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Analysis of structural patterns in highly disaggregated bioeconomy sectors by EU Member States using SAM/IO multipliers

Mainar Causapé, A. J.
Philippidis, G.
Sanjuán, A. I.

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Contact information
Name: Alfredo J. Mainar Causapé
Address: c/ Inca Garcilaso 3, Edificio Expo, 41092 Seville, Spain
Email: alfredo.mainar-causape@ec.europa.eu
Tel.: +34 95 44 88313

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Authors

Alfredo Mainar Causapé is with the Joint Research Centre (JRC.D.4, Seville), he is the lead scientist for the construction of the BioSAMs and the calculation of the multipliers.

George Philippidis is with Aragonese Agency for Research and Development (ARAID) and was responsible for providing the analysis and writing of the report.

Ana Isabel Sanjuán is with the Centro de Investigación y Tecnología Agroalimentaria de Aragón (CITA) and was responsible for the statistical analysis.

1. Introduction and Background

The concept of the 'circular-economy' goes back to the work of Boulding (1966) who employed space travel as a metaphor to represent the finite resource limitations facing the Earth's population. Boulding (1966) postulated that for the crew (i.e. world's population) to attempt a long journey through space, required a fundamental understanding of the 'first law of thermodynamics'[1] to conceptualise a model of 'everything as an input into everything else' and a formal recognition of the assimilative capacity of the Earth's ecosystem. With the spectre of both climate change and resource depletion looming, the circular-economy once again finds itself challenging the existing dogma of a 'linear' (i.e. take-make-dispose) approach to economic prosperity and growth.

As a production system oriented toward the conversion of biologically renewable resources and biological waste streams (hitherto known as 'biomass') into value added produce such as food, feed, bio-based industrial and energy applications, the compatibility of bio-based activity to the circular-economy paradigm is clear. As a result, this shift in attitudes has re-kindled rapidly growing interest in the concept of a bio-based economy (or bioeconomy), both in European Union (EU) policy-circles under the auspices of the so-called bioeconomy strategy (EC, 2012; EC, 2014) and within the academic arena (e.g., McCormick and Kautto, 2013; M'barek *et al*., 2014, Fritsche and Iriarte, 2014).

It has been noted, however, that whilst the bioeconomy strategy (EC, 2012) represents an important first step toward developing a sustainable model of growth, it faces significant challenges. From a conceptual perspective, Ramcilovic-Suominen and Pülzl (2017) suggest that it panders overtly to economic criteria (i.e. bio-technological efficiency, competitiveness), without paying sufficient heed to the broader aspects of sustainability indelibly linked to environmental- (e.g., biodiversity, air, water, soil quality) and social- (e.g., equity, justice, human rights etc.) considerations. Furthermore, McCormick and Kautto (2013) allude to the practical challenges of adopting said strategy in terms of the necessary (bio-) technological progress and institutional reform, whilst De Besi and McCormick (2011) highlight the need for a fundamental shift in the mind-sets of society, industry and government, through increased dialogue and awareness campaigns.

In pragmatic policy terms, the fundamental question is how to responsibly optimise the economic potential of this biologically renewable resource. To this end, a 'cascading model of biomass use' (EC, 2012) has been tabled which promotes the idea of prioritising high value added biomass uses before subsequent recycling/reuse into lower value added economic streams. Whilst this idea is intuitively appealing, in a union of 28 member states, it is encumbered by variations in available biomass and differing regional perceptions of what constitutes 'high value', which renders a 'one-size-fits-all' EU strategy difficult to implement (Fritsche and Iriarte, 2014).

Whilst recognising that economic, environmental and social facets govern the implementation of a truly sustainable model of growth, the development of a single quantitative model or framework to assess each of the pillars of 'economy-environment-society' discussed above with meaningful metrics to complement the policy debate, presents a significant challenge. For this reason, the paucity of relevant applied studies which currently exist in the economics literature take a 'second-best' approach and focus on narrower questions relating to (*inter alia*) market competitiveness, wealth generation, resource usage and employment.

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[1] The first law of thermodynamics states that energy and matter cannot be created or destroyed. Thus, raw materials used in production processes are not destroyed, but rather are converted or dissipated into an alternative form (e.g., liquid, gas) within the environmental system (Pearce and Turner, 1990).

As a basis for quantitatively assessing the macroeconomic contribution of the bio-based industries, a common feature of these studies is the usage of economy-wide supply and use (SUT) or social accounting matrix (SAM) national accounts data (United Nations, 1999). That there is a relative dearth of EU focused studies to draw from, lends itself to the lack of bio-based sector representation typically found within the statistical classification of economic activities in the European Community (NACE) (Eurostat, 2008). To address this limitation requires significant additional resources in terms of further secondary data, statistical know-how, plausible assumptions and man-hours to derive credible sector splits which capture greater bio-based activity detail.

As a first attempt in this direction, the Joint Research Centre (JRC) of the European Commission sponsored an ambitious project to identify significant primary agricultural and food activities at member state level ('AgroSAMS') for the year 2000 (Müller et al., 2009). Employing SAM multiplier analysis, for the disaggregated bio-based sectors within the AgroSAM, a structural classification in terms their wealth and employment generation potential was performed by Cardenete et al. (2014) for the Spanish economy. Philippidis et al., (2014) updated the AgroSAM database to 2007 and extended the multiplier analysis employing statistical clustering and segmentation tests to derive typical structural bio-based sector typologies for groups of EU member states. The study revealed six groupings of EU countries, whilst both upstream and downstream dairy production was found to generate significant wealth effects. Notwithstanding, in general terms, both studies converged on the conclusion that the wealth generating potential of bio-based sectors compared with the average of all economic activities, remained relatively limited.

Two further EU based studies (van Meijl et al., 2016; Philippidis et al., 2016) represent a different, although related, strand of literature which takes a longer term view of biomass usage under different futures or 'narratives' defined either by bio-based policy and/or technology assumptions. In both cases, further sector splits were performed to include more contemporary industrial and energy uses of biomass.

Focusing on the Dutch economy, van Meijl et al. (2016) examine the impacts on energy use and CO2 emissions by 2030 under different applications of biomass. Four scenarios are developed which cross-reference the Dutch economy's degree of trade access to biomass inputs with its rate of technological progress, whilst a sensitivity analysis through variations in the fossil fuel price is also considered. The study suggests that the bioeconomy has a potentially key role in helping to achieve renewable energy and greenhouse gas (GHG) targets, although this finding is highly sensitive to a combination of factors: high rates of expected technological progress; higher fossil fuel prices; low biomass prices and greater openness to extra-EU sources of biomass trade.

With a greater emphasis on policy drivers (*vis-a-vis* technological drivers) for channeling biomass usage, Philippidis et al. (2016) examine different policy futures up to 2030. The narratives are defined in terms of the EU's degree of willingness to promote biomass for energy use; openness to trade and market orientation; and its pursuit of greener policies in the agricultural sectors. A general conclusion is that the EU bioeconomy faces a challenge to become a competitive engine of job creation and growth, highlighting in turn a clear need for significant and targeted EU investments in bio-technology initiatives to generate innovative solutions to meet these societal challenges. Furthermore, policy drivers (especially biofuel mandates) heavily influence biomass usage, whilst within a fragmented biomass policy landscape, policy incoherence occurs, especially on the dual fronts of reducing GHG emissions and fostering biomass energy usage.

The current study follows previous SAM based multiplier analyses of the EU's bio-based activities (Cardenete et al., 2014; Philippidis et al., 2014). It employs a newly constructed set of SAMs for 2010 for the EU28. A further improvement on the aforementioned studies is that sector splits have been performed to represent both additional sources of biomass and contemporary bio-technological applications in the areas of fuel, electricity and chemicals. Taking an approach more akin to Philippidis et al. (2014), the main aim is to profile bio-economic activity both by sectors and regions in terms of their wealth and employment generation with a view to understanding whether statistical patterns or typologies exist across EU member states. More specifically, are bio-based activities in some EU member states statistically more active in terms of wealth and employment generation? Is there a statistical correlation between the socioeconomic characteristics of these regional typologies and their propensity to generate wealth and employment? Is it possible to identify whether specific bio-based activities consistently generate relatively more value added across EU members (so-called 'key sectors')?

The rest of this report is structured as follows. Section two discusses the construction of the SAM database and the multiplier analysis employed in this study. Section 3 discusses the results. Section four provides a discussion and conclusions.

2. SAM Database

2.1 BioSAMs

A Social Accounting Matrix (SAM) is a database that collects and organizes the economic and social data for all transactions between economic agents within an economy, at a given point in time. It 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 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). A SAM integrates social statistics in the traditional input-output model. In this way, the interdependence of the productive and institutional sectors and their relationships to final demand are captured, as well as the income flows between production factors and the components of final demand, thus completing the circular income flow in a square matrix.

As one of the pioneers of social accounting, Stone (1955) integrated production accounts, in the form of input-output tables, with the national accounts to generate an economy-wide database. 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 applied to issues of economic growth (Robinson, 1988), income distribution and redistribution (Roland-Holst and Sancho, 1992), the circular flow of income (Pyatt and Round, 1979; Defourny and Thorbecke 1984; Robinson and Roland- Holst 1988), price formation (Roland-Holst and 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 and Perez-Mayo, 2010).

A major obstacle in using a SAM based analysis for analysing detailed bioeconomy activities is the lack of available data. More specifically, in the standard national accounts framework, bio-economic activities are typically represented as broad sectoral aggregates (i.e. agriculture, food processing, forestry, fishing, wood, pulp) or even subsumed within their parent industries (e.g., chemical sector, wearing apparel, energy). The current study takes the AgroSAM work (Müller et al., 2009) mentioned in the introduction, one step further. Dubbed the 'BioSAMs' and benchmarking to the year 2010, this study maintains the sectoral detail of the agricultural and agro-food industries inherent within the AgroSAM, whilst also providing an explicit representation of contemporary uses of biomass in the areas of bio-energy, bio-chemicals and bio-industry.

The elaboration of BioSAMs consists of two basic stages, subdivided into several steps, each of which is repeated systematically for each Member State. The first stage consists of designing a standard SAM, distinguishing activities and commodities following the classification of activities and products in the Eurostat NACE[2] Rev. 2 (Statistical classification of economic activities in the European Community, revised version 2) and CPA (Classification of Products by Activity), respectively. Initially, a macro-SAM, containing a structure of double-entry, the macro-magnitudes of each national economy considered for the reference year 2010. The objective of these initial macro-SAMs is to serve as a benchmark in the process of constructing the matrix and, fundamentally, in calculating the closure matrix of the SAM (linking factors and institutions). For this estimation data of non-financial transactions of the Annual Sector Accounts (nasa_10_nf_tr) are used.

On the basis of these macro-SAMs of individual Member States, standard SAMs were obtained entering information for the Supply-Use Tables (SUT) 2010, correcting, in some cases, minor differences in allocation of concepts that can arise between the two statistical operations (e.g. consumption by residents abroad, payments to labour, indirect taxes, etc.). The result of this procedure is a SAM with broad sectorial classifications which can be used independently for modelling or analysis, but also serve as a basis for obtaining highly disaggregated BioSams. Finally, to complete this first stage, the resulting SAMs are slightly adapted, by aggregating certain accounts, to the classification of activities pursued by the databases of the Global Trade Analysis Project (GTAP).[3] The reason for this is to facilitate the subsequent use of additional databases on agriculture and bio-fuel, which adhere to this classification (in particular to calculate the technical coefficients for bio-energy and bio-chemical related activities).

The second major step in the construction of the BioSAMs was the disaggregation of agriculture and food industries, as well as the bio-energy and bio-industry sectors. The basis for this estimate is obtained from the MAGNET[4] model database of interindustry relations and the data on employment and turnover available in the European Commission (JRC, 2017). Thus, a series of non-agricultural bioeconomy accounts are generated by extracting from their identified parent industries. More specifically, new bio-energy and bio-industrial sectors were stripped out from their parent industries of ‘chemicals’, ‘forestry’, ‘wood products’ and ‘electricity and gas’, (Table 1). In addition, a further split of primary agricultural and food industries was undertaken, using as a principal source of data, the Common Agricultural Policy Regionalised Impacts (CAPRI) analysis modelling system database (Britz and Witzke, 2012), in combination with the Economic Accounts for Agriculture (EAA) of Eurostat[5] (see Table 1).

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[2] NACE is the acronym for “Nomenclature statistique des Activités économiques dans la Communauté Européenne”

[3] GTAP (Global Trade Analysis Project) is a global network of researchers and policy makers conducting quantitative analysis of international policy issues (Aguiar et al., 2016).

[4] Magnet (Modular Applied General equilibrium Tool) is an advanced neoclassical global general equilibrium model. Magnet has been used to simulate the impacts of agricultural, trade and biofuels policies, as well as wide-ranging issues such as land-use, nutrition, income distribution in developing countries and food security. The MAGNET consortium, led by Wageningen Economic Research (WEcR), includes the European Commission’s Joint Research Centre (JRC).

[5] http://ec.europa.eu/eurostat/cache/metadata/en/aact_esms.htm

TABLE 1: Bio-based activities and their (NACE) parent industries

NACE Parent sector	**Bio-based sector splits**
Primary Agriculture (crops)	paddy rice, wheat, barley, maize, other cereals, tomatoes, other vegetables, grapes, other fruits, soya, sunflower, rapeseed, olives, olive oil, other oils, sugar beet, plant fibres, potatoes, live plants, fodder crops, tobacco, other crops.
Primary Agriculture (livestock)	live cattle and goats, swine, poultry, other animals products, other products, raw milk.
Processed Foods	meat of bovine animals, fresh, chilled or frozen, meat of swine, fresh, chilled or frozen, meat of sheep, goats and equines, poultry, prepared animal feeds, olive oil, oil-cakes, dairy products, rice, milled or husked, processed sugar, prepared animal feeds, other food products, wine production, other beverages and tobacco.
Forestry	energy crop plantations.
Wood products	pellets.
Chemicals	bio-chemicals, fertilisers (non bio-based), first generation bio-diesel, first generation bio-ethanol, second generation bio-fuel (biochemical pathway), second generation bio-fuel (thermal pathway).
Electricity and Gas	bio-electricity.

Source: Own elaboration.

Once the SAMs obtained in the first stage were disaggregated in detail in accordance with the information of the agricultural, food, bio-energy and bio-industrial sectors, they were corrected eliminating discrepancies between the accounts which, not surprisingly, arise when processing SAMs using different sources of data which are not always directly compatible. To ensure the smooth adjustment of the cells of the BioSAMs, subject to cells targets for activities and products for which statistical information was available as well as the macroeconomic targets (macro-SAMs), RAS and Cross Entropy methods were employed.

The final result is a set of 28 member state BioSAMs for 2010, which contain 80 activity/commodity accounts. There are 22 for cropping activities, six for livestock, 14 for food processing (including three animal feed accounts for animal feed and oilcakes), five for bioenergy (biofuels of first and second generation, and bioelectricity), three biomass supply accounts (forestry, energy crops and pellets), three other bio-industrial accounts (textiles, wood and biochemical) and a fishing account. The remaining 27 sectors/commodities cover fossil fuels (2), manufacturing (11) and services accounts (14). In addition, the BioSAM contains two production factors (capital and labour), one account for trade and transportation margins and three tax accounts (taxes and subsidies on production and consumption and direct taxes). Finally, there is a single account for the private household, corporate activities, central government, investments-savings and the rest of the world.

2.2. Backward and forward linkages and employment multipliers

As a principal tool of SAM based analysis to assess the wealth generating properties of the bio-based sectors, two 'traditional' multiplier indices known as backward linkage (BL) and a forward linkage (FL) multipliers, are employed. Assuming Leontief technologies (i.e. fixed prices), the FL multiplier (or supply driven multiplier) follows the distribution chain through subsequent layers of end users, whilst the BL multiplier (or demand driven multiplier) examines the network of upstream linkages with intermediate input suppliers.

Employing a mathematical exposition, the BL and FL multipliers are based on the Leontief inverse M = $(I - A)^{-1}$, where each element m_{ij} in M depicts the output requirements of account i to increase final demand of account j by one unit and employing the same logic, the input requirements of account i to produce one unit by account j. Following Rasmussen (1956), the aggregate multipliers by columns and rows are expressed as:

$$M_{\bullet j} = \sum_{i=1}^{n} m_{ij} \qquad \forall\, j = 1, 2, ..., n \tag{1}$$

$$M_{i \bullet} = \sum_{j=1}^{n} m_{ij} \qquad \forall\, i = 1, 2, ..., n \tag{2}$$

where BL and FL multipliers are given as:

$$BL_{\bullet j} = \frac{\sum_{i=1}^{n} m_{ij}}{\frac{1}{n}\sum_{j=1}^{n} m_{ij}} \tag{3}$$

$$FL_{i \bullet} = \frac{\sum_{j=1}^{n} m_{ij}}{\frac{1}{n}\sum_{i=1}^{n} m_{ij}} \tag{4}$$

By normalizing both indices, it is possible to attain a relative measure of economic structure and influence and therefore directly compare between accounts and EU28 regions.[6] Thus, a BL (FL) exceeding unity implies that the generation of economic activity exceeds the average of the rest of the economic accounts ‘i’ or ‘j’. Expressed another way, a BL (FL) multiplier greater than one shows that every euro of intermediate input demand (output supply) generates more than one euro of economic activity to the upstream input suppliers (downstream end users). A sector with BL (FL) greater than unity, and FL (BL) linkages less than unity is classified as ‘backward’ (‘forward’) oriented. If neither linkage is greater than unity, the sector is designated as 'weak', whilst 'key sectors' are those which exhibit simultaneously FL and BL values greater than unity.

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[6] Notwithstanding, care should therefore be taken when interpreting multipliers across regions. For example, a higher multiplier by sector ‘x’ in region ‘A’ over region ‘B’, does not necessarily imply that sector ‘x’ in region ‘A’ generates more absolute wealth than in region ‘B’, per se. Rather, what it means is that relative to the average of all economic activities in region ‘A’ the importance of sector ‘x’ in generating wealth is greater than it is in region ‘B’.

The *employment multipliers* are the result of a new diagonal matrix called *E* (equation 5) containing priors on the ratio of the number of labour posts per million euros of output value. To populate this matrix, employment data are taken from Eurostat. In general, data from the Labour Force Survey (lfs_egan22d) are used, but in the case of agriculture, they are combined with data from the Economic Accounts for Agriculture (aact_eaa01). For non-agricultural bioeconomy sectors, estimates from JRC are employed (see footnote 6).

This matrix is multiplied by the part of the multiplicative decomposition called *Ma* that incorporates the rows and columns corresponding to the productive accounts plus endogenous accounts as labour, capital and households, in our case, and so, the multipliers are higher than only using productive accounts. When increasing the income of an endogenous account, one obtains the impact of said change on the corresponding column of *Ma* and, via the matrix *E*, this is converted into the number of jobs created (or lost). The expression of the employment multiplier, *Me*, is the following:

$$Me = E * Ma \qquad (5)$$

Each element in *Me* is the increment in the number of jobs of the account *i* when the account *j* receives a unitary exogenous injection. The sum of the columns gives the global effect on employment resulting from an exogenous increase in demand. The rows show the increment in employment that the activity account in question experiences if the rest of the accounts receive an exogenous monetary unit, i.e. the multipliers give the number of additional jobs per million of additional output from each 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 driven by changes in household labour income demand for sector ‘j’.

3. Results

3.1 Statistical Profiling of the Bio-Based Sector Multipliers

The first phase of the analytical research consists of generating representative classifications of EU member country groupings in function of the wealth generating properties of their bio-based sectors. In order to make the analysis more manageable, the original 80 accounts in the BioSAM have been aggregated to 36 sectors, of which 32 are representative bio-based sectors (Table 2).

The BL and FL multipliers calculated from each of the 28 member state SAMs for 32 selected bio-based sectors (Table 2) are employed as segmenting variables to derive ‘typical’ country groupings. Examining the classification of sectors, there is a representation of both ‘traditional’ and more contemporary bio-based activities. In terms of the agri-food chain, primary agriculture is aggregated into seven cropping and four livestock activities, whilst the food industry is divided into ten sectors. In addition, three animal feed sectors are represented. Following the SUT classifications, our sample of traditional bio-based sectors also includes fishing, forestry and wood and textile activities. Beyond these traditional bio-based activity classifications, the sector aggregation also captures emerging biomass supply chains and applications which are grouped into energy crops, pellets, bio-electricity, bio-chemicals and first- and second-generation bio-fuels.

TABLE 2: Description of sectors

Sector code	Description	Aggregated sector code
Cereal	Cereals: paddy rice, wheat, barley, grain maize, other cereals	Agric
Veg	Vegetables: tomatoes, potatoes, other vegetables	
Fruit	Fruits: grapes, fruits	
Oilseeds	Oilseeds	
OilPlant	Oil plants	
IndCrop	Industrial Crops: sugar beet, fibre plants	
OCrop	Other crops: live plants and other crops	
ExtLiveProd	Extensive livestock and products: bovine cattle, sheep, goats, horses, asses, mules and hinnies	
IntLiveProd	Intensive livestock and products: swine and poultry, live	
OliveProd	Other live animals and animal products: other animals products	
RawMilk	Raw milk: raw milk from bovine cattle	
Fishing	Fishing	
AnFeed	Animal feed, fodder crops, biodiesel by-product oilcake	Food
RedMeat	Red meat: meat of bovine animals, sheep, goats and equines, fresh, chilled or frozen	
WhMeat	White meat: meat of swine and poultry, fresh, chilled or frozen	
VegOil	Vegetable oils: vegetable oils and fats, crude and refined; oil-cake and other solid residues, of vegetable fats or oils	
Dairy	Dairy	
Rice	Processing of rice, milled or husked	
Sugar	Processed sugar	
OliveOil	Olive oil	
Wine	Wine	
BevTob	Beverages and Tobacco	
OFoodProd	Other food	
EnergyCrops	Energy crops	BioMass
Pellet	Pellets	
Forestry	Forestry, logging and related service activities	
BioElectricity	Bio-electricity	BioEnergy
Biofuel1	Bio-fuel 1st generation: bio-ethanol and bio-diesel	
Biofuel2	Bio-fuel 2nd generation: bio-chemical and thermal technologies biofuel	
Wood	Wood products	BioIndustry
Textile	Textiles, wearing apparel and leather	
BioChem	Bio-chemicals	
NatRes	Natural resources: coal mining activities, petroleum and coal, raw minerals	NonBio
Energy	Energy: electricity and gas	
Manu	Manufactures: paper and publishing, chemicals, fertilizers, mineral products nec., metals, motor vehicles and parts, transport equipment nec., electronic equipment, machinery and equipment nec., other manufactures	
Service	Services: water distribution, construction, trade, transport, water and air transport, communication, financial services, insurance, business services, recreational and other services, public administration, defence, education, health, dwellings	

Source: Own elaboration.

A hierarchical cluster analysis[7] reveals five regional groups (Table 3), which fall into broadly recognizable geographical clusters. These clusters are Northern and Central EU ('Northern & Central'), the EU Mediterranean islands and Luxembourg ('Isles & Lux'), a group mainly consisting of newer accession members (‘Mainly Eastern'), two Baltic member states (‘Baltic’) and the EU’s Mediterranean peninsula ('Mediterranean').

TABLE 3: EU country clusters based on backward and forward linkage multipliers

Cluster	Name	Member State Composition
1	Northern & Central	[n=10] Austria, Belgium, Denmark, Germany, Ireland, Lithuania, Netherlands, Slovenia, Sweden, United Kingdom
2	Isles & Lux	[n=3] Cyprus, Luxembourg, Malta
3	Mainly Eastern	[n=9] Bulgaria, Croatia, Czech Republic, Finland, France, Hungary, Poland, Romania, Slovakia
4	Baltic	[n=2] Estonia, Latvia
5	Mediterranean	[n= 4] Greece, Italy, Portugal, Spain

Notes: n denotes the size of the sample i.e. number of countries.

Source: Own elaboration.

Table 4 summarises the mean values of the backward and forward multiplier linkages in the five regional clusters for six bio-based sectoral aggregates. In addition to the single sector aggregate of all bio-based activity (BioEcon), a further five bio-based sector aggregates follow the definitions in the final column of Table 2: (i) agriculture; (ii) food; (iii) biomass supply; (iv) bio-energy; and (v) bio-industry. In Table 4 are presented the BL and FL multipliers averaged across the individual sectors within each of the six broad sectors (see data presented in Table A.1 in the Appendix); and across EU member states corresponding to each of the regional clusters.

A general pattern that emerges is that in all cases, the backward linkage statistics reported are higher than the corresponding forward linkage results. For example, in the EU28 bioeconomy, one million euro of additional demand generates €1.6 million for upstream supply industries and only €0.67 million for downstream sectors and retailers.

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[7] Ward linkages and squared Euclidean distance are used in the cluster analysis. In a second stage, a k-means cluster technique was also applied starting with the centroids selected by the hierarchical procedure, but the clusters’ composition remained unchanged.

TABLE 4: Backward and forward linkage multipliers for aggregated bioeconomy sectors in regional clusters

	Northern & Central		**Isles + Lux**		**Mainly Eastern**		**Baltic**		**Mediterranean**		**EU28**	
	BL	FL	BL	FL	BL	FL	BL	FL	BL	FL	BL	FL
BioEcon^{bbb,fff}	1.42	0.59***	0.81	0.39*	1.87	0.80***	1.50	0.68	2.07	0.80***	1.60	0.67***
Agric^{bbb,fff}	1.46	0.59***	0.94	0.52**	2.02	0.92***	1.68	0.73^{**a}	2.05	0.78***	1.69	0.72***
Food^{bbb,fff}	1.21	0.51***	0.76	0.32***	1.64	0.71***	1.12	0.49	2.03	0.87***	1.41	0.60***
BioMass^{bbb,fff}	1.71	0.78***	0.70	0.36	2.16	0.95***	2.15	1.09	2.18	0.66***	1.85	0.80***
BioEnergy^{bbb,fff}	1.76	0.64***	0.47	0.18**	1.99	0.63***	1.53	0.42	2.28	0.68***	1.75	0.58***
BioIndustry^{bbb,fff}	1.38	0.60***	0.95	0.38**	1.65	0.73***	1.53	1.07	1.93	0.87***	1.51	0.69***

Notes: $^{***,\ **}$ Represent significant mean differences between backward and forward linkages, using a paired t-test, at 1% and 5% level of significance, respectively, against the alternative hypothesis Ha: BL-FL≠0; ^{**a} stands for significance differences at 5% against Ha: BL-FL>0. $^{bbb\ (fff)}$ Represent significant differences of the mean of backward (forward) linkages across clusters, at 1% level of significance, based on the Anova analysis when Levene statistics does not reject the null of homogeneity of variances, or the W test, otherwise.

Source: Own elaboration.

Interestingly, across all sector aggregates, the magnitude of the BL (demand driven) multipliers is typically above one (with the exception of the Isles+Lux cluster), suggesting that relative to economic activities in general, bio-based activities in each regional cluster generate above average demand driven wealth up the supply chain. Further, comparing bio-based demand driven BL multipliers across regional clusters, there is no clear ranking pattern. For example, in the regional clusters 'Mediterranean' and 'Northern & Central', as well as the EU28 aggregate region, the sectors of 'BioMass' and 'BioEnergy' present higher backward linkages than more traditional agrifood sectors. On the other hand, in the 'Mainly Eastern' and 'Baltic' clusters, 'BioMass' has the highest BL, followed by 'Agriculture' and 'BioEnergy'. Finally, amongst the bio-based sector aggregates, the sector 'food' typically generates relatively less demand driven wealth in all clusters.

A comparison for each individual bio-based sector across the regional clusters shows that for the aggregate 'bioeconomy' sector, the relative importance of the BL wealth generating multiplier effect is highest in the Mediterranean, followed by 'Mainly Eastern', 'Baltic', 'Northern&Central' and 'Isles +Lux'. In the other bio-based sector aggregates, this same ordering remains broadly consistent (with the exception that in 'Food' and 'BioEnergy', the 'Northern&Central' moves above 'Baltic' in the ranking).

In contrast to the BL results, FL (supply driven) multipliers typically fall below one, leading to the conclusion that in comparison with economic activity in general, bio-based sectors generate relatively little wealth down the supply chain. Forward linkages in the bioeconomy aggregate sector are highest in 'Mediterranean' and 'Mainly Eastern' regions, followed by 'Baltic', 'Northern&Central and finally, 'Isles + Lux'. The 'Mediterranean' region is also ranked within the top two highest forward linkages in traditional agri-food sectors as well as new bioeconomy sectors, such as 'BioEnergy' and 'BioIndustry'. In a similar vein, for the 'BioMass' and 'BioIndustry' FL multipliers, the 'Baltic' cluster scores the highest, such that both sector aggregates are 'key sectors' (i.e. BL and FL multipliers higher than one).

To understand whether the above wealth generating properties of the bio-based sectors are statistically significant, (i) paired mean t-tests are conducted to ascertain statistical differences between backward and forward linkages for each aggregate sector within each regional cluster of EU countries; and (ii) one-way Anova test searches for statistical differences between BL multipliers by aggregate sector across regional clusters of EU countries, with the exact same test carried out again for the case of the FL multipliers. When the Levene statistic rejects the null of variance homogeneity, the Anova is replaced by the W-test.

Examining the within-group means tests, with the exception of 'Baltic', there are statistical differences in the BL and FL means within each regional grouping, statistically confirming the hypothesis that bio-based activities do generate more wealth to intermediate input suppliers than to downstream retailers and other bio-based material/product applications. Looking at the tests for differences between BL/FL means *across* EU regional clusters, both sets of tests, for all aggregate bio-based sectors considered, reveal statistical differences. Thus, for a given bio-based sector aggregate, the wealth generating properties both up the supply chain (BL) and down the supply chain (FL) are statistically different across the groups.

In Table 5 the analysis is broadened further to consider a more detailed breakdown of bio-based sectors in terms of their BL and FL multipliers for the five regional clusters (+EU28) under consideration.

Confirming our previous observation from Table 4, a cursory view of the results for the 32 specific bioeconomy sectors (Table 5), shows numerous examples of BL multipliers exceeding one. It is noteworthy that in the Mediterranean cluster, of the 32 bio-based activities, there are 20 sectors where BL multipliers exceed the value of two, and 14 such cases in the cluster 'Mainly Eastern'. Examining the mean backward linkage multipliers within each EU cluster (bottom rows, Table 5), 'Northern & Central', 'Mainly Eastern' and 'Mediterranean' EU are characterised by BL values greater than one and a relatively lower coefficient of variation (CoV). These regional clusters therefore contain a reasonably strong and homogeneous structural classification of bio-based sector driven wealth effects. On the other hand, in the cluster 'Isles + Lux' and 'Baltic', there is a more heterogeneous range of demand driven wealth effects, owing to the narrower focus of bio-based activity (existence of zero BL multipliers) which is explained by climatic factors or geographical limitations.[8]

In accordance with the FL multiplier results from Table 5, for the 32 bio-based sector split, low FL multipliers are prevalent. Across the five groups of regional clusters (bottom rows, Table 5), the mean values are more uniform, whilst within-group CoVs are generally higher (vis-à-vis BL multipliers) implying that supply driven wealth effects across different bio-economic activities are more varied.

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[8] In the Baltic region group, climatic factor preclude the cultivation of fruit, sugar, olive oil and many industrial crops. Similarly, in the islands of Cyprus and Malta, and Luxembourg, a simple lack of land endowment restricts a broad competence in a diverse range of bio-based activities.

TABLE 5: Backward (BL) and Forward (FL) linkages for individual sectors in each cluster

	Northern & Central		**Isles+Lux**		**Mainly Eastern**		**Baltic**		**Mediterranean**		**EU28**	
Sector	**BL**	**FL**	**BL**	**FL**	**BL**	**FL**	**BL**	**FL**	**BL**	**FL**	**BL**	**FL**
Cereal^{bbb,fff}	1.48	0.67***	0.17	0.10	2.24	1.69**	1.78	1.35	1.68	1.03**	1.63	1.04***
Veg	1.22	0.50***	0.96	0.52	1.57	0.86**	1.15	0.59	1.96	0.85***	1.40	0.68***
Fruit^{bbb,fff}	0.28	0.11**	0.62	0.32	0.83	0.45**	0.21	0.09	2.20	0.94***	0.76	0.36***
Oilseeds^{bbb,fff}	1.19	0.41***	0.03	0.01	2.43	1.04***	2.66	0.98**	0.67	0.22	1.50	0.58***
OilPlant	0.67	0.21**	0.25	0.12	0.62	0.21***	0.30	0.07	0.86	0.34	0.61	0.21***
IndCrop^{bbb,fff}	0.89	0.30***	0.02	0.0	1.54	0.57***	0.0	0.0	0.90	0.30	0.94	0.33***
Ocrop^{bbb,fff}	2.12	0.82***	1.10	0.54	2.36	0.93***	1.66	0.63	2.50	0.86***	2.11	0.82***
ExtLiveProd^{bbb}	2.28	0.78***	1.58	0.69	3.36	1.05***	3.62	0.81	3.10	1.02***	2.77	0.89***
IntLiveProd^{bbb}	2.29	1.03***	1.48	0.93	2.64	1.30***	2.76	1.06	3.09	1.25***	2.46	1.14***
OliveProd^{bb,ff}	1.73	0.65***	2.03	0.97**	2.08	0.87***	1.92	0.73	2.76	0.81***	2.04	0.78***
RawMilk^{bbb,fff}	2.18	1.21***	1.84	1.33	2.90	1.57***	2.53	1.80	2.84	1.20***	2.50	1.38***
Fishing^{bbb}	1.22	0.36***	1.18	0.76	1.69	0.45***	1.60	0.68***	2.07	0.51***	1.52	0.48***
AnFeed^{bbb}	1.69	0.89***	0.63	0.32**	1.95	1.44	2.39	1.84	2.38	1.32***	1.81	1.14***
RedMeat^{bbb,ff}	1.76	0.55***	0.97	0.35***	2.0	0.56***	1.86	0.51	2.30	0.70***	1.84	0.55***
WhMeat^{bb}	1.81	0.61***	1.20	0.46**	2.0	0.84***	1.76	0.66**	2.29	0.73**	1.87	0.69***
VegOil^{bb}	0.92	0.31***	0.69	0.36	1.61	0.47***	1.05	0.29	1.31	0.53**	1.18	0.40***
Dairy^{bbb,ff}	1.62	0.81***	1.13	0.39**	1.88	0.88***	1.40	0.82	2.22	1.07***	1.72	0.83***
Rice^{bbb,fff}	0.52	0.02	0.41	0.0	1.54	0.23***	1.25	0.0	2.32	0.62***	1.15	0.17***
Sugar^{bbb,fff}	1.17	0.40***	0.35	0.0	1.42	0.46***	0.21	0.0	1.65	0.47***	1.16	0.36***
OliveOil^{bbb,ff}	0.10	0.01***	0.68	0.40	0.53	0.10**	0.06	0.0	1.56	0.57***	0.50	0.16***
Wine^{bbb,fff}	0.60	0.14***	1.01	0.44**	1.63	0.52***	0.14	0.03	1.92	0.62***	1.13	0.36***
BevTob^{bbb,fff}	1.64	0.70***	0.58	0.21**	1.80	0.97***	1.12	0.55**	2.24	1.02***	1.63	0.77***
OFoodProd^{bbb,fff}	1.48	1.18**	0.69	0.60	1.71	1.31***	1.09	0.69	2.18	1.93	1.54	1.23***
EnergyCrops^{bbb,fff}	1.75	0.71***	0.10	0.0	2.26	0.79***	2.14	0.78	2.29	0.64***	1.84	0.65***
Pellet^{bb}	1.53	0.56***	1.19	0.47	1.87	0.61***	1.85	0.78	2.18	0.59***	1.72	0.59***
Forestry^{bbb,fff}	1.84	1.08***	0.81	0.60	2.36	1.45***	2.46	1.71	2.08	0.76***	1.98	1.15***
BioElectricity^{bbb}	1.78	0.78***	0.47	0.25	2.23	0.87***	2.90	0.89	2.36	0.92***	1.95	0.78***
Biofuel1^{bbb,ff}	1.49	0.47***	0.93	0.28***	1.60	0.39***	1.10	0.25	1.81	0.39***	1.48	0.40***
Biofuel2 ^{ff}	2.01	0.68***	0.0	0.0	2.14	0.63***	0.60	0.12	2.67	0.73***	1.83	0.56***
Wood^{bbb,fff}	1.70	0.90***	1.22	0.60**	2.14	1.06***	2.46	2.36	2.35	1.01***	1.94	1.04***
Textile^{bbb,fff}	1.03	0.33***	0.80	0.25***	1.38	0.62***	1.14	0.53	1.71	1.12***	1.22	0.54***
BioChem^{bbb,ff}	1.40	0.57***	0.82	0.30**	1.44	0.50***	0.98	0.30	1.73	0.49***	1.37	0.49***
Mean	1.42	0.59	0.81	0.40	1.88	0.81	1.52	0.70	2.08	0.81	1.60	0.68
Std.Dev.	0.58	0.33	0.52	0.32	0.60	0.41	0.94	0.61	0.59	0.35	0.53	0.33
CoV	40%	55%	64%	80%	32%	51%	62%	88%	28%	44%	33%	48%

Notes: ***, ** denote significant mean differences between BL and FL at 1% and 5%. $^{bbb\ (fff)}$ denote significant differences of mean BL (FL) across clusters, at 1%. Std.Dev: standard deviation; CoV: coefficient of variation (i.e. standard deviation/mean * 100).

Source: Own elaboration.

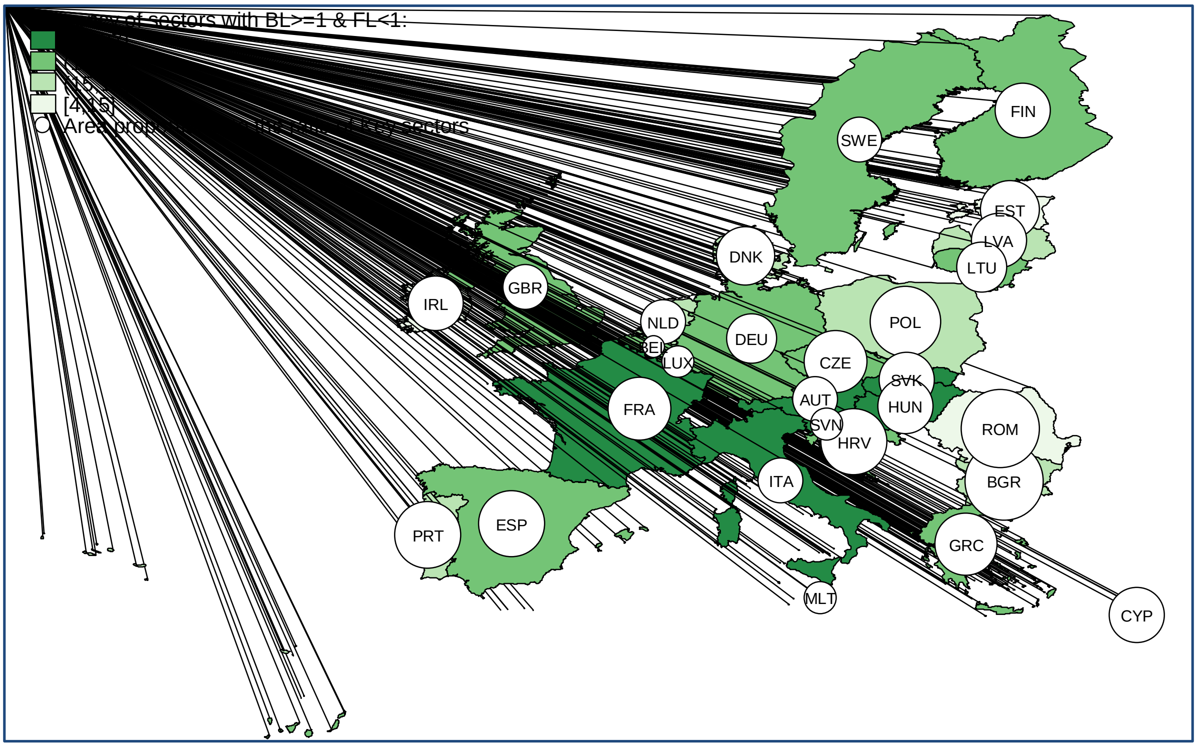
Interestingly, meat and livestock related activities (i.e. meat, livestock, milk, dairy), ‘fishing’, ‘pellets’, and ‘wood’ sectors in all clusters have significant demand driven wealth generating potential (i.e. mean BL multipliers greater than one). By contrast, some of the agricultural sectors, BL wealth effects are only moderate. For example, ‘oil plants’, have mean BL multipliers of less than one in all regional clusters; ‘industrial crops’ BL multipliers are only greater than one in ‘Mainly Eastern’; whilst ‘fruit’ and ‘olive oil’ BL multipliers are only greater than one (2.20 and 1.56, respectively) in the ‘Mediterranean’ region. In terms of the FL mean multipliers, only intensive livestock, and raw milk have supply driven wealth values which are consistently above one in at least four of the five clusters (raw milk in all five), whilst only one case (wood sector in Baltics) is there a FL multiplier above two.

As before, paired-mean t-tests are carried out to establish whether a statistical difference is exhibited between the BL and FL multiplier on a sector-by-sector basis within each regional cluster (Table 5). In the EU28 group, the BL and FL are found to differ significantly in all of the 32 individual bio-based sectors. Of the 32 bio-economic sectors under consideration, there are numerous examples of statistically significant differences between mean FL and BL values in 'Northern & Central EU' (21 sectors), 'Mainly Eastern' (31 sectors), and 'Mediterranean' (28 sectors), owing to the presence of relatively higher BLs discussed above. The only exception to this trend appears to be the 'Islands+Lux' and ‘Baltic’ regions, where statistical evidence of relatively stronger BL mean multipliers are restricted to 11 and 4 sectors, respectively. To summarise, given the pervasiveness of statistical significance between pairwise means in three of the five clusters (which represent 23 countries), this statistically confirms that the vast majority of bio-based activities have a high degree of 'backward orientation'.

Finally, repeating the one-way Anova tests (or W-test in the case of heterogeneous variance) for the 32 disaggregated activities, 29 (22) sectors show statistically significant structural differences in the BL (FL) across the five clusters. In short, bio-based BL (FL) wealth generation on a sector-by-sector basis is statistically found to be highly heterogeneous across the five clusters, in particular when backward linkages are considered. Examining the five clusters of EU Member States, there is statistical homogeneity (i.e. non-significant mean differences) in both BL and FL wealth generation for ‘vegetables’ and ‘oil plants’; in BL wealth generation for second-generation biofuels; and in FL wealth generation for ‘extensive’ and ‘intensive livestock’, ‘fishing’, ‘animal feed’, ‘white meat’, ‘vegeTable oils’, ‘pellets’, and ‘bioelectricity’.

From the tests carried out in section 3.1, Table 6 reveals the key characteristics of each of the regional clusters. Figure 1 plots the number of ‘backward oriented’ sectors (shades of green), whilst the size of the circles indicate the importance of bio-based ‘key sectors’ (i.e. larger circles designate greater ‘key sector’ presence). As illustrated in Figure 1, the EU’s bioeconomy sector is largely ‘backward oriented’. Whilst there is a high degree of backward orientation, the number of ‘key sectors’ varies considerably across EU member states, ranging from one in Belgium to 12 in Bulgaria and Romania.

FIGURE 1:
Backward Orientation (frequency) and Bioeconomy 'Key-Sectors' (proportion)



Note: (a,b] denotes interval, excluding 'a' and including 'b'
Source: Own elaboration

TABLE 6: Summary Table of Regional Cluster 'Typologies'

	Frequency (n = 32 sectors)					Mean values		CoV (%)	
Regional cluster	**BL>1**	**BL>2**	**FL>1**	**FL>2**	**'Key'**	**BL**	**FL**	**BL**	**FL**
'Northern & Central'	25	5	4	0	4	1.42	0.59	40	55
'Isles & Lux'	11	1	1	0	1	0.81	0.40	64	80
'Mainly Eastern'	29	14	9	0	9	1.88	0.81	32	51
'Baltic'	24	9	6	1	6	1.52	0.70	62	88
'Mediterranean'	29	20	10	0	10	2.08	0.81	28	44

Source: Own elaboration.

In reference to Table 6, there are four broad descriptors applied to the five clusters:

- The 'Mediterranean' (four EU MS) and 'Mainly Eastern' (nine EU MS) regional clusters have an active bioeconomy with particularly strong backward orientation (BL mean ≈ 2, FL mean ≈ 0.8). Across the 32 sectors, the frequency of BL wealth generation is highly pervasive, strong compared with economy-wide activities (high BL means particularly in the 'Mediterranean') and homogeneous (relatively low CoVs). A reasonable frequency of supply driven wealth is also observed, which in both regional clusters are also relatively homogeneous. In both clusters, approximately one-in-three bio-based activities are 'key sectors' (BL > 1; FL > 1).

- The 'Baltic' (two EU MS) regional clusters is characterised by a moderately active bio-based economy with strong backward orientation (BL mean ≈ 1.5, FL mean ≈ 0.7). Across the 32 sectors, the frequency of demand driven wealth generation effects is pervasive, moderately strong although highly heterogeneous by sectors (relatively high CoV). Evidence of supply driven wealth is only intermittent and heterogeneous across the 32 sectors (relatively high CoV). Approximately one-in-five bio-based activities are 'key sectors'.

- The 'Northern & Central' (ten EU MS) regional cluster is characterised by a moderately active bio-based economy with strong backward orientation (BL mean ≈ 1.5, FL mean ≈ 0.6). Across the 32 sectors, the frequency of BL wealth generation is pervasive, moderately strong (BL means > 1) although relatively heterogeneous by sectors (relatively high CoV). Evidence of supply driven wealth across sectors is weak, although relatively homogeneous across sectors (lower CoV). This cluster only contains one key sector (raw milk).

- The 'Isles & Lux' (three EU MS) regional cluster has a relatively less developed bioeconomy sector (BL mean < 1, FL mean = 0.4). Across the 32 sectors, evidence of BL wealth generation is moderate, relatively low compared with other economic activities (BL < 1) and very heterogeneous (higher CoV). Examples of supply driven wealth are scarce, with also a high level of instability across sectors (higher CoV). This cluster only contains one key sector (raw milk).

3.2. Statistical Profiling of the EU Regional Clusters

Given the structural wealth generating descriptors for each of the clusters, a further step was then taken to statistically refine their profile. The rationale is that it may be possible to forge a pattern of associations between said profiling characteristics and the structural bio-based classifications inherent within the clusters.[9] The profiling variables (fully described in Table 7) cover different socio-economic (i.e. per capita income; education; bio-based employment) and biophysical characteristics (i.e. land cover) and are taken from Eurostat.

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[9] It should be made clear that the absence of a statistical difference in profiling variable 'x' across the regional clusters does not necessarily imply that the variable is not important in the development of the bio-based economy. It is indicative that said variable 'x' may either be uniformly important (i.e. across all regional clusters), or uniformly not important.

TABLE 7: Profiling Variables and their Descriptors

Variable	Description	Source
GDPpc: GDP per capita	GDP in current million US $. Period: 2010.	Own calculation based on The World Bank, World Development indicators for GDP and population.
EDUC: Education (%): **_Prim**: primary education **_Sec**: secondary education **_Univ**: university education	Percentage of population between 15 and 64 years old, with primary, secondary or university level of education. Period: 2015.	EUROSTAT
E_: Employment (% of total employment) [see Table 1 for sectors composition] **_Bio**: in bioeconomy **_Agr**: in agriculture **_Food**: in food sectors **_BioMass**: in other biomass sectors **_BioEnergy**: in bioenergy sectors **_BioIndustry**: in bioindustry sectors	Percentage of number of persons (in thousands) employed equivalent full time in the sector with respect to total. Period: 2010-2014 average	EUROSTAT Labour Force Survey, JRC (2017).
O_: Output share (% over total output): [see Table 2 for sectors composition] **_Bio**: in bioeconomy **_Agr**: in agriculture **_Food**: in food sectors **_BioMass**: in other biomass sectors **_BioEnergy**: in bioenergy sectors **_BioIndustry**: in bioindustry sectors	Share of economic output value by bio-based activity. Period: 2010.	BioSAM
Land Cover (% over country area): **Cov_crop**: cropland **Cov_wood**: woodland **Cov_shrub**: shrubland **Cov_grass**: grassland **Cov_bare**: bare land	Land cover percentage over total country area. Period: 2012	EUROSTAT

Source: Own elaboration.

In each case, the choice of the profiling variable underlies a hypothesis about the bio-based economy. For example, under the hypothesis that more developed economies with higher per capita incomes specialise more in non bio-based manufacturing and service industries, is there an inverse association between per capita incomes and the level of bio-based wealth generating potential? Similarly, does the skill level of the workforce or the proportion of workers employed in bio-based activities have an association with the wealth generating potential of the sector? Finally, does the heterogeneous pattern and proportion of non-urban land cover contain any relationship with the bio-based defined clusters? 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.

The results of the tests are provided in Table 8. Examining the socio-economic variables, it is found that there is a statistically significant differentiation between the groups for GDP per capita, all three education levels, three of the five employment variables and two of the five land cover variables.

With a high degree of significance (GDPpc, $p<0.01$), regional clusters with stronger relative bio-based wealth potential typically exhibit lower per capita incomes (e.g. Mediterranean and Mainly Eastern) than those clusters with weaker relative bio-based wealth generating potential ('Isles and Lux', 'Northern&Central'). Similarly, up to secondary education level ($p<0.01$) and up to University education ($p<0.1$), there are statistical differences between the regional clusters. On the one hand, the proportion of university educated individuals rises in those regional clusters where GDP per capita is highest (i.e. 'Isles and Lux', 'Northern&Central'), which points to a tentative association between relatively stronger bio-based wealth generating patterns and relatively lower levels of university education. On the other hand, there does not appear to be any discernible pattern between the percentage of 15-64 year olds in primary or secondary categories and the relative propensity of the bio-based sector to generate demand/supply driven wealth. In part this may be driven by difficulties in mapping heterogeneous enterprise based training schemes (i.e. apprenticeships) across each of the EU28 member states to the United Nations International Standard Classification of Education (ISCED) employed by Eurostat.

In terms of employment patterns, there is a statistically significant differentiation between clusters in terms of the share of workers employed in (i) the bio-industrial sectors (i.e. wood, textiles, bio-chemicals) ($p<0.01$), (ii) the bio-mass supply sectors (forestry, pellets, energy crops) ($p<0.05$) and (iii) the bioeconomy ($p<0.10$). In particular, a statistical association appears between the higher share of workers employed in the bio-industrial sectors and the bioeconomy in general, and the bio-based sectors' greater ability to generate wealth.

TABLE 8: Profiling of EU country clusters

	Northern & Central [n=10]	**Isles+Lux [n=3]**	**Mainly Eastern [n=9]**	**Baltic [n=2]**	**Mediterra. [n=4]**	**EU28**
GDPpc***	41477.7	51133.4	19710.6	12980.5	28999.4	31697.6
EDUC_Prim***	14.4	26.9	10.4	7.8	34.5	16.8
EDUC_Sec***	46.2	34.8	59.8	54.9	34.8	48.3
EDUC_Univ*	39.4	38.3	29.8	37.3	30.7	34.8
E_Bio*	7.5	5.9	15.3	15.5	12.6	11.1
E_Agric	3.5	3.0	7.1	5.6	6.8	5.2
E_Food	2.5	2.1	4.5	3.9	3.1	3.3
E_Biomass**	0.3	0.1	0.7	1.6	0.2	0.5
E_BioEnergy	0.0	0.0	0.3	0.0	0.1	0.1
E_BioIndustry***	1.2	0.7	2.7	4.4	2.4	2.0
O_Bio***	8.08	4.11	10.30	14.01	8.93	8.91
O_Agric	1.65	1.22	2.88	2.42	2.15	2.12
O_Food	4.46	2.17	4.88	4.67	3.93	4.29
O_Biomass**	0.21	0.03	0.44	1.85	0.25	0.38
O_BioEnergy	0.04	0.00	0.02	0.02	0.03	0.03
O_BioIndustry***	1.73	0.68	2.08	5.06	2.58	2.09
Cov_crop	22.3	27.0	31.0	12.0	25.5	25.1
Cov_wood	32.1	18.8	38.1	53.1	32.5	34.0
Cov_shrub*	3.3	12.9	3.0	2.3	16.6	6.2
Cov_grass	30.3	19.3	20.5	22.1	15.5	23.4
Cov_bare*	1.2	4.4	0.7	1.0	3.2	1.7

Notes: ***,**,* denote significant differences of the descriptor mean across clusters at 1, 5 and 10% level of significance, respectively.

See Table 6 for the variable descriptors.

Source: Own elaboration.

Finally, the biophysical variables denominating the share of land dedicated to shrub land and bare land are statistically differentiated across the clusters (p<0.10), although the highest land shares in both of these cases are found in the clusters 'Isles & Lux' and 'Mediterranean', which represent polar opposites in terms of their relative bio-based sector wealth potential. These differences may therefore reflect the geographical idiosyncrasies of the clusters under observation rather than any potentially causal link with the structure of their bio-based activities. Despite a woodland share by clusters which varies from 53% in the 'Baltic' to 19% in 'Isles & Lux', variation in this profiling variable across clusters is not found to be statistically significant. The reason for this is because in the remaining clusters containing 23 member states, variation in mean woodland shares is only slight.

3.3. Bioeconomy Employment Multipliers

Employment multipliers are calculated to examine the generation of labour resulting from additional bio-economic activity. In Table 9, mean employment multipliers for the broad bio-based sub-sectors classifications are presented for the EU28, EU15, EU10 (2004 accession), EU3 (2007 and 2013 accessions) and the five regional clusters derived in section 3.1. These figures are calculated by averaging both over activities within each bio-based sector aggregate and EU countries within each regional cluster. Thus, the figures in the columns define the mean number of new jobs (direct, indirect and induced effects) generated per million euros of additional output.[10]

TABLE 9: Comparison of employment multipliers by regional clusters

Region [a]	**BioEcon*****	**NonBio****	**Agric*****	**Food*****	**BioMass*****	**BioEnergy****	**BioIndustry*****
EU15	13	10	17	11	14	11	11
EU10	29	21	39	22	30	20	23
EU3	50	35	66	38	50	35	39
BL & FLClusters [c]	**BioEcon***	**NonBio****	**Agric****	**Food****	**BioMass***	**BioEnergy****	**BioIndustry****
Northern & Central	15	12	19	12	16	13	13
Isles+Lux	9	7	13	6	9	3	8
Mainly Eastern	34	23	46	26	33	24	25
Baltic	34	28	44	24	38	25	31
Mediterranean	23	15	28	20	23	17	18
	BioEcon	NonBio	Agric	Food	BioMass	BioEnergy	BioIndustry
EU28	23	16	30	18	23	17	18

Notes: ***, ** and * denote significant differences at 1, 5 and 10% level of significance, respectively, of the mean employment multiplier across regional clusters, based on the Anova analysis when Levene statistics does not reject the null of homogeneity of variances, or the W test, otherwise.

[a] Region: EU15 is old EU15 countries; EU10, includes the 10 (2004 accession); EU3 (2007 and 2010 accessions: Bulgaria, Romania and Croatia).

[c] Back & Forward linkages: regional clusters identified with back and forward linkages and described in Table 3.

Source: Own elaboration.

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[10] In the appendix, a full set of employment multipliers is presented for all EU28 members for the seven sectoral aggregates

A cursory review of the statistics presented in Table 9 shows that the employment multipliers for the EU15 (the 'old' EU members) are consistently below those for the 2004 accession members (EU10), whilst for the most recent accession grouping, the employment multipliers are the highest. For example, for every million euros of new output in the bioeconomy composite sector ('BioEcon'), 13, 29 and 50 new jobs on average are created in the EU15, EU10 and EU3, respectively. A series of of Anova tests (or W-tests in the case of non-homogeneous variances) was conducted to confirm that the means of the employment multipliers differed statistically between the different regional groupings. In all cases, statistical significance was found with at least 5% significance.

Examining further the different types of bio-based activities in Table 9, one observes that employment generation per million euros of additional output is consistently highest in the primary agricultural sector of the EU15, EU10 and EU3, recorded at 17, 39 and 66 new jobs, respectively, on average. By contrast, the lowest marginal employment generation is recorded in the bio-energy sector. With its higher level of capitalisation, for every one million additional euros of bio-energy output, 'only' 11, 20 and 35 new jobs are created in the EU15, EU10 and EU3, respectively. Indeed, it is interesting to note from Table 9, that even in the bio-energy sector where new job creation prospects are lowest, this is still comparable with the employment generation figures corresponding to the non bio-based composite sector ('NonBio'). Furthermore, comparing bio-based and non-bio-based head count multipliers in each of the EU15, EU10 and EU3, bio-based employment generation per million euros of output is higher by 30%, 38% and 43%, respectively.11

In Figure 2, a box-plot is used to picture the heterogeneity of employment multipliers within these three EU groups. In the vertical axis is the number of new jobs per one million euro of new output for seven aggregate subsectors (horizontal axis). The upper and lower limit of the box capture the 75th (third quartile Q3) and 25th (first quartile Q1) percentile of the observations in each sub-sector. The horizontal lines in the boxes are the median values; the upper and lower limits of the employment multipliers are marked by the lines which extend above and below the boxes,12 whilst the dots are outlier values.

For example, in the EU3 primary agricultural sector (Agric, marked in green), with a median employment multiplier of 65, the observations from Bulgaria, Croatia and Romania are 74, 65 and 60, respectively. Note that the median represented in the box plot is in general different from the mean reported in Table 9. This is the result of a non-symmetric distribution of country employment multipliers. Thus, a median greater (lower) than the mean implies that country-specific employment multipliers are skewed to the left (right). In the EU10, the range of agricultural employment multipliers is between 70 new jobs (Poland) and 16 new jobs (Malta), whilst the EU10 median and mean is 37 and 39, respectively. Similarly, in the EU15 primary agricultural sector, the range is between 37 new posts (Portugal) and 4 new posts (Luxembourg), with a median and mean value of 17.

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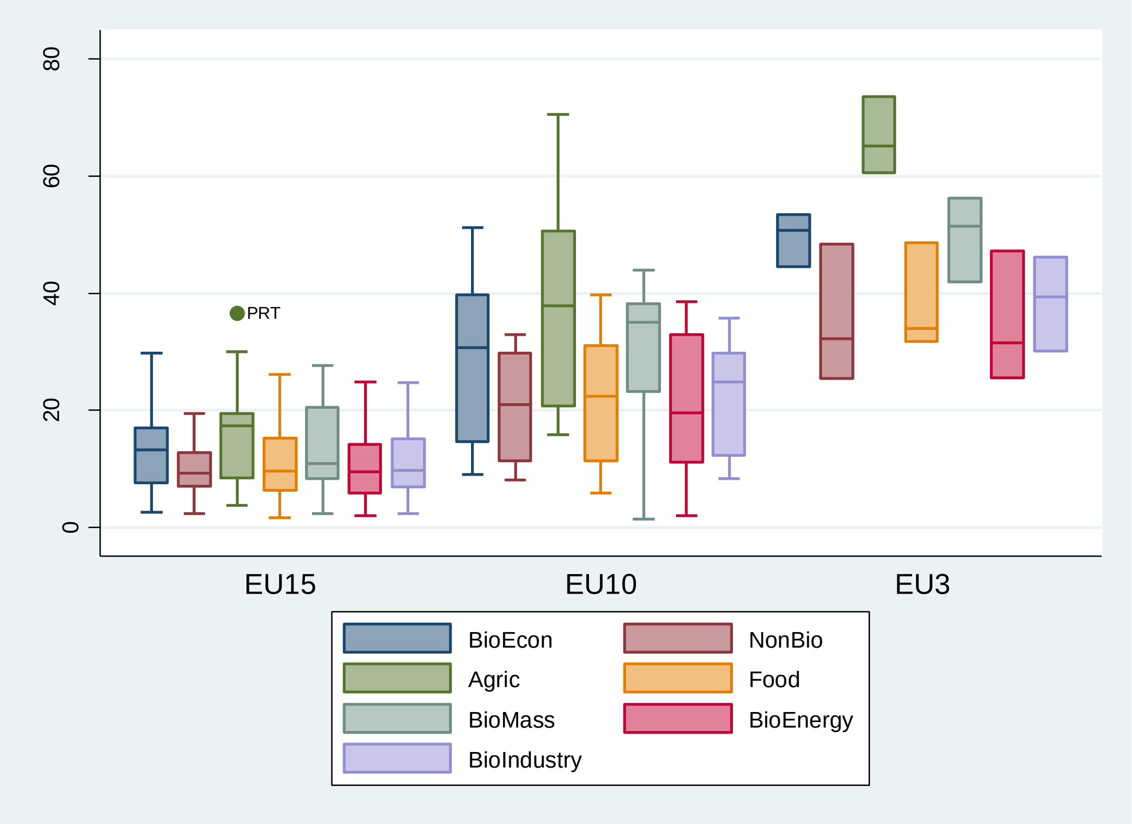
[11] The general observation is robust across all 28 member states, where bio-based activity generates the same or more employment than non bio-based sectors, per million euros of new output.

[12] These are known as adjacent values, and are calculated to include all observations within 1.5 Inter-Quartile (Q3-Q1) range).

FIGURE 2: Employment multipliers for broad sectors across EU Regions



Note: The limits of the box represent the 25th percentile (lower hinge) and 75th percentile (upper hinge). The line within the box is the median. The ends of the lines (whiskers) represent the lower and upper adjacent (i.e. to include all observations within 1.5 Inter-Quartile range), while dots are outside values**.**

Source: Own elaboration.

An even closer inspection shows that compared with the EU28 average for the bioeconomy sector (22.9 new jobs per one million of new output, standard deviation of 11.9 across regions – see Table A.2 in the Appendix), some bio-based activities perform well in terms of employment generation. For example, Table 10 shows that those EU28 agricultural activities where employment generation is consistently high are 'extensive livestock' (66), 'other crops' (50), 'raw milk' (41), 'intensive livestock' (32) and 'industrial crops' (31). In food processing, it is the 'red meat' (27) and 'white meat' (22) sectors with above average employment generation potential, whilst in biomass supply sectors, 'forestry' (31) is the only one that scores above the EU bioeconomy average. In bio-industry and bio-energy sectors, employment generation is limited. Indeed, for the new biomass sectors (energy crops, pellets), bio-energy and (in particular) bio-chemicals, new employment generation is below the EU28 average for the bioeconomy, whilst the lowest employment generator (5) is found to be olive oil.

TABLE 10: Employment multipliers by bio-based activities for the EU28

Sector		Multiplier	Std. Dev.	Sector		Multiplier	Std. Dev.
Cereal	AGRIC	21.8	16.7	**Dairy**	FOOD	18.2	12.5
Veg	AGRIC	26.7	16.5	**Rice**	FOOD	16.7	18.7
Fruit	AGRIC	17.5	19.0	**Sugar**	FOOD	12.8	11.3
Oilseeds	AGRIC	23.5	24.8	**OliveOil**	FOOD	5.0	6.3
OilPlant	AGRIC	13.2	14.7	**Wine**	FOOD	13.1	11.3
IndCrop	AGRIC	31.0	40.8	**BevTob**	FOOD	16.4	10.0
Ocrop	AGRIC	50.1	39.8	**OFoodProd**	FOOD	20.0	12.4
ExtLiveProd	AGRIC	65.6	43.0	**EnergyCrops**	BIOMASS	16.4	12.6
IntLiveProd	AGRIC	31.8	23.0	**Pellets**	BIOMASS	21.5	13.4
OliveProd	AGRIC	20.9	15.9	**Forestry**	BIOMASS	31.5	22.1
RawMilk	AGRIC	41.5	30.5	**BioElectricity**	BIOENERGY	17.8	14.5
Fishing	AGRIC	18.4	11.7	**Biofuel1**	BIOENERGY	15.4	9.1
AnFeed	FOOD	32.2	26.8	**Biofuel2**	BIOENERGY	17.4	14.7
RedMeat	FOOD	27.3	19.8	**Wood**	BIOINDUSTRY	24.2	15.4
WhMeat	FOOD	21.6	14.1	**Textile**	BIOINDUSTRY	17.6	13.0
VegOil	FOOD	12.6	11.0	**BioChem**	BIOINDUSTRY	13.3	7.4

Note: For sector descriptions, see Table 2. Mean multiplier over EU-28 countries.
Source: Own elaboration

In rationalising the difference in employment generation across the three regions (defined by accession dates), an examination of the total employment share data reveals an unambiguous link between the heterogeneous employment generation potential in each region and the share of total employment engaged in bio-based activities (direct employment effect). In the EU15, EU10 and EU3, approximately 7.2%, 16.3% and 27.6% of the total workforce is connected to the bioeconomy, respectively (JRC, 2016). One particular sector is primary agriculture which accounts for 2.9%, 9.6% and 18.2% of the workforce, respectively. Thus, in the bio-based sector, it appears that the direct employment effect is key since employment potential is greater in those regions whose bioeconomic sub-sectors employ a larger share of the labour pool.

Turning to the five clusters derived in section 3.1, Anova (or W-tests) once again reveal that the employment multipliers are statistically different between the regional groupings (Table 9). Examining the five clusters, in 'Mainly Eastern' and 'Baltic' where the bio-based BL and FL multipliers are relatively stronger, the average employment generation prospects are found to be the strongest across each of the bio-based sector classifications. In the regional cluster 'Mediterranean' which was found to exhibit the strongest FL and BL multiplier effects, employment generation is approximately the same as the EU28 average across all of the bio-based sector classifications. In the relatively less developed bio-based regional cluster 'Isles and Lux', job creation in bio-based sectors is also particularly limited with, for example, as few as three jobs per million euros of additional output in bio-energy (compared with 17 jobs in the EU28). To statistically test the positive relationship between BL, FL and employment multipliers, pairwise correlation tests were conducted, with the results shown in Table 11.

Table 11: Correlations between employment multipliers and backward and forward linkages

	a. Employment multiplier and Backward Linkage	b. Employment multiplier and Forward Linkage
Agric	0.55***	0.76***
Food	0.50***	0.55***
BioMass	0.60***	0.37**
BioEnergy	0.55***	0.32*
BioIndustry	0.44**	0.60***
BioEcon	0.51***	0.69***
NonBio	0.56***	0.31

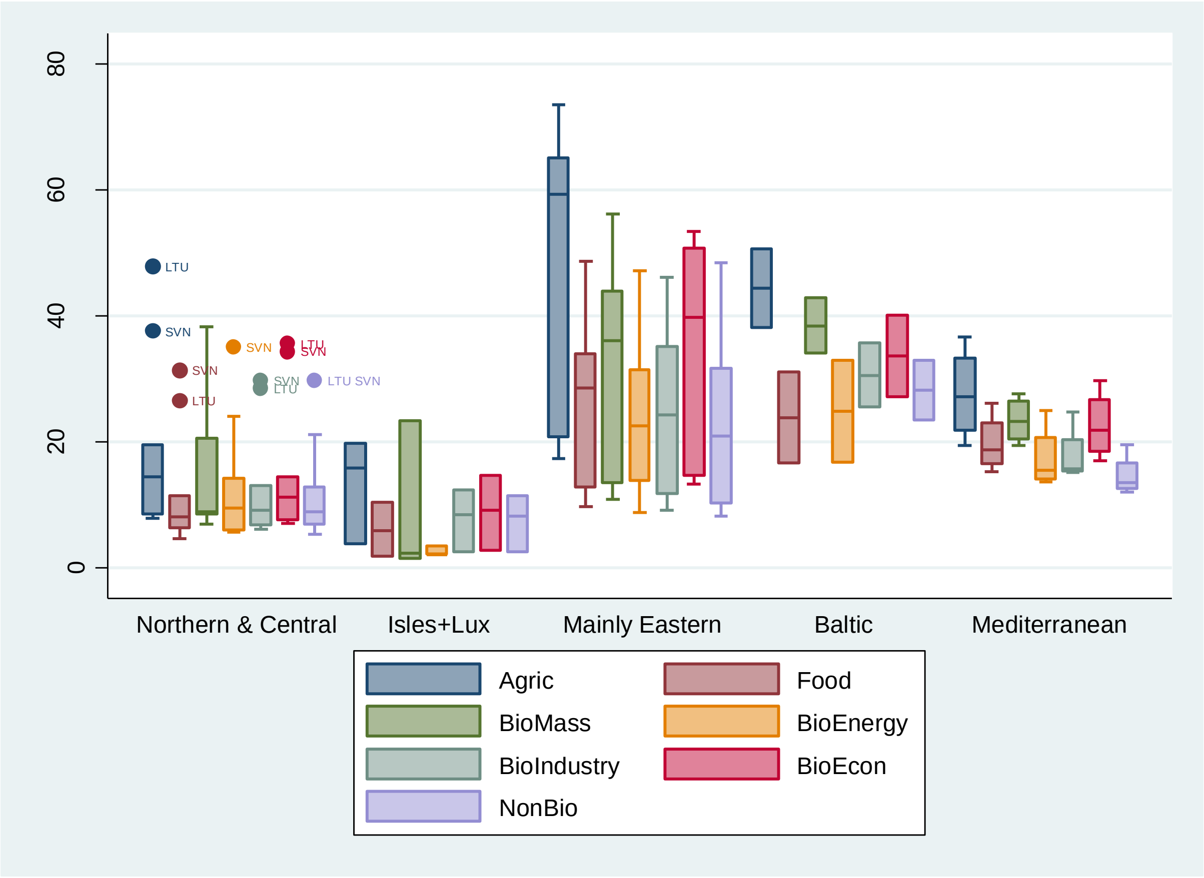
Note: ***, *** and * denote significant pairwise correlations at 1, 5 and 10%, respectively.

Source: Own elaboration.

In all bio-based sector cases there are positive correlations and there is statistical evidence that activities with stronger bio-based BL and FL multipliers also have higher employment generation potential. For the 'employment multiplier-backward linkage' correlation coefficient, this effect is strongest in the biomass supply (pellets, energy crops, forestry) sector, whilst in the case of the 'employment multiplier-forward linkage' correlation coefficient, it is primary agriculture which clearly exhibits the strongest effect.

The range of employment multipliers in each of the EU group clusters is presented in the box diagram in Figure 3. The Figure clearly shows that although the 'Mainly Eastern' group is amongst the strongest bio-based employment groupings, within-group dispersion of the multipliers is also particularly high in all of its sector aggregates. For example, for the primary agriculture sector, the median multiplier in 'Mainly Eastern' is 59 jobs per one million euros of new output, although the upper limit is 73 jobs per million euros, whilst the lower limit is 10 jobs per million euros. Note, however, the mean is 46. In the Mediterranean region, however, where bio-based (BL and FL) wealth generation has the strongest relative base, the range of employment multiplier values is relatively compacted around the median which is also very close to the mean in any broad sector. For example, the lower bound employment multiplier for the primary agriculture aggregate sector in 'Mediterranean' (19) is higher than the corresponding value in the cluster 'Mainly Eastern' (17). The large 'Northern & Central' cluster exhibits generally lower employment multiplier values (as observed previously), although there is evidence of upper 'outlier' values which are particularly pronounced in primary agriculture, food, bioenergy, bio-industry and the bioeconomy aggregate sector, and that correspond to Lithuania and Slovenia.

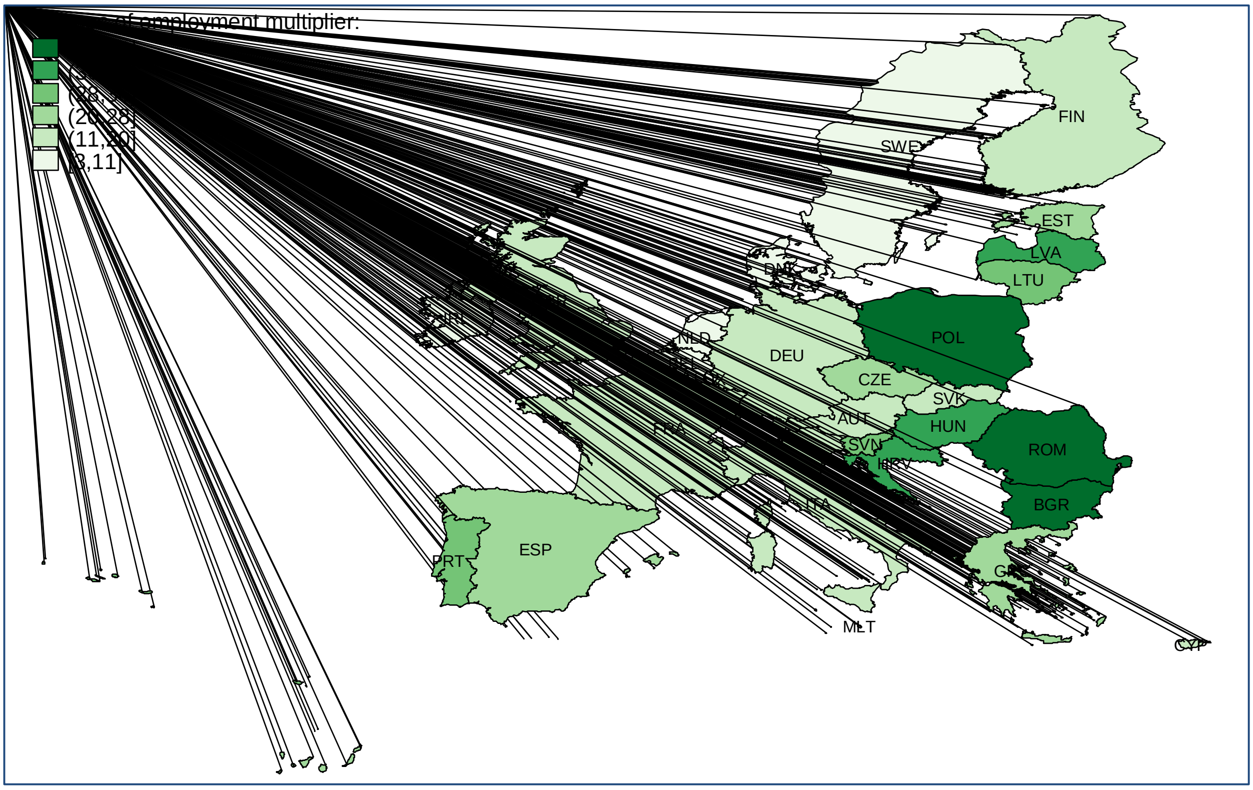
FIGURE 3: Employment multipliers
for broad sectors across the five group clusters



Source: Own elaboration

As a final summary for the whole bioeconomy, Figure 4 plots the mean employment multiplier in each country.

FIGURE 4: Bioeconomy employment multiplier (sectoral mean)



Note: (a,b] denotes interval, excluding 'a' and including 'b'

Source: Own elaboration.

3.4. Key sector analysis

In section 3.1, a brief discussion of the key sector (BL > 1; FL > 1) frequencies in each of the group clusters was presented, revealing 30 cases of key sectors (see Tables 5 and 6 and Figure 1). This section focuses on identifying which specific sectors are the most significant wealth generators. An examination of Table 5 shows all of the key sectors highlighted in green. Furthermore, the Table shows that the most prolific key sectors are generally in the agriculture and food industries, whilst in 20 of the bio-based sector categories in this study, there are no examples of 'key sector' performance.

The activity which exhibits key sector status in all five of the regional clusters is 'raw milk' production. Another sector with particularly strong key sector credentials across four regional clusters is 'intensive livestock', whilst in the fifth case (Isles and Lux) it is a 'potential key sector' (marked in pink in Table 5) with a FL multiplier exceeding 0.9. The sectors 'cereals', 'animal feed', 'forestry', 'wood' and 'other food' are strong contenders (three regional clusters), whilst in a fourth regional cluster group ('Northern & Central'), both 'animal feed' and 'wood' have 'potential key sector' status (Table 5). The remaining cases are extensive livestock (two regional clusters) and 'oilseed', 'dairy', 'beverages and tobacco' and 'textiles' (one regional cluster). Of the newer bio-based activities (i.e. first- and second-generation biofuels, bio-chemicals, bio-electricity, biomass from energy crops and pellets), none have key sector status, although bio-electricity has 'potential key sector' status in three group clusters (FL ≈ 0.9).

Cross referencing each activity's key sector status with its employment generation potential (Table 11), it is curious to note that both 'industrial crops' and 'other crops' which show evidence of high employment multipliers are not key sectors in any of the clusters. On the other hand, 'raw milk' and 'intensive livestock' are sectors which score exceptionally well in both the indicators of relative wealth and employment generation. Both 'cereals' and 'animal feed' also generate employment above the EU28 bioeconomy average (i.e. 22.9 jobs per million euros of new output) and score well as key sectors.

In the newer bio-based sectors (bio-energy, bio-chemicals, biomass from pellets and energy crops), Table 9 shows that relative employment generation is below the EU28 bioeconomy average for employment generation with an absence of key sector status. Comparing between the bio-energy sectors' employment potential, EU bio-electricity performs the best, followed by second generation bio-fuels and then first generation bio-fuels. With an average employment multiplier of only 13.3 new jobs per million euros of output, bio-chemicals exhibit the lowest employment generation of all the 'new' bio-industry and bio-energy sectors. Indeed, this general ranking of the four sectors is also observed in Table 5 when comparing the demand and supply driven wealth potential of the sectors.

4. Conclusions

According to 2014 figures, the bioeconomy sectors in the European Union (EU) account for approximately 2.228 billion euros in turnover and 18.6 million jobs (JRC, 2017). Consequently, the bioeconomy strategy has an important role to play in contributing to a sustainable model of EU growth. To statistically profile the relative wealth and employment generating properties of the bioeconomic activity across sectors and 28 EU regions, the current study follows previous research (Philippidis et al., 2014) which employs social accounting matrix (SAM) multipliers and statistical clustering techniques. A significant improvement in the current paper is the construction of a new database for the year 2010. Moreover, compared with Cardenete et al. (2014) and Philippidis et al. (2014), the coverage of bioeconomy is greatly enhanced to include additional sources (i.e. pellets, energy crops) and applications (i.e. bio-energy and bio-industry activities) of biomass in the economy.

The main finding is that the economic value added of bioeconomic activity is highly heterogeneous, both across sectors and regional clusters. In two regional clusters ('Mediterranean' and 'Mainly Eastern'), the bioeconomy is a key engine of wealth generation, whilst in all EU regions, the sector is found to be predominantly backward-oriented (i.e. demand-driven). This general result was also observed and reported in Philippidis et al. (2014). The higher degree of backward orientation is consistent with the existence of a multi-layered logistical network of intermediate input suppliers to bioeconomic activities. Indeed, 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. As noted in Philippidis et al. (2014), in developed economies and the EU in particular, high BLs owing to highly diversified input requirements are perhaps to be expected given strict legal regulations regarding food standards, food safety requirements and animal welfare.

On the other hand, the implication of the generally low FL multipliers (i.e. < 1) is that the supply chain for bioeconomic outputs is concentrated into a smaller number of possible outlets requiring relatively less ancillary service support to process and distribute one unit of a given bioeconomy sector's output to end users. As a result, this generates relatively smaller ripple effects throughout the economy. For example, in primary agriculture and biomass supply sectors, the output remains as an unprocessed or raw good, with few alternate uses. Similarly, biofuel is an intermediate product which is solely targeted (via transportation suppliers) to blenders for use in petroleum.

Further statistical profiling of the regional clusters reveals that the two groups with greater bioeconomy wealth potential typically exhibit lower per capita incomes, higher shares of employment in bioeconomic sectors and relatively lower levels of university education. A similar result is found in Philippidis et al. (2014). This finding apparently supports the notion that more developed EU economies, engage in greater specialisation in non bioeconomy activities (particularly primary agriculture), which in part may also be attributed to climatic factors. If an EU-wide model of bioeconomy growth is to be promoted, this structural observation suggests that it could be more of a challenge in some EU member states than others.

Turning to the employment multipliers, bioeconomy sectors typically generate relatively greater employment compared with other sectors, being generally higher in the relatively poorer EU member states. As noted in Philippidis et al. (2014), a degree of caution should be taken when interpreting these results. Although employment multipliers can give quantitative estimates of employment generation, they cannot make qualitative inferences. In particular, given the importance of agricultural labour, this is a case in point, where typically less affluent regions of the EU28 (i.e. EU3, EU10) may employ lower skilled; less productive and/or lower remunerated labour or part time or occasional labour on the farm, reflecting (in part) the less commercial agricultural orientation of the enterprise. If the marginal and average value products of labour on the farm are lower, then the productivity and, by extension, the productivity and competitiveness of the sector is lower. Comparing between sectors, agricultural activity (particularly intensive and extensive livestock) is a key generator of employment. Perhaps not surprisingly, more highly capitalised bio-industrial (particularly bio-chemicals) and bio-energy sectors generate relatively less bioeconomy employment, although they are still comparable with the rest of the economy.

In the current paper, 12 of the 32 bioeconomy categories considered are 'key sectors', whilst a further four sectors exhibit potential key sector status. Furthermore, the two notable key sectors of raw milk and intensive livestock also post impressive employment generation. Taken from a purely economic perspective, continued promotion of these two sectors could be seen as advisable. On the other hand, taking into account the notion of responsible biomass usage to meet non-economic goals (i.e. climate change), the two sectors in question generate some of the largest sources of non CO_2 non-combustion greenhouse gases.

Comparing with previous studies, the 'key sector' results reported here diverge considerably from Cardenete et al., (2014) and Philippidis et al. (2014). Philippidis et al. (2014) only report key sector status for the milk and dairy chain, whilst a study for the Spanish economy by Cardenete et al. (2014) does not report any key sectors. Indeed, a deeper look into our backward- and forward-linkage multipliers for Spain shows that of the 53 disaggregated bioeconomic sector definitions, 21 sectors exhibit key sector status. Perhaps the most plausible explanation is due to the resulting structural change that has occurred between 2000 (Cardenete et al., 2014) and 2010 (current study),[13] exacerbated by the financial crisis which began in 2007. By way of example, characterized by typically lower income elasticities of demand, it was reported that primary agriculture would be expected to be relatively more resilient to the ongoing process of macro adjustment (see OECD, 2009). As a result, the relative wealth generating importance of the sector may have grown in the ensuing period.

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[13] Although employing a significant number of target data sources for 2007, the source SAM data employed in Philippidis et al. (2014) is taken from the coefficients of the 2000 EU AgroSAMs database.

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6. Appendix

TABLE A.1: Backward Linkages per country for broad sectors

Country	Backward Linkages						Forward Linkages					
	BioEcon	Agric	Food	BioMass	BioEn	BioInd	BioEcon	Agric	Food	BioMass	BioEne	BioInd
AUT	1.48	1.61	1.23	1.69	1.69	1.48	0.59	0.61	0.49	0.86	0.55	0.67
BEL	1.27	1.26	1.20	1.48	1.29	1.31	0.51	0.47	0.55	0.57	0.45	0.54
BGR	1.94	2.31	1.55	2.30	1.80	1.68	0.87	1.12	0.70	0.95	0.53	0.77
CYP	1.06	1.28	0.97	1.23	0.31	1.09	0.54	0.73	0.46	0.65	0.07	0.39
CZE	1.81	2.01	1.57	2.11	1.63	1.74	0.77	0.74	0.72	1.24	0.57	0.75
DEU	1.63	1.61	1.48	1.80	2.06	1.66	0.62	0.56	0.60	0.82	0.65	0.66
DNK	1.30	1.28	1.24	1.68	1.31	1.22	0.58	0.61	0.53	0.77	0.51	0.48
ESP	2.23	2.19	2.31	2.30	2.20	2.02	0.91	0.83	1.18	0.69	0.61	0.75
EST	1.35	1.62	0.92	1.93	1.21	1.38	0.67	0.77	0.45	0.95	0.37	1.03
FIN	1.80	2.08	1.51	1.92	1.72	1.68	0.69	0.77	0.53	1.05	0.58	0.74
FRA	2.07	2.12	1.96	2.22	2.46	1.71	0.80	0.84	0.81	0.82	0.79	0.62
GBR	1.81	1.99	1.32	2.43	2.40	1.65	0.63	0.71	0.44	0.88	0.77	0.58
GRC	1.96	2.13	1.80	2.13	2.00	1.60	0.77	0.97	0.72	0.47	0.60	0.59
HRV	1.84	2.21	1.57	2.02	1.59	1.46	0.79	0.98	0.68	0.83	0.44	0.72
HUN	1.58	1.90	1.34	1.71	1.43	1.22	0.76	1.01	0.61	0.78	0.54	0.56
IRL	1.15	1.14	0.85	1.75	1.66	1.25	0.64	0.62	0.52	1.05	0.82	0.57
ITA	2.18	2.06	2.21	2.15	2.52	2.24	0.76	0.64	0.82	0.67	0.75	1.13
LTU	1.40	1.52	1.15	1.79	1.54	1.31	0.64	0.69	0.56	0.70	0.55	0.77
LUX	0.66	0.65	0.58	0.60	0.78	0.93	0.29	0.33	0.19	0.30	0.36	0.45
LVA	1.66	1.75	1.32	2.37	1.86	1.68	0.70	0.69	0.53	1.23	0.46	1.10
MLT	0.71	0.89	0.72	0.27	0.31	0.82	0.35	0.52	0.31	0.11	0.10	0.31
NLD	1.24	1.26	1.17	1.09	1.75	1.06	0.53	0.57	0.54	0.31	0.73	0.33
POL	2.18	2.35	1.93	2.39	2.48	1.91	0.86	0.91	0.84	0.89	0.74	0.74
PRT	1.91	1.82	1.81	2.16	2.40	1.86	0.76	0.68	0.76	0.82	0.76	1.02
ROM	1.90	1.47	1.95	2.60	2.60	1.97	1.02	1.11	1.06	0.90	0.73	0.89
SVK	1.70	1.76	1.41	2.21	2.19	1.50	0.67	0.76	0.42	1.09	0.74	0.73
SVN	1.47	1.45	1.31	1.65	2.08	1.34	0.54	0.50	0.41	0.80	0.71	0.76
SWE	1.43	1.50	1.15	1.73	1.84	1.49	0.59	0.53	0.47	1.04	0.71	0.64
EU28	1.60	1.69	1.41	1.85	1.75	1.51	0.67	0.72	0.60	0.80	0.58	0.69

Note: see Table 2 for sectors description. Average linkage across sectors within the broad sector descriptor.

Source: Own elaboration.

TABLE A.2: Employment multipliers by country for broad sectors

	BioEcon	**NonBio**	**Agric**	**Food**	**BioMass**	**BioEne**	**BioInd**
AUT	13	9	20	9	9	9	9
BEL	7	6	8	6	8	6	7
BGR	51	32	74	34	51	31	39
CYP	15	11	20	10	23	3	12
CZE	25	20	32	18	29	16	24
DEU	14	12	19	11	12	13	12
DNK	7	7	8	6	8	6	8
ESP	20	13	24	18	21	14	15
EST	27	23	38	17	34	17	25
FIN	13	9	19	10	11	9	10
FRA	14	10	17	13	13	14	12
GBR	14	13	17	10	21	14	13
GRC	24	14	30	20	28	16	16
HRV	44	25	65	32	42	25	30
HUN	40	21	59	29	36	22	24
IRL	8	5	12	5	8	6	6
ITA	17	12	19	15	19	14	15
LTU	36	21	48	26	38	24	28
LUX	3	2	4	2	2	2	2
LVA	40	33	51	31	43	33	36
MLT	9	8	16	6	1	2	8
NLD	7	7	8	7	7	9	7
POL	51	32	71	40	44	39	35
PRT	30	19	37	26	25	25	25
ROM	53	48	60	49	56	47	46
SVK	15	8	21	11	11	11	9
SVN	34	30	37	31	37	35	30
SWE	9	8	12	7	8	9	9
EU28							
mean	23	16	30	18	23	17	18
Std.Dev.	15	11	21	12	16	12	12
CV %	66%	66%	68%	68%	67%	70%	64%

Notes: See Table 2 for sector composition. Mean multipliers across the sectors within the broad sector. Eg. On average, each agricultural sector in Austria generates 20 jobs per million €.

Source: Own elaboration

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JRC Mission

As the science and knowledge service of the European Commission, the Joint Research Centre's mission is to support EU policies with independent evidence throughout the whole policy cycle.

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