigation was created using the Qualtrics Research Suite survey software and was administered, following the CAWI (Computer-Assisted Web Interview) technique (Falcone and Sica, 2019). A final list of 20 experts took part to the questionnaire, encompassing a broad range of academicians and researchers (i.e. research fellows, lecturers, associate professors, full professors) with long term expertise in the field of bioeconomy.

Finally, the fifth step regards the distribution of weights among socio-economic parameters that is defined in function of the AHP based on the knowledge of the experts, while one among bio-based sectors is evaluated in function of statistical data. It is referred to the average value of EU 28 in 2017.

3. Results

A quantitative analysis concerning bioeconomy sectors is proposed in this work. A new indicator is defined to compare several European countries and it is based on three components.

Concerning the first, values of the socio-economic parameters are referred to the historical data and consequently, they objectively reflect the current picture of the European MSs (2017 is the last year available in Eurostat).

Regarding the second, the weights of the socio-economic parameters are obtained by the AHP. Responses of a pair-wise comparison of the experts were collected. Aggregating the judgement of all experts, turnover is the most important parameter for eight of them, while this role is played by value added and workers for seven and five interviewees, respectively. However, the numerical value of weights is not the same and the calculation of the mean is able to define an exact priority level according to the theory of the AHP – Table 1.

Table 1. Normalized weights of socio-economic parameters

	K = 1	K = 2	K = 3	K = 4	K = 5	K = 6	K = 7	K = 8	K = 9	K = 10
Workers	0.289	0.321	0.323	0.318	0.332	0.321	0.305	0.307	0.315	0.319
Turnover	0.368	0.352	0.347	0.347	0.337	0.345	0.359	0.355	0.356	0.353
Value Added	0.343	0.327	0.330	0.335	0.330	0.334	0.336	0.338	0.329	0.328

Turnover is considered the main socio-economic parameter able to measure the performance of a MS in terms of the development of bioeconomy. In all sectors, it assumes the most significant weight varying from 0.337 ($\wp_{S5-P1}$) to 0.368 ($\wp_{S1-P1}$). Value added occupies, instead, the second position in nine out of ten sectors ("K" = 5 is the exception) varying from 0.327 ($\wp_{S2-P2}$) to 0.343 ($\wp_{S1-P2}$). Finally, the weight of workers ranges from 0.289 ($\wp_{S1-P3}$¿ to 0.332 ($\wp_{S5-P3}$). The normalized weights of socio-economic parameters do not change in function of specific MSs.

The third component of SEIB is represented by the weight of bio-based sectors. WS_{SK-PJ} as $\wp_{SK-PJ}$ represents a distribution of weights which is not more defined by experts but it is calculated on the historical data. WS_{SK-PJ} as $VP_{SK-(MS)-PJ}$ measures the performance of socio-economic parameters and it is not more necessary to apply a normalization of input data. In fact, the value of reference is represented by the EU 28. Figure 1 shows the percentage distribution of three socio-economic parameters.

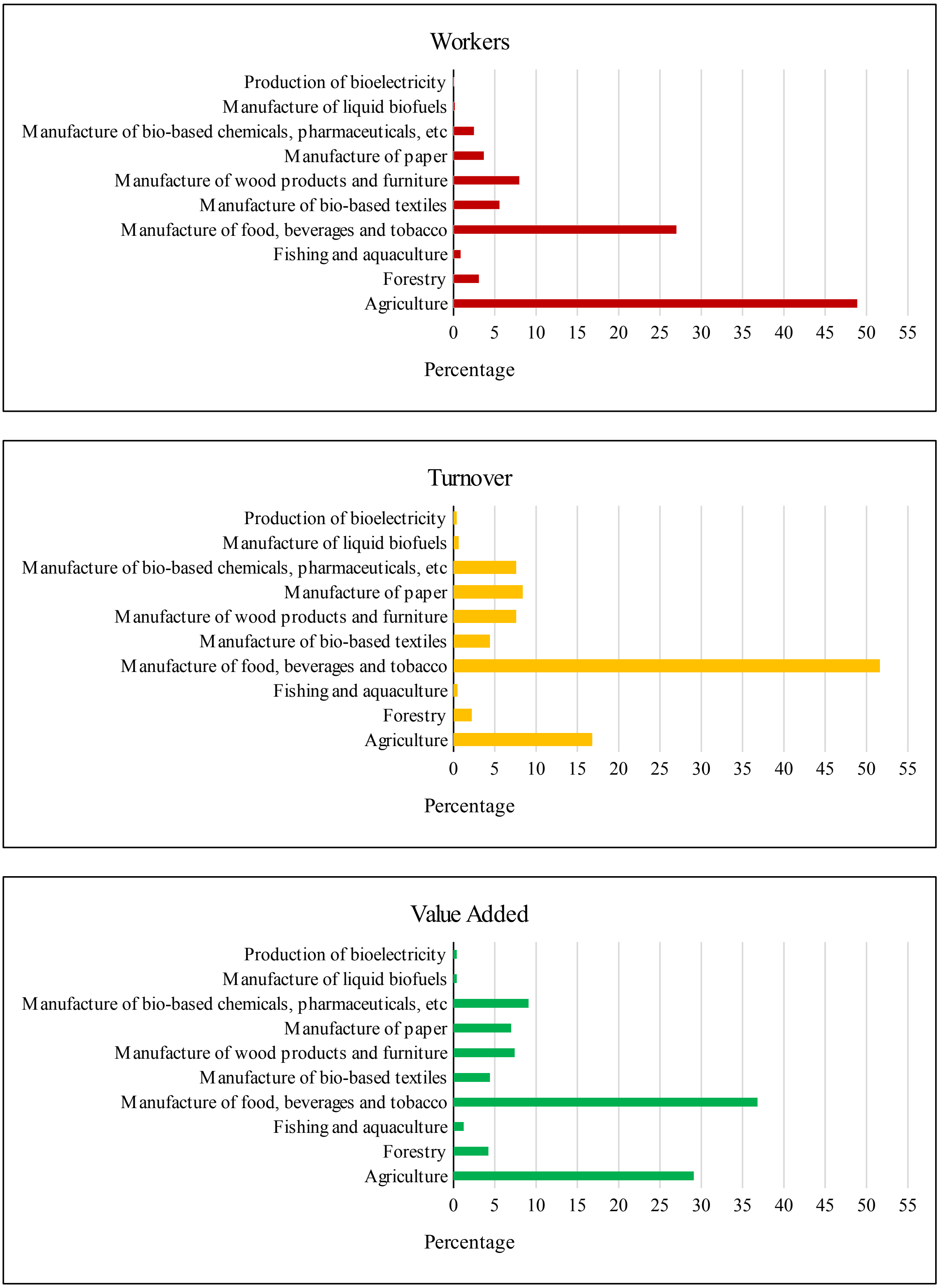

Figure 1. Percentage distribution of the European bioeconomy sectors in 2017 (European Commission, 2019; Eurostat, 2018)

A comparison with existing literature (Ronzon and M'Barek, 2018) shows an increase of 118,910 million € and 39,299 million € for turnover and value added, respectively in 2017 than 2015. Instead, a decrease of 429,837 regards the number of workers. The analysis of single bio-based sectors defines the key-role played by agriculture ("K" = 1) and manufacture of food, beverages and tobacco ("K" = 4):

- Sector S1 occupies the first position for the number of workers ("J" = 3) with WS_{S1-P3} = 0.489 and the second position in terms of turnover ("J" = 1) with WS_{S1-P1} = 0.168 and value added ("J" = 2) with WS_{S1-P2} = 0.291, respectively.
- Sector S4 occupies the first position for both turnover with WS_{S4-P1} = 0.516 and value added with WS_{S4-P2} = 0.368 and the second position in terms of workers with WS_{S4-P3} = 0.270.
- Nine of ten bio-based sectors increase both turnover and value added in 2017 than 2015 (the exception is represented by the production of bioelectricity). Regarding turnover, the most significant increase concerns sector S4 of 74,721 million € followed by sector S1 with 18,217 million €. Concerning value added, instead, an opposite situation arose. The most relevant increase regards sector S1 of 18,585 million € followed by sector S4 with 9410 million €. Finally, five bio-based sectors increase the number of workers (sector S4 with 211,794 units) and the same number of bio-based sectors presents a decrease (sector S1 with 605,800 units).

Finally, it is possible to calculate SEIB in European MSs. According to equations (1) – (2), SEIB is calculated in two distinct steps. The first evaluates the bioeconomy performance in each bio-based sector - $SEIB_{SK-(MS)}$ (Figure 2). The second shows an overall indicator that integrates both socio-economic parameters and bio-based sectors - $SEIB_{(MS)}$ (Table 2).

The European average is used as level of reference and for example, equation (3) reports its value for the sector agriculture ("K" = 1). The same operation is repeated for other nine sectors and finally, SEIB of the EU 28 is calculated in equation (4).

$$SEIB_{S1-(EU28)}=0.146*0.29*0.489+0.369*0.37*0.168+0.381*0.34*0.291=0.081 \qquad (3)$$

$$SEIB_{(EU28)}=0.081+0.003+0.002+0.116+0.011+0.017+0.010+0.011+0.000+0.000=0 \qquad (4)$$

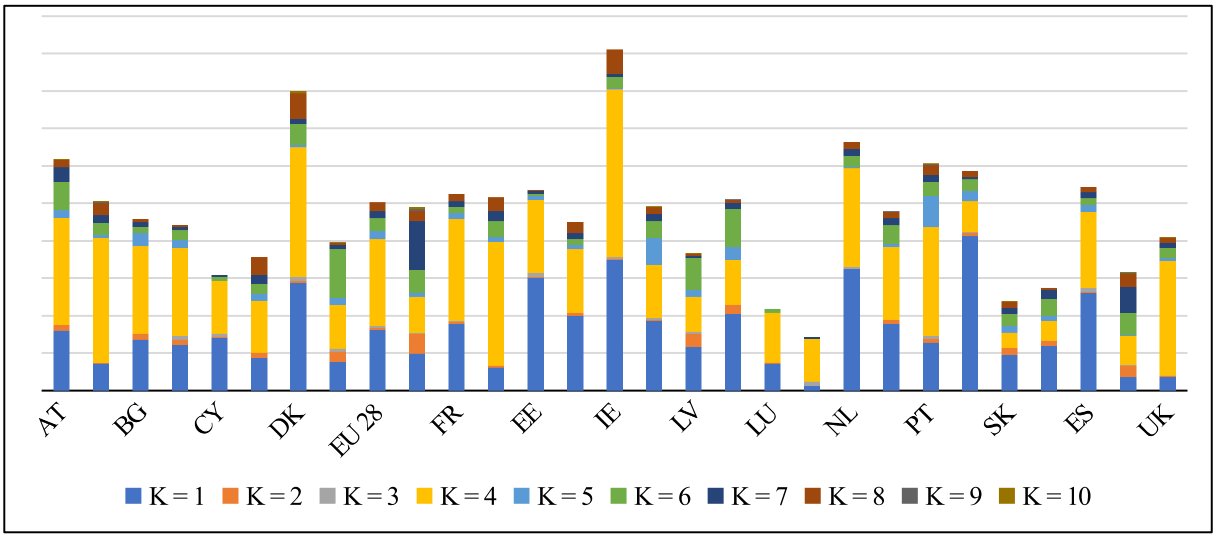

Figure 2. SEIB for bio-based sectors in 2017

Table 2. Overall SEIB in European MSs in 2017

Countries	SEIB (dimensionless)
Ireland	0.456
Denmark	0.400
Netherlands	0.331
Austria	0.309
Portugal	0.302
Romania	0.294
Spain	0.271
Greece	0.270
France	0.262
Germany	0.259
Lithuania	0.255
Belgium	0.253
EU 28	0.252
Italy	0.245
Finland	0.245
Poland	0.238
Bulgaria	0.229

Hungary	0.226
Croatia	0.221
United Kingdom	0.205
Estonia	0.198
Latvia	0.185
Czechia	0.177
Sweden	0.158
Cyprus	0.154
Slovenia	0.138
Slovakia	0.119
Luxembourg	0.109
Malta	0.072

The analysis of results indicates clearly how all sectors perform. Overall, the final value of SEIB is highly affected by two bio-based sectors (agriculture K=1 and manufacture of food, beverages and tobacco K=4). Both are completely pure, namely use only biomass feedstock. This result should not be interpreted as a lower attention towards other sectors, but steam directly from the quantitative approach used to evaluate socio-economic parameters defines a priority.

Another relevant result is the subdivision of European MSs, initially, in two groups: i) the first composed by twelve MSs that have an overall value of SEIB higher than European average and ii) the second composed by other sixteen MSs with an overall value of SEIB lower than European average. The weight of sectors ("K = 1" and "K = 4") is the following in MSs of the first group: Greece (92%, it is first in the sector "K = 3"), Netherlands (89%), Ireland (87%, it is first in the sector "K = 4" and it occupies the second position in one "K" = 1). France and Spain (86%), Romania (84%, it is first in the sector "K = 1"), Belgium (80%, it is first in the sector "K = 9"), Denmark (79%, it is first in the sector "K = 8" and it occupies the second position in one "K = 4"), Germany (76%), Austria (72%), Portugal (70%, it is first in the sector "K = 5") and Lithuania (64%).

The second observation is that the weights of socio-economic parameters has a lower influence than values of these parameters. For example, the weight of turnover ("J = 1") is equal to 35% against 34% of value added ("J = 2") in the sector "K=4", while the difference is more significant regarding sector "K = 1" (37% vs 34%). Nonetheless, focusing the attention on the first two countries of the ranking, Ireland ($SEIB_{(IE)}$ = 0.456) and Denmark ($SEIB_{(DK)}$ = 0.400), the contribution of $SEIB_{S1-(IE)-P1}$ is equal to 0.062 lower than $SEIB_{S1-(IE)-P2}$ equal to 0.086 and the same is verified also for $SEIB_{S1-(DK)-P1}$ and $SEIB_{S1-(DK)-P2}$ (0.059 < 0.074). This result must be determined by $VP_{SK-(MS)-PX}$. Regarding the sector K = 4, instead, the impact of $SEIB_{S4-(MS)-PJ}$ are more significant than $SEIB_{S1-(MS)-PJ}$ and in this case, they are coherent with the weight preference order. However, the final difference between two socio-economic parameters is more significant in particular for the case study of Denmark: $SEIB_{S4-(IE)-P2}$ (0.082) < $SEIB_{S4-(IE)-P1}$ (0.119) and $SEIB_{S4-(DK)-P2}$ (0.038) < $SEIB_{S4-(DK)-P1}$ (0.116).

4. Discussion

The focus on the bioeconomy performance highlights, from one hand, that the MSs better performing (e.g. Germany occupies the first position in both turnover and value added followed by France and Italy) are those countries which have developed a national bioeconomy strategy, reflecting thus an evident political support towards the bioeconomy development. Indeed, national bioeconomy strategies were first released in North European countries in 2014 (i.e. Finland and Germany, etc.), while others strategies were released recently in Mediterranean MSs (i.e. France, Italy and Spain).

Europe has the priority to work towards a circular economy, where wastes will be recognized increasingly as resources (Cucchiella et al., 2017). The realization of a circular bioeconomy requires a joint effort of all concerned parties such as citizens, public authorities and industry (Falcone, 2018). It is clear that such an effort makes good sense when harmonized among different MSs. Further research objectives could be related provide relevant information about a relevant pillar not examined in this research, namely the environmental one. For example, resource efficiency, climate change and biodiversity aspects could be added to assess, by means of a unique indicator, the overall country sustainability.

5. Conclusions

The world is characterized by a great revolution to provide concrete answers to the current environmental challenges. In this context, the concept of sustainability represents an opportunity and a link among all interested parties (i.e. citizens, researchers, firms and policy-makers) that try to propose real solutions. Bioeconomy moves towards this direction, because it presents an optimal use of renewable biological resources.

Literature does not present detailed indicators on this topic and this work try to cover this gap proposing a new indicator (SEIB) based both on national statistics data and participatory approach. SEIB key components are: employment, turnover and value-added, which are then aggregated for each Member State (MS) in order to show a picture of the current development of bioeconomy. Results allow clustering countries in different groups. Twelve MSs have a value of SEIB greater than European average for three components (Ireland with 0.456, Denmark with 0.400 and Netherlands with 0.331) this value exceeds the reference value (EU 28 equal to 0.252) by more than 30%. SEIB gives additional information than both turnover/workers and value added/workers, measuring not the absolute performance but comparing to the best performance. This indicator can be yearly monitored proposing a ranking among several MSs. The monitoring and assessment of indicators with management practices is a step required not only for European countries but should be performed on a global scale.

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