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RESEARCH ARTICLE

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Employing social accounting matrix multipliers to profile the bioeconomy in the EU member states: is there a structural pattern?[1]

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Abstract

The concept of 'bioeconomy' is gathering momentum in European Union (EU) policy circles as a sustainable model of growth to reconcile continued wealth generation and employment with bio-based sustainable resource usage. Unfortunately, in the literature an economy-wide quantitative assessment covering the full diversity of this sector is lacking due to relatively poor data availability for disaggregated bio-based activities. This research represents a first step by employing social accounting matrices (SAMs) for each EU27 member encompassing a highly disaggregated treatment of traditional 'bio-based' agricultural and food activities, as well as additional identifiable bioeconomic activities from the national accounts data. Employing backward-linkage (BL), forward-linkage (FL) and employment multipliers, the aim is to profile and assess comparative structural patterns both across bioeconomic sectors and EU Member States. The results indicate six clusters of EU member countries with homogeneous bioeconomy structures. *Within cluster* statistical tests reveal a high tendency toward 'backward orientation' or demand driven wealth generation, whilst *inter-cluster* statistical comparisons by bio-based sector show only a moderate degree of heterogeneous BL wealth generation and, with the exception of only two sectors, a uniformly homogeneous degree of FL wealth generation. With the exception of forestry, fishing and wood activities, bio-based employment generation prospects are below non bioeconomy activities. Finally, milk and dairy are established as 'key sectors'.

Additional key words: SAM; forward and backward-linkage multipliers; employment multipliers.

Introduction

In the 21st century, the issues of climate change, natural resource depletion, population growth and environmental degradation, to name but a few, are posing challenging questions for policy makers. As a significant political and economic player on the world stage, the European Union (EU) has taken a pro-active role in areas relating to greenhouse gas (GHG) emissions reductions, renewable energy usage and the greening of its agricultural policy. More recently, in 2012, a policy strategy paper (EC, 2012, p. 3) was released by the European Commission (EC) for a sustainable model of growth which could reconcile the goals of con-

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Abbreviations used: BL (backward linkage); CoV (coefficient of variation); EC (European Commission); EP (European Parliament); EU (European Union); FL (forward linkage); GHG (greenhouse gas); GTAP (Global Trade Analysis Project); I-O (input output table); RoW (Rest of the World); SAM (social accounting matrix).

[1] The views expressed are purely those of the author and may not in any circumstances be regarded as stating an official position of the European Commission.

tinued wealth generation and employment with sustainable resource usage. To this end, the term 'bioeconomy' was coined which, *«encompasses the production of renewable biological resources and the conversion of these resources and waste streams into value added products, such as food, feed, bio-based products and bioenergy»* (EC, 2012, p. 3). Under this definition, one is led to understand that bio-based output not only includes more obvious examples such as agricultural and food output, but can be extended to embrace any additional value added activities which employ organic matter of biological origin (*i.e.*, non-fossil) which is available on a renewable basis (*e.g.* plants, wood, residues, animal and municipal wastes, fibres etc.).

The EU's Bioeconomy Strategy (EC, 2012) is an attempt to stimulate research and development activities which can identify and enhance knowledge of bioeconomic markets and develop forward-looking policy recommendations to meet the aforementioned, and sometimes conflicting, challenges.[2] As an initial step to understanding the economic importance of the bioeconomy in the EU, one must first have a clear picture of the *status quo* relating to (*inter alia*) biomass' availability, potential bio-economic output and trade. Unfortunately, questions of this nature give rise to immediate concerns regarding data availability. For example, according to official estimates (EC, 2012) the EU bioeconomy represents a market worth over € 2 trillion, providing 20 million jobs and accounting for 9% of total employment. Notwithstanding, these estimates remain imprecise since there is a paucity of EU-wide comprehensive biomass balance sheets for varying uses (*i.e.*, trade, fuel, waste uses etc.) (M'barek *et al.*, 2014).[3] Furthermore, existing national accounts data, reported by Eurostat (2014a), has a very limited coverage of bioeconomic activities.

As a (partial) response to this data limitation, the current study employs a complete set of EU Member State social accounting matrices (SAMs). These SAMs, known as the AgroSAMs, were developed by the Joint Research Centre (JRC) of the EC (Müller *et al.*, 2009) and contain an unparalleled level of sector disaggregation of the traditional bio-based agricultural and food sectors.[4] In this study, we update the AgroSAM to a more recent year, with the aim of profiling and assessing comparative structural patterns within 'identifiable' bioeconomic sectors across EU Member States. In particular, the analysis also sets out to recognize those bioeconomic sectors which potentially maximise economic value added, with a view to formulating a coherent approach for reconciling wealth- and/or employment generation with sustainable resource usage.

As a tool of analysis, this research follows previous SAM based multiplier studies relating to agriculture (Waters *et al.*, 1999; Rocchi, 2009) and the macroeconomy (Cardenete & Sancho, 2006), although in this study this is applied in a novel way to understand the inter-linkages between detailed bioeconomic accounts and the wider economy. Employing statistical techniques, the objective of the paper is to create a typical profile of bioeconomic activity , both across sectors and regions, and to identify certain bioeconomic activities with greater than average wealth generating properties as 'key sectors'. A further *ex-post* assessment is carried out for those 'key sectors' to evaluate the extent to which they have thrived in the ensuing period.

Material and methods

SAMs and multipliers

The main theoretical developments in social accounting owe much to the work of Stone (1955) by integrating the production accounts (in the form of input-output tables) into the national accounts to create an economy-wide database. The resulting SAM database, an example of which is presented in Table 1, is a square matrix which, for a given time period, provides a comprehensive, complete and consistent picture of all economic transactions between productive and non-productive institutions and markets, such as factor markets, savings-investments, households, government, and the

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[2] Indeed, encouraging biomass usage for energy may adversely affect carbon sequestration and therefore GHG emissions limits. Similarly, implementing a strategy for responsible sustainable growth may induce limits on employment generation in times of post-crisis. For a detailed analysis of different viewpoints on the relationship between the bioeconomy and sustainability, see Pfau *et al.* (2014).

[3] Biomass is defined as the 'Biodegradable fraction of products, waste and residues from agriculture (including vegetal and animal substances), forestry and related industries, as well as the biodegradable fraction of industrial and municipal waste' (Eurostat, 2014b)

[4] This paper confines itself to a discussion of the 27 EU Members (*i.e.*, pre-2013 accession)

Table 1. Stylized macro social accounting matrix (SAM) structure

	Activities	Commodities	Labour	Capital	Enterprises	Households	Government	Capital account	RoW	Total
Activities		Supply matrix								Domestic supply
Commodities	Intermediate inputs					Households consumption	Government consumption	Investments	Exports	Commodity demand
Labour	Compensation of employees								Labour income from abroad	Labour income
Capital	Operating surplus									Capital income
Enterprises				Distribution of capital income			Transfer to enterprises			Enterprises income
Households			Distribution of labour income	Distribution of capital income			Transfer to households			Households income
Government	Production taxes and subsidies	Sales tax		Distribution of capital income	Direct tax	Direct tax			Transfer from abroad	Government income
Capital account					Enterprises savings	Households Savings	Government savings/deficit		Foreign savings	Savings
RoW		Imports	Labour income paid abroad				Transfer			RoW income
Total	Total production	Commodity supply	Labour	Capital	Enterprise expenditure	Households expenditure	Government expenditure	Investments	RoW expenditure	

RoW: Rest of the world.

rest of the world. Thus, each cell entry simultaneously depicts an expenditure flow from column account 'j' and an income flow to row account 'i', whilst corresponding column and row account totals (i = j) must be equal (*i.e.*, total expenditure equals total income).

Due to its accounting consistency, comprehensiveness in recording data and flexibility, the SAM approach (fix price linear models) in the last three decades has been extensively used to analyse (*inter alia*) growth strategies in developing economies (Robinson, 1989), income distribution and redistribution (Roland-Holst & Sancho, 1992), the circular flow of income (Pyatt & Round, 1979; Defourny & Thorbecke, 1984; Robinson & Roland-Holst 1988), price formation (Roland-Holst & Sancho, 1995), structural and policy analysis of the agricultural sector in developed (Rocchi, 2009) and developing countries (Arndt *et al*., 2000), and the effects of public policy on poverty reduction (De Miguel-Velez & Perez-Mayo, 2010).

Within a SAM model, all (endogenous[5]) accounts can be ranked according to a hierarchy derived from two 'traditional' types of multiplier indices, known as the backward linkage (BL) and a forward linkage (FL), calculated from the Leontief inverse (Rasmussen, 1956).[6] Both FL and BL are 'relative' measures of supplier-buyer relationships within the economy under conditions of Leontief (fixed-price) technologies. More specifically, for each activity, the FL follows the distribution chain of bioeconomic outputs to end users, whilst the BL examines upstream inter-linkages with intermediate input suppliers. Thus, for a given sector, a BL or FL exceeding one implies that € 1 of intermediate input demand (BL) or supply (FL) generates a greater than average level (*i.e*., greater than € 1) of wealth compared with the remaining sectors of the economy. A sector with backward (forward) linkages greater than one, and forward (backward) linkages less than one, is classified as backward (forward) orientated. If neither linkage is greater than one, the sector is designated as 'weak', whilst 'key sectors' are those which exhibit FL and BL values greater than one.

As a further tool of analysis, employment multipliers are calculated to examine the generation of la-

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[5] The endogenous accounts are those for which changes in expenditure directly follow any change in income, while exogenous accounts are those for which expenditures are set independently of income. In SAM models, Government and Rest of the World are typically held as exogenous.

[6] As a substitute to the 'traditional' multiplier approach, the 'hypothetical extraction' model approach has also been employed (*e.g*. Schultz, 1977; Dietzenbacher & Van der Linden, 1997) to assess the importance of a sector by analysing the impacts from its elimination.

bour resulting from additional bioeconomic activity. More specifically, the employment multiplier calculates the resulting 'direct', 'indirect' and 'induced' ripple effects resulting from an increase or decrease in output value in activity 'j'. Thus, the direct employment effect is related to the output increase in the specific activity 'j', the indirect employment effect is the result of a higher level of supporting industry activity, whilst the induced employment effect is due to the change in household labour income demand for sector 'j'.[7]

AgroSAM database and update to 2007[8]

An important obstacle to using a SAM based analysis for analysing the bioeconomy is the high degree of sector aggregation typically found in the national accounts data. As the main data source for constructing the SAM accounts, EU member state Supply- and Use-Tables (SUT) traditionally represent bioeconomic activities as broad aggregates (*i.e.*, agriculture, food processing, forestry, fishing, wood, pulp) or even subsume said activities within their parent industries (*e.g.* chemical sector, wearing apparel, energy). Consequently, this limits the scope of any study attempting to perform a detailed analysis of the bioeconomy; whether it is SAM based (multipliers) or employing a computable general equilibrium (CGE) framework.

As a (partial) response, a set of SAMs for each EU Member State, dubbed the 'AgroSAMs', was developed (Müller *et al.*, 2009).[9] This data source is the only EU-wide SAM based dataset of its type, whilst a further important characteristic is the potential analytical insight resulting from the unparalleled level of sector disaggregation of the bio-based agricultural and food sectors (28 and 11 accounts, respectively). The construction of the AgroSAMs involved three main steps (Müller *et al.*, 2009): consolidating macroeconomic indicators for the EU27; combining Eurostat datasets into a set of SAMs with aggregated agricultural and food-industry accounts and finally; the disaggregation of agri-food accounts employing the Common Agricultural Policy Regionalised Impacts analysis modelling system (CAPRI) database (Britz & Witzke, 2012).

With the exception of the agriculture and food accounts, the AgroSAM follows the same sectoral concordance as the Eurostat SUTs. Thus, of the 97 activity/commodity accounts, 29 cover primary agriculture, one agricultural services sector, 7 primary sectors (forestry, fishing and mining activities), 12 food processing, 20 (non-food) manufacturing and construction, and 29 services sectors. In addition, the AgroSAM contains two production factors (capital and labour), trade and transportation margins and several tax accounts (taxes and subsidies on production and consumption, VAT, import tariffs, direct taxes).[10] Finally, there is a single account for the private household, corporate activities, central government, investments-savings and the rest of the world.

Although the AgroSAM provides a detailed disaggregation of agriculture and food related bio-economic activities, the benchmark year of 2000 was no longer considered to be relevant for meaningful policy analysis. Consequently, it was deemed necessary to perform an update procedure prior to carrying out any subsequent multiplier analysis. A reasonably proximate year of 2007 was selected based on the availability of Eurostat SUT information for all EU Member States. Apart from the potential structural bias that may arise when updating over long time periods, it was also not deemed wise to choose a 'crisis' period (*i.e.*, post 2007) since the resulting shock to the economic system may have accelerated structural change even further.[11]

As an initial step, all non agro-food productive rows and column cell entries are overwritten with external data from the 2007 EU27 SUT tables (*i.e.*, structure of industry costs, commodity supplies, exports, imports, household- corporation- and government-final demands, gross fixed capital formation, stock changes, margins and net taxes on production and products). In a second step, the resulting SAM was inputted into a modified version of the SAMBAL program for square matrices (Horridge, 2003). Aside from maintaining the corresponding row and column balances, the SAM-

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[7] See the Suppl Table 1 [pdf online] for a technical description of the multipliers used in this analysis.

[8] Subject to approval, the AgroSAM data are available from JRC IPTS upon request.

[9] In the latest two versions of the GTAP database (vers. 7 and 8), this dataset has been employed to populate the I-O tables of the 27 EU member countries in the GTAP database.

[10] The direct tax accounts include «Property income», «Current taxes on income and wealth», «Social contributions and benefits», «Other current transfers» and «Adjustment for the change in net equity of households in pension funds reserves»

[11] In those cells where update assumptions are applied, it is recognised that the temporal gap should not be excessive in order the limit structural change bias in the resulting updated SAM arising from technological change in the ensuing period.

BAL program is further modified with additional code to (i) target aggregate agricultural and food column totals to 2007; (ii) maintain 2007 Eurostat SUT non agri-food target totals as close as possible, and (iii) preserve the economic structure of the SAM.

To achieve this, exogenous multiplier variables in each equation are swapped with target variables. Furthermore, the update procedure also incorporates a set of behavioural equations for certain flow values with a view to maintaining, as much as possible, the structural integrity of the SAM, thereby avoiding large fluctuations in cell values when the balancing procedure is carried out. For example, taxes, subsidies and retail/transport margins are assumed to change proportionally with the transactions upon which they are levied. Moreover, given the difficulty of finding detailed institutional accounts data for all of the EU27 members, it is assumed in the pre-crisis period (2000 to 2007) that cell entries vary in proportion to GDP.

For the agricultural industry accounts, the technical coefficients in the existing AgroSAM were maintained subject to 2007 target data for value added and intermediate cost totals taken from the Eurostat's 'economic accounts for agriculture' (Eurostat, 2014a). This data source was also employed to implement subsidies on production and products for the 28 agricultural accounts. Target values for agricultural and food exports and imports in 2007 were calculated employing the COMEXT database (Eurostat, 2014a), where a concordance was carried out between the agricultural and food sectors in the AgroSAM and the Eurostat HS2-HS4 sectors, supplemented by a HS6 concordance where necessary. To maintain the macro restriction equating GDP by income and expenditure, data for 2007 on aggregate demand by components are also taken from Eurostat (2014a).

Results

Statistical profiling of the EU regional clusters

As a first step, BL and FL multipliers from the 43 selected bioeconomy sectors (Table 2) are employed as segmenting variables to derive homogenous country groupings. For this purpose, a hierarchical clustering technique is applied, where the number of clusters or groups is not determined *a priori*, but rather based on the results of a dendrogram. The dendrogram graphically depicts how objects (*e.g.*, countries) are grouped sequentially into a fewer number of groups.[12] Any clustering technique needs a measure of the distance (*i.e.* dissimilarity) between objects, and a linkage method for forming the clusters. Given that our data are continuous, the Euclidean distance is selected. Among alternative linkage methods the Ward linkage is used.[13]

Only those sectors where a clear bioeconomic input is identifiable are chosen (based on an examination of the intermediate input structure in the SUTs across the 27 EU members in 2007). As can be seen from Table 2, the majority are agriculture and food related, whilst additional sectors include forestry (*i.e.*, timber production); fishing; pulp and wood based manufacturing. On the other hand, those (aggregate) sectors such as chemicals, textiles, energy etc. where a bio-economic input is present, were discarded owing to a large non bio-economic component in that sector.

The inspection of the dendrogram generated by the hierarchical cluster analysis reveals six potential groupings (Table 3), which for the most part, fall into recognisable geographical clusters. These clusters are labelled 'Northern EU', 'Luxembourg', 'Mediterranean Islands', 'Mediterranean and Eastern EU', 'Central EU' and a residual cluster called 'Mixed'.

In an attempt to further characterise the regional clusters, statistically significant heterogeneous patterns are explored based on both economic- (*i.e.*, per capita incomes; unemployment rates; employment in agriculture, forestry and fishing) and biophysical indicators (*i.e.*, land cover statistics) taken from Eurostat (2014a) (Table 4).[14] Results show statistical differences in per capita income (GDPpc, $p < 0.01$) and unemployment rates (UnRate, $p < 0.05$) across the six clusters, although there is no perfect ranking of clusters in terms of per capita income (social 'good') and unemployment rates (social 'bad'). On the one hand, Luxembourg enjoys the highest income index (267.8) and the lowest unemployment rate (5.2%) and 'Northern EU' and 'Central

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[12] This is an agglomerative approach. Alternatively, a divisive clustering can also be applied, which starts with only one all-inclusive cluster, and by successive splitting ends up with single clusters with only one individual.

[13] The Ward linkage evaluates the distance between clusters with an Analysis of Variance (*i.e.*, it minimizes the sum of squares of any two hypothetical clusters that can be formed at each step).

[14] An ANOVA test is applied to examine differences in means of all these descriptors across clusters, whilst a W-test replaces the ANOVA when heterogeneous variances are found with the Levene statistic.

Table 2. Description of original and aggregated bioeconomy sectors

Description of individual sectors	Description of aggregated sectors	Sectoral aggregation code
1 Production of other wheat 2 Production of durum wheat 3 Production of barley 4 Production of grain maize 5 Production of other cereals 6 Production of paddy rice	Cereals	Cereal
7 Production of rape seed 8 Production of sunflower seed 9 Production of soya seed 10 Production of other oil plants	Oilseeds	Oilseed
11 Production of other starch and protein plants 12 Production of potatoes	Starch and protein products	Starch
13 Production of sugar beet 14 Production of fibre plants	Industrial products	Industrial
15 Production of grapes 16 Production of fresh vegetables, fruit, and nuts	Fruits and vegetables	FrVeg
17 Production of live plants 18 Other crop production activities 19 Production of fodder crops	Other crops	Ocrops
20 Production of raw milk from bovine cattle, sheep and goats	Raw milk	Rmk
21 Production of bovine cattle, live 22 Production of sheep, goats, horses, asses, mules and hinnies, live	Extensive live animals and animal products	ExtLiveProd
23 Production of swine, live 24 Production of eggs 25 Production of poultry, live	Intensive live animals and animal products	IntLiveProd
26 Production of wool and animal hair; silk-worm cocoons suitable for reeling 27 Production of other animals, live, and their products	Other live animals and animal products	OLiveProd
28 Forestry, logging and related service activities	Forestry	Forestry
29 Fishing, operation of fish hatcheries and fish farms; service activities incidental to fishing	Fishing	Fish
30 Processing of rice, milled or husked 31 Production of other food	Other food products	OFoodRice
32 Processing of sugar	Sugar	Sugar
33 Production of vegetable oils and fats, crude and refined; oil-cake and other solid residues, of vegetable fats or oils	Vegetable oils	Vol
34 Dairy	Dairy	Dairy
35 Production of meat of bovine animals, fresh, chilled, or frozen 36 Production of meat of sheep, goats, and equines, fresh, chilled, or frozen	Red meat	RedMeat
37 Production of meat of swine, fresh, chilled, or frozen 38 Meat and edible offal of poultry, fresh, chilled, or frozen	White meat	WhMeat
39 Production of beverages 40 Manufacture of tobacco products	Beverages and tobacco	BevTob
41 Production of prepared animal feeds	Animal feed	AnFeed
42 Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials 43 Manufacture of pulp, paper and paper products	Wood and paper	WoodPaper

Table 3. Cluster classification based on backward and forward linkages

Cluster	Name	Member State Composition
Cluster 1	'Northern EU'	Denmark, Finland, Lithuania, Latvia, Poland, Sweden, United Kingdom, Belgium, Netherlands
Cluster 2	'Mixed'	Estonia, Ireland and Slovenia
Cluster 3	'Luxembourg'	Luxembourg
Cluster 4	'Mediterranean Islands'	Cyprus, Malta
Cluster 5	'Mediterranean and Eastern EU'	Spain, France, Greece, Italy, Portugal, Bulgaria, Romania, Hungary
Cluster 6	'Central EU'	Austria, Czech Republic, Germany, Slovakia

Table 4. Profile of clusters based on macroeconomic and bioeconomic indicators

Indicators[1]	Northern EU	Mixed	Luxembourg	Med. Islands	Med. & Eastern EU	Central EU
GDPpc***	101.2	94.9	267.8	90.0	79.0	99.7
UnRate**	12.7	25.0	5.2	7.3	14.1	13.5
EmplPrim	4.9	5.9	1.3	2.5	9.3	3.3
Cropland*	22.7	9.1	18.3	22.8	30.8	28.1
Woodland	39.2	44.7	30.5	17.3	35.3	41.3
Grassland***	1.5	1.8	0.3	18.2	7.2	1.2

[1] Per capita GDP (GDPpc) is a mean index based on values between 2007 and 2012. Percentage rates for unemployment (UnRate) and workers employed in 'agriculture, forestry and fishing' (EmplPrim) are also means based on values between 2007 and 2012. The remaining land use statistics are ratios in percentage form based on 2012 data. ***, **, * mean significant differences of the descriptor mean across clusters at 1, 5 and 10% level of significance, respectively. Based on the ANOVA analysis when Levene statistic does not reject the null of homogeneity of variances, or otherwise the W test.

EU' clusters exhibit average EU per capita income and intermediate unemployment rates (12-13%). On the other hand, the 'Mixed' grouping with a per capita income close to the EU average (94.9) displays the highest unemployment rate (25.0%), whilst 'Mediterranean and Eastern EU' and 'Mediterranean Islands' have the lowest per capita incomes but with lower to intermediate unemployment rates (7.3% and 14.1%, respectively). No statistically significant differences were found for the proportion of the total workforce engaged in 'agriculture, forestry and fishing' activities (EmplPrim).

Statistically significant differences are also evident in terms of the percentage of total land employed for crops (Cropland, $p < 0.10$) and pasture (Grassland, $p < 0.01$), whilst the percentage of woodland use was not found to be significantly different across regional clusters. Indeed, relatively higher levels of cropland use are evident in 'Mediterranean and Eastern EU' (includes France, Spain, Romania) and Central EU (includes Germany), whilst in the clusters covering Mediterranean and Eastern EU areas, the relative usage of pasture land is also considerably higher.

Statistical profiling of bioeconomy sector multipliers

Examining the 21 specific bioeconomy sector multipliers[15] (Table 5) shows a number of examples of BL multipliers which are greater than one. In other words, € 1 of output change generates more than € 1 of demand for intermediate inputs. The result suggests that there is considerable scope for bioeconomic activity to generate above average wealth in upstream supply sectors. In the remaining bioeconomy sectors (fishing, forestry, wood and paper), BL values are also generally

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[15] The 43 bio-economic sectors are collapsed to 21 which reflect similar activity groupings (see Table 1). Initially FL and BL multipliers were employed within a statistical factor analysis but the resulting data reduction did not generate any sensible sector groupings.

Table 5. Backwards and forward linkages in each cluster[1]

Sector	Northern EU		Mixed		Luxembourg		Mediterranean Islands		Mediterranean and Eastern EU		Central EU	
	Backward	Forward	Backward	Forward	Backward	Forward	Backward	Forward	Backward	Forward	Backward	Forward
Cereal ^{bbb}	0.70	0.45^{***}	0.67	0.42	0.83	0.44	0.44	0.33	0.94	0.49^{***}	0.82	0.45^{***}
Oilseed ^{bbb}	0.62	0.31^{***}	0.48	0.32	0.49	0.33	0.43	0.33	0.81	0.31^{***}	0.95	0.38^{***}
Starch	1.00	0.48^{***}	0.88	0.48^{***}	1.20	0.38	0.78	0.54	0.97	0.45^{***}	0.97	0.40^{***}
Industrial ^{bbb,ff}	0.94	0.34^{***}	0.25	0.25	0.31	0.31	0.31	0.31	0.87	0.29^{***}	0.79	0.30^{**}
FrVeg ^{bbb,fff}	0.68	0.31^{***}	0.70	0.32^{***}	0.80	0.32	0.94	0.70^{**}	1.02	0.54^{***}	0.65	0.27^{***}
Ocrops ^{bbb}	0.89	0.47^{***}	0.81	0.53^{**}	0.98	0.73	0.78	0.52	0.77	0.48^{***}	0.87	0.40^{***}
Rmk	1.20	1.20	1.25	1.18	1.71	1.62	1.19	1.16	1.11	0.97	1.08	1.16
ExtLiveProd ^{bb}	1.21	0.57^{***}	1.21	0.61^{***}	1.01	0.55	1.12	0.64^{**}	1.10	0.57^{***}	1.13	0.52^{***}
IntLiveProd ^{bb}	1.23	0.63^{***}	1.22	0.59^{***}	0.79	0.34	1.19	0.76^{***}	1.13	0.62^{***}	1.21	0.58^{***}
OLiveProd	0.69	0.29^{**}	0.64	0.29	0.80	0.32	0.77	0.56	0.60	0.29^{***}	0.60	0.27^{***}
Forestry	1.19	0.63^{***}	1.30	0.68^{**}	1.27	0.42	0.71	0.34	1.14	0.48^{***}	1.16	0.82^{**}
Fish	1.11	0.39^{***}	1.21	0.44^{**}	0.31	0.31	1.30	0.62	1.08	0.35^{***}	1.12	0.32^{***}
OFoodRice ^{bbb}	0.85	0.62^{***}	1.22	0.46	0.96	0.32	0.86	0.61	1.20	0.66^{***}	1.02	0.54
Sugar	1.12	0.38^{***}	0.76	0.32	1.08	0.39	0.31	0.31	1.03	0.33^{***}	1.07	0.36^{***}
Vol	0.87	0.34^{***}	1.13	0.32^{**}	1.12	0.68	0.31	0.31	0.96	0.43^{***}	1.08	0.38^{***}
Dairy	1.38	1.09^{**}	1.39	1.20	1.99	0.54	1.51	0.94	1.32	0.91^{***}	1.30	0.89^{**}
RedMeat	1.40	0.42^{***}	1.36	0.54^{**}	1.63	0.38	1.38	0.52	1.27	0.49^{***}	1.35	0.41^{***}
WhMeat	1.42	0.50^{***}	1.34	0.52^{***}	1.06	0.46	1.52	0.67	1.31	0.55^{***}	1.36	0.44^{***}
BevTob ^{bbb}	1.00	0.36^{***}	0.69	0.30^{***}	1.23	0.46	1.32	0.50	1.10	1.12	0.38	0.38^{***}
AnFeed	1.14	0.81^{**}	1.18	0.85^{**}	1.20	1.73	1.10	0.82	1.08	0.73^{**}	1.07	0.68^{***}
WoodPaper ^{bb}	1.24	0.73^{***}	1.26	0.68^{**}	1.14	0.66	1.34	0.61^{**}	1.14	0.64^{***}	1.22	0.73^{***}
St. Dev.	0.24	0.25	0.33	0.27	0.41	0.39	0.42	0.23	0.18	0.23	0.25	0.23
Mean	1.04	0.53	1.00	0.53	1.05	0.55	0.91	0.56	1.03	0.54	1.01	0.50
Coef. Variation (CoV)	23%	47%	33%	51%	39%	70%	46%	40%	18%	42%	25%	47%

[1] Means comparisons tests excludes 'Luxembourg' and 'Mediterranean Islands'. $^{***, **}$ Represent significant mean differences between backward and forward linkages, using a paired t-test, at 1% and 5% level of significance, respectively. $^{bbb, bb\ (fff, ff)}$ Represent significant differences of the mean of backward (forward) linkages across clusters, at 1 and 5% level of significance, respectively, based on the ANOVA analysis when Levene statistics does not reject the null of homogeneity of variances, or the W test, otherwise.

high, also suggesting above average wealth generation potential for those sectors and factors of production which support these bio-based activities.

Examining the mean backward linkage multipliers *within each EU cluster* (bottom rows, Table 5), 'Northern EU', 'Mediterranean and Eastern EU' and 'Central EU' are characterised by BL values greater than one and a relatively lower coefficient of variation (CoV). These clusters therefore contain a reasonably strong and homogeneous structural classification of bioeconomy sector demand driven wealth effects. On the other hand, in the clusters 'Luxembourg' and 'Mediterranean Islands' (*i.e.*, Cyprus and Malta), there is a more heterogeneous range of demand driven wealth effects owing to the narrower focus of bioeconomic activity in these small regions.

In contrast, low FL multipliers across bioeconomic sectors within each EU cluster (Table 5) demonstrate that the level of per unit activity required to process and distribute one unit of a given bio-economic sector's output to end users is limited. Examining the FL multipliers within each of the six clusters (bottom rows, Table 5), the mean values are remarkably uniform, whilst CoVs are generally higher (vis-à-vis BL multipliers) implying that supply driven wealth effects across different bioeconomic activities are more varied.

Interestingly, animal related (*i.e.*, meat, livestock, milk, dairy and animal feed sectors), 'wood and paper' and 'forestry' sectors in (almost) all clusters have significant buyer generating wealth potential (*i.e.*, mean BL multipliers greater than one). By contrast, cropping activities (*i.e.*, industrial crops, other crops, cereals, fruit and vegetables, oilseeds) have mean BL multipliers of less than one in all clusters. In terms of FL mean multipliers, only dairy and raw milk sectors have values which are consistently close to, or above one.

Additional statistical tests focus on identifying bioeconomic structural heterogeneity *across the six clusters*. In other words, the aim is to understand the extent (if any) to which demand and supply driven wealth generation in a given bioeconomic sector differs across the EU region clusters. Thus, a paired t-test (5% significance) is conducted in order to ascertain the presence of a statistically significant difference in the mean BL and FL for each of the 21 sectors (Table 5).[16] Of the 21 bio-economic sectors under consideration, there are numerous examples of statistically significant differences between mean FL and BL values in 'Northern EU' (21 sectors), 'Mediterranean and Eastern EU' (20 sectors), 'Central EU' (20 sectors) and in the 'Mixed' grouping (14 sectors), owing to the pervasiveness of relatively higher BLs discussed above. The only exception to this trend appears to be the 'Mediterranean Islands' where relatively stronger BL mean multipliers are restricted to 'fruit and vegetables', both livestock sectors and 'wood and paper'. Interestingly, the statistically significant difference in the mean FL and BL multipliers in five of the six clusters for these four specific bio-economic activities confirms that the bioeconomy has a high degree of 'backward orientation'.

Furthermore, two sets of one-way ANOVA tests focus on the differences in the BL mean multiplier by sector and the FL mean multiplier by sector *comparing across the six EU country clusters*. Of the 21 sectors, 16 (six) sectors show statistically significant structural differences in the BL (FL) across the *six* clusters (not shown). Notwithstanding, repeating the test across only *four* clusters (excluding 'Luxembourg' and 'Mediterranean Islands', which between them include only three EU members with less than 1% of EU27 Gross Domestic Product), the degree of statistical significance falls to only ten and two sectors for BL and FL multiplier means, respectively (Table 4).[17] In other words, bioeconomic BL (FL) wealth generation on a sector-by-sector basis is statistically homogeneous in 12 (20) of the 21 sectors considered.

Examining the four clusters of EU Member States, there is a statistically significant heterogeneity in BL wealth generation for 'cereals', 'oilseeds', 'industrial crops', 'fruit and vegetables', 'other crops', 'extensive livestock', 'intensive livestock', 'other food and rice', 'beverages and tobacco' and 'wood and paper'. A closer look reveals that in 'cereals', 'oilseeds', 'industrial crops' and 'other crops' sectors, the strongest BL multipliers are reported in the 'Mediterranean and Eastern EU' and 'Central EU' clusters. On the other hand, the 'Mediterranean and Eastern EU' cluster contains relatively stronger BL multipliers in 'fruit and vegetables'. In intensive and extensive livestock activities, whilst BL multipliers are strong in all four clusters, 'Northern EU' and 'Mixed' clusters exhibit the strongest BL multipliers across the two sectors, whereas in the beverages and tobacco sectors, 'Mixed' and 'Central EU' have very weak BL multipliers. Finally, in 'wood and paper', 'Northern EU', 'Mixed' and 'Central EU' clusters exhibit the strongest BL multipliers. In two of the aforementioned ten sectors ('industrial crops' and 'fruit and vegetables'), there is also statistically significant heterogeneity across the four EU clusters in terms of FL wealth generation. This suggests that both sectors have very disparate input-output structures across the EU.

Bioeconomy employment multipliers

Employment multipliers are presented in Table 6, defined as the number of new jobs generated per million euros of additional output value (see Suppl. Table S1 [pdf online] for details). Calculations are presented for raw milk and dairy (see next subsection), forestry, fishing, wood, pulp and the aggregate sectors 'agri-food' and 'bioeconomy'.[18] For the EU27, the employment multiplier analysis suggests the creation of 14 new posts for every million euros of additional bioeconomic output value.[19] In comparison, the corresponding EU27 average for non-bioeconomy sectors reveals a slightly higher level of job creation (17 jobs/million euros). This finding is broadly robust across all EU27 Member States (ex-

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[16] In group 3, there is only one observation per sector (*i.e.* Luxembourg), so this test is not performed.

[17] This result suggests that Luxembourg, Cyprus and Malta are structural outliers which increases the tendency to reject the null hypothesis (*i.e.* means are equal) across the six groups. For example, in the case of fish (both FL and BL multipliers) Luxembourg has no industry, whilst for the Cyprus and Malta cluster, as expected, these sectors are (relatively speaking) strategically more important compared with the other clusters.

[18] Given the relative output value share weight of agri-food activity within the definition of bioeconomy employed here, the multipliers in both aggregates move closely together.

[19] Note that the broadness of the definition of bioeconomy is limited in this study

Table 6. Employment generation (head) per million euros of output value

Region	Milk	Dairy	AgFood	Forestry	Fishing	Wood	Pulp	Bioecon [1]	NonBioecon
Belgium	5	7	9	16	8	9	8	**9**	**12**
Bulgaria	24	48	50	135	68	114	73	**55**	**89**
Czech Rep.	25	23	32	40	42	43	28	**34**	**33**
Denmark	7	5	8	14	9	11	10	**9**	**12**
Germany	8	10	13	16	16	15	12	**13**	**17**
Estonia	51	25	33	33	45	33	24	**33**	**33**
Ireland	4	6	6	16	12	15	9	**7**	**12**
Greece	7	13	12	81	29	45	16	**14**	**22**
Spain	12	13	14	24	27	22	14	**15**	**20**
France	11	10	11	9	18	13	10	**11**	**14**
Italy	7	11	10	58	31	18	11	**12**	**16**
Cyprus	11	15	16	172	18	29	21	**18**	**27**
Latvia	41	35	37	26	38	40	36	**36**	**45**
Lithuania	25	26	33	58	54	54	39	**38**	**46**
Luxembourg	3	3	9	19	0	6	2	**7**	**6**
Hungary	22	21	26	74	95	70	27	**29**	**36**
Malta	1	1	2	0	3	3	2	**2**	**3**
Netherlands	4	5	7	50	9	12	8	**7**	**14**
Austria	5	7	9	13	15	11	9	**10**	**12**
Poland	16	20	25	0	63	52	31	**29**	**41**
Portugal	13	15	20	23	35	33	19	**22**	**31**
Romania	23	38	29	110	129	88	41	**35**	**56**
Slovenia	9	13	15	59	39	32	18	**20**	**24**
Slovakia	25	17	27	43	28	40	22	**30**	**28**
Finland	5	7	8	8	15	10	8	**9**	**13**
Sweden	9	8	9	9	13	10	9	**9**	**13**
UK	7	8	11	21	12	15	9	**11**	**12**
EU27	**10**	**11**	**13**	**19**	**23**	**21**	**12**	**14**	**17**
EU15	**8**	**9**	**11**	**14**	**22**	**15**	**11**	**12**	**15**
EU12	**21**	**22**	**28**	**39**	**51**	**52**	**30**	**32**	**40**
EU10	**20**	**20**	**27**	**29**	**46**	**46**	**28**	**30**	**36**
EU2	**23**	**40**	**33**	**115**	**100**	**91**	**48**	**39**	**63**

[1] The definition of bioeconomy is extended to only include agri-food, forestry, fishing, wood and pulp/paper activities. As noted in the main text, owing to data limitations, there is no bioenergy, biochemical and textiles component.

cept for the Czech Republic, Luxembourg and Slovakia), whilst in the 2007 Balkan accession members (EU2), non bioeconomy job creation is notably higher. Interestingly, the results suggest that forestry, fishing and wood sectors are relatively strong bioeconomy drivers of job creation (Table 6), where the latter two sectors in particular compare favourably across all EU regions in relation to the non-bioeconomy averages.

A further breakdown by Member States reveals that fishing is the largest generator of new posts in the EU15 (22 jobs/million euros); fishing and wood sectors in the EU10 (both 46 jobs/million euros), whilst in the EU2 forestry and fishing sectors (115 and 100 jobs/million euros, respectively) have the highest job creation potential. The highest bioeconomy job creation figures appear in the Balkan (Bulgaria and Romania) and Baltic regions (Lithuania and Latvia), which contrasts with the average for the EU15 (12 posts/million euros).[20] As a member of the EU10, but with scarce natural resources, Malta exhibits the lowest average level of bioeconomy job creation (only two posts per million euros) with consistently low levels of job creation across individual bioeconomic activities.

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[20] Amongst the EU15 members, the highest employment multipliers are in Spain (15 jobs/million euros) and Greece (14 jobs/million euros) - the two EU15 and eurozone regions with the highest unemployment rates.

Table 7. Backward and forward linkages in raw milk and dairy for the EU27

Sector Linkage	Milk		Dairy	
	BL	FL	BL	FL
Austria	1.119	1.158	1.362	0.768
Belgium	1.112	0.722	1.310	0.792
Bulgaria	0.974	1.588	1.437	0.959
Cyprus	1.086	1.347	1.589	0.955
Czech Republic	1.103	1.069	1.286	0.994
Denmark	1.283	1.113	1.486	1.218
Estonia	1.388	1.424	1.354	1.528
Finland	1.008	1.428	1.338	0.956
France	1.108	0.896	1.315	0.874
Germany	1.073	0.969	1.364	0.86
Greece	1.221	0.963	1.329	0.853
Hungary	1.102	1.060	1.242	1.125
Ireland	1.114	0.977	1.469	1.049
Italy	1.194	0.821	1.349	0.722
Latvia	1.369	1.901	1.507	0.932
Lithuania	1.296	1.677	1.336	1.432
Luxembourg	1.706	1.623	1.988	0.545
Malta	1.291	0.983	1.438	0.929
Netherlands	1.098	1.177	1.461	1.245
Poland	1.331	1.070	1.221	1.628
Portugal	0.994	0.957	1.294	0.987
Romania	1.233	0.794	1.333	1.036
Slovakia	1.015	1.426	1.207	0.943
Slovenia	1.239	1.137	1.346	1.033
Spain	1.097	0.697	1.284	0.757
Sweden	1.208	0.877	1.427	0.924
United Kingdom	1.100	0.807	1.324	0.679

BL: backward linkage. FL: forward linkage.

Key sector analysis

Focusing on the identification of key sectors within the bioeconomy, the results (Table 5) show a clear tendency toward the EU's raw milk and dairy supply chain. Under the strict definition (*i.e.*, BL and FL > 1), raw milk is a key sector in five of the six clusters except the 'Mediterranean and East EU', whilst dairy is a key sector in the 'Northern EU' and 'Mixed' regions. Loosening the definition to 'potential key' sectors (*i.e.*, BL and FL both greater than 0.9), dairy is a key sector in four clusters ('Northern EU', 'Mixed', 'Mediterranean Islands', 'Mediterranean and East EU') and raw milk is a key sector in *all* six clusters. Nevertheless, t-test results reveal that the null hypothesis cannot be rejected that raw milk and dairy BL and FL are at least one in the whole sample and within each cluster.[21]

Examining the BLs and FLs for all EU27 Member States (Table 7) reveals that raw milk is *potentially* (*i.e.*, FL and BL > 0.9) a key sector in 20 of the 27 EU members (except Belgium, France, Italy, Romania, Spain, Sweden and the UK). Similarly, dairy is *potentially* a key sector in 18 of the 27 EU members (except in Austria, Belgium, France, Germany, Greece, Italy, Luxembourg, Spain and the UK).

The employment multipliers for raw milk and dairy exhibit a similar regional pattern highlighted in the previous section. More specifically, higher multipliers are positively correlated with those EU members with lower per capita incomes. The highest employment multipliers in raw milk are found in the Baltic regions of Estonia (51 posts/million euros of value) and Latvia (41 posts/million euros of value), whilst in dairy the highest employment multipliers are exhibited in the Balkan regions of Bulgaria (48 posts/million euros of value) and Romania (38 posts/million euros of value), as well as Latvia (35 posts/million euros of value). Importantly, comparing with the agri-food and bioeconomy sector averages (Table 7), the level of job creation in raw milk and dairy is, in general, lower, which reflects the higher degree of capitalisation within these sectors.

From a policy perspective, this research suggests that for most EU members, raw milk and dairy bio-based sectors constitute a priority in terms of wealth generation, although neither is a strong employment generator. Notwithstanding, given the choice of benchmark year (2007), it is interesting to conduct an *ex-post* analysis to ascertain the extent to which said key sectors have performed in the ensuing period. As an initial observation, in the financial crisis period between 2007 and 2011, Eurostat (2014a) figures reveal that the EU dairy sector posted impressive growth of 5.5% in milk production and 4.3% in cheese. These statistics compare with an agricultural sector increase of 2% while food industry production witnessed a decrease of 1.7%. Indeed, despite high energy and feed prices, and the abolition of export refunds, milk and dairy related industries continued to thrive in a climate of economic downturn. This is due to favourable demand conditions on the world market as well as steady improvements in cow yields (DG-AGRI, 2013).

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[21] BL and FL in each sector and each cluster are tested to be equal 1 against the alternative hypothesis of being less than 1, with resulting *p*-values of over 0.90 in most of the cases. The only exception is FL of dairy in cluster 5 where the *p*-value is 0.06.

At the EU member state level, it is interesting to note that milk/dairy production over the period 2007 to 2011 has fallen in those members (*i.e.*, Bulgaria and Romania) where milk/dairy is not considered as a key sector (DG-AGRI, 2013). Equally, it is anticipated that in the Netherlands, Denmark, Germany, Austria and Cyprus, where raw milk quota is currently fully utilised, increases in production are expected to appear from 2015 onwards when the quota is abolished (DG-AGRI, 2013). In all of these EU members, except Germany, the current research identifies raw milk as a key sector, whilst in Germany, raw milk is a potential key sector (Table 6). Moreover, the largest growth in cheese production between 2007 to 2013, which is the industry which provides the highest value added to collected milk, comes from Estonia, Lithuania and Poland (DG-AGRI, 2013). Examining the results of the current paper, the dairy sector in each of these three members is a key sector, with the highest dairy FL multipliers of all the 27 EU members (see Table 7).

Discussion

The creation of the EU's bioeconomy strategy (EC, 2012) reflects a broader attempt by EU policy makers to engage in a process of responsible resource usage whilst fostering economic growth. In particular, the remit of this strategy includes the optimisation of biological resources including waste, reduced dependency on fossil fuels and lowering the negative economic growth inducing impacts on the environment (EC, 2014a). Moreover, the promotion of bioeconomy as a policy tool could become an important vehicle for the promotion of rural development in Europe. Unfortunately, quantitative approaches to measuring bioeconomic activity are constrained by a shortage of available published data, which consequently narrows the definition of bioeconomy in this study. Notwithstanding, as a partial response, a consistent set of social accounting matrices (SAMs) for each of the 27 EU Member States updated to 2007, known as the AgroSAMs (Müller *et al.*, 2009), is employed, with a highly detailed representation of agricultural and food sectors, in addition to fishing, forestry, wood and paper/pulp activities.

Employing backward-linkage (BL) and forward-linkage (FL) multipliers as segmenting variables, a cluster analysis generates six groupings of EU member with homogeneous bioeconomic wealth generation properties, broadly clear geographical distinctions, and statistically significant heterogeneity between groups in terms of economic development and land use variables. Hence, a potential link is forged between bioeconomic structure, geographical location and relative economic development. Furthermore, *within cluster* statistical tests reveal a uniformly high degree of 'backward orientation' or backward wealth generation across bioeconomic sectors. In the agro-food sectors, this interpretation is rationalised by the reliance on a diverse portfolio of inputs (*e.g.* fertilisers, pesticides, veterinary services, machinery, transport services, energy requirements etc.) which generate, in relative terms, greater than average economic ripple effects through the rest of the economy. Furthermore, in developed economies and the EU in particular, high BLs owing to highly diversified input requirements are perhaps to be expected given the strict legal regulations regarding food standards, food safety requirements and animal welfare. By the same token, the implication of low FL wealth generation is that the supply chain for bioeconomic outputs is less dispersed, thereby leading to smaller ripple effects. For example, in many cases, bioeconomic outputs remain as unprocessed or raw goods, and therefore do not have many alternative uses.

Additional *inter-cluster* statistical comparisons by bioeconomic sector show only a moderate degree of heterogeneity in terms of BL wealth generation. Performing the same test for FL multipliers reduces the statistical degree of structural heterogeneity to only two sectors. In the case of the industrial crops sector (predominantly sugar beet, *Beta vulgaris* L.), the result is supported by earlier literature (Renwick *et al.*, 2011) showing notable differences in sugar beet competitiveness across the EU.[22] A similar argument could be made for fruit and vegetable production, which owing to climatic factors, is concentrated in the hands of those EU-members on the northern basin of the Mediterranean.[23]

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[22] Competitive differences owe as much to institutional arrangements between beet suppliers and processors as well as agronomic and climatic factors. The relatively competitive cluster groups are 'Northern Europe' (UK, Sweden, Netherlands, Finland, Denmark, Poland); 'Mediterranean and Eastern Europe' (France and Hungary); and 'Central Europe' (Slovakia, Germany, Austria).

[23] The strategic importance of Belgian and Dutch vegetable sectors is lost within the large EU cluster of 'Northern Europe' where the multiplier impact of the fruit and vegetable sector is representative of nine Member States.

Comparing with the non-bioeconomic sector aggregate, the bioeconomy generates relatively less employment. On the other hand, comparatively favourable levels of bio-based employment growth can be found in the forestry, fishing[24] and wood industries, whilst an inverse relationship is found between lower economic development (per capita income) and higher bioeconomy employment generation. Finally, the bio-based sectors of milk and dairy are found to be significant wealth generators, although their employment generation is below the agri-food average. Furthermore, analysing the evolution of milk and dairy markets since 2007 reveals a striking congruence between the policy recommendations of this research and the positive ex-post evolution of milk and dairy sectors in certain EU Member States.

An initial caveat to this research is that it cannot make informed judgements on the environmental sustainability relating to the policy recommendations (*i.e.*, key sectors) within this study. For example, although milk and dairy are strategic bio-based wealth generators, the incremental harm to the environment (*i.e.*, enteric fermentation, manure management) may have notable consequences when respecting emissions limits. Secondly, the finding that the fishing activity could be a significant employment generator ignores both political (*i.e.*, fishing quotas) and resource (*i.e.*, finite fishing stocks) constraints. Thirdly, whilst the employment multipliers are intuitively appealing, when comparing between sectors and EU regions, one cannot make strong inferences between the number of head employed and the resulting impact on labour income generation and economic growth, since there is no *a priori* indication of the relative 'quality' of the labour force. Importantly, in the poorer members there is a higher job creation elasticity to bioeconomic output value changes which (in part) suggests a higher labour (lower capital) intensive production technology in these sectors, much of which may be lower skilled; less productive and/or with a lower remuneration. Fourthly, in SAM based studies of this nature, one implicitly assumes a fixed proportions technology (*i.e.*, no substitutability), such that the results reported most adequately reflect the profile of bioeconomic activity in the year to which the analysis is benchmarked (*i.e.*, 2007).

A fifth and final cautionary note relates to the selective bioeconomic focus on agri-food, forestry, fishing, wood and paper/pulp activities, which are typically identified in the standard system of national accounts. The agri-food sectors are disaggregated, although there remain significant areas of bio-based activity which remain 'hidden' within the official EU national accounts statistics. To further illustrate the policy relevance of this point, the 'cascading principle' (EP, 2013) posits that the usage of biomass should flow from higher levels of the value chain down to lower levels, thereby maximising the productivity of the raw material. Within this guiding paradigm, the use of biomass for energy generation is placed at the end of the cascade. Thus, whilst the multiplier approach could lend itself to test the cascading biomass hypothesis by comparing BL and FL multipliers (*i.e.*, wealth generation properties) across an all-encompassing selection of bio-based activities, at present such an approach is limited by data availability. Thus, a clear avenue for further research is to address this shortfall to provide a more comprehensive depiction of this complex and diverse sector.

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[24] Given that fishing activity is constrained by quotas, most job creation would likely occur through aquaculture

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