

Economic impact of the bioeconomy in Spain: Multiplier effects with a bio social accounting matrix



Valeria Ferreira, Laia Pié*, Antonio Terceño

Markets and Financial Analysis Research Group, Department of Business Management, Faculty of Business and Economics, Universitat Rovira i Virgili, Av. Universitat No 1, 43204, Reus, Spain

ARTICLE INFO

Article history:

Received 16 April 2020

Received in revised form

11 March 2021

Accepted 12 March 2021

Available online 24 March 2021

Handling editor: Prof. Jiri Jaromir Klemes

Keywords:

Bioeconomy

Spain

Social accounting matrix

Multisectoral models

Impact analyses

Multipliers

ABSTRACT

The bioeconomy emerges as a new economic model to help address issues related to environmental care and focus on a more sustainable economy. In the last decade, it has become a global priority and many countries have published their own strategies that clearly refer to the development of the bioeconomy. The symmetric social accounting matrix with basic prices was constructed, including the breakdown of biobased accounts belonging to the bioeconomy to determine which sectors of the bioeconomy are most strategic to promote sustainable economic growth. This constructed matrix was used to analyse the economic influence of the bioeconomy products and their impact on job creation. The analysis was carried out using the diffusion and absorption multipliers, which enabled the interpretation of the linkages between the different economic agents. The results were analysed in depth and the multipliers decomposed into their different effects, own, open and circular, and complemented with the calculation of the employment multiplier to evaluate the most important sectors for employment generation. The analysis was applied to the case of Spain. The results of this research enabled the identification of the strategic sectors where economic policies can be applied since these are the ones that increase economic growth and activities within the bioeconomy and create jobs. The conclusions indicated that the Spanish bioeconomy is still focused on traditional sectors and has not yet developed its potential in more innovative biobased products, demonstrating that the bioeconomy in Spain still has a long way to go.

© 2021 The Authors. Published by Elsevier Ltd. This is an open access article under the CC BY license (<http://creativecommons.org/licenses/by/4.0/>).

1. Introduction

In recent years, the debate has emerged about the need to reconsider the current economic model and challenge issues related to food security, resources scarcity, environmental pressures, and climate change. A new economic paradigm has emerged as one of the main instruments to tackle global sustainability problems: the bioeconomy, defined as an economy which comprises all economic activities related to the use of biological products and processes to produce food, feed, biological products and bioenergy. Its significance and potential benefits have been recognized globally through the promotion of related policies. By early 2018, nearly 50 countries were trying to incorporate the bioeconomy into their policy strategies (German Bioeconomy Council, 2018). Several articles have analysed some of the published bioeconomy strategies, highlighting among them the lack of

instruments to measure their progress (Staffas et al., 2013), the need for a solid scientific base, and greater collaboration among academics, companies, and the government (Dietz et al., 2018; Koukios et al., 2018).

Despite the increase in publications related to the bioeconomy in recent years, it remains a concept that must be analysed in greater depth in terms of evaluating its economic, environmental, and social impacts (D'Amato et al., 2017). The main problems when analysing activities related to the bioeconomy are the lack of available data and the failure to disaggregate the accounts related to bioproducts in the national accounts (Mainar et al., 2017; Ronzon and M'Barek, 2018). There is currently no established international methodology to measure progress of the bioeconomy. Considering that there are many bioeconomy policies around the world, this type of unification methodology is needed to compare its impact.

Several studies attempting to measure the bioeconomy using different methodologies and databases have emerged in recent years (Wesseler and von Braun, 2017). Most of the research has been focused on Europe and the EU member countries or the USA and has been carried out using multisectoral models based on

* Corresponding author.

E-mail address: laia.pie@urv.cat (L. Pié).

Input-Output analysis, the Social Accounting Matrix (SAM), and the computable general equilibrium model (Bracco et al., 2018; Smeets et al., 2014). The Input-Output model has been used to analyse the bioeconomy and its sectors with national, regional, and multiregional tables in countries like Poland (Loizou et al., 2019), the USA (Joshi et al., 2012), the Netherlands (Heijman, 2016), Japan (Wen et al., 2019), Nicaragua (Zúniga and Trejos, 2014), Germany (Budzinski et al., 2017), China (Song et al., 2015), Finland (Lehtonen and Okkonen, 2013), the Baltic Region (Brizga et al., 2019), and for many other countries in Asia, Europe, and the Americas (Asada et al., 2020; Bruckner et al., 2019). The SAM, which extends the information contained in an input-output table, has been used to analyse the bioeconomy and related sectors in Turkey (Çağatay et al., 2017), Mexico (Becerril and Albornoz, 2010), Brazil (Machado et al., 2019), Spain (Cardenete et al., 2014; Mainar, 2019), Uganda (Nakamya and Romstad, 2020), and the EU (Fuentes et al., 2017; Philippidis et al., 2014; Philippidis and Sanjuán, 2018).

At the European level, almost all the countries have bioeconomy strategies or similar initiatives either already published or currently under development (Lusser et al., 2018). The bioeconomy is considered a current priority, which is why the strategy published in 2012 was updated in 2018 to focus on accelerating the deployment of a sustainable European bioeconomy and meeting global goals (European Commission, 2018). Furthermore, the European Green Deal published in 2020 emphasizes the significant contribution of the bioeconomy to achieve a climate-neutral Europe by 2050 (European Commission, 2019). To this end, the official database BioSAM (Bioeconomy Social Accounting Matrix) published by the Joint Research Centre of the European Commission for 2010 was an important contribution to the analysis of the bioeconomy for each European country, which included a detailed breakdown of the bioeconomy accounts (Mainar et al., 2018).

A SAM facilitate the description of the economic reality of a country and are used as databases for linear multiplier models, enabling the linkages between sectors to be analysed which is useful for studying the impact of different policies. The significance of the SAM as a database and the influence of the linear SAM models is evidenced in their consistent use in global research over the years, including to analyse the bioeconomy, as was mentioned previously. Consequently, this type of model and the BioSAM database was used in this research.

The aim of this paper was to carry out an analysis of the bioeconomy in Spain as, one of the countries that has promoted a Bioeconomy strategy (2016) while lacking a deeper, updated analysis of its impact (Lainez et al., 2018).

First, a new version of the BioSAM was constructed to facilitate the application of multisectoral analysis and interpretation of the results. To this effect, this paper outlined the construction of the bioeconomy matrix for Spain for the year 2010, with a symmetric product-by-product framework and valued at basic prices. The use of a matrix valued at basic prices is more suitable for analytical purposes (Eurostat, 2008; Rueda-Cantuche, 2011) and constructing a symmetric matrix is recommended for macroeconomic analyses (Eurostat, 2008).

The main objective was to discuss the economic importance of the Spanish bioeconomy, quantifying and analysing the contribution of the bioeconomy products to the economy, thus revealing the products on which the variation of the final demand produces the greatest impact. The diffusion and absorption multipliers were calculated and the effects of both multipliers were decomposed, enabling the identification of the channels through which the effects of income can be produced and transmitted throughout the economy. This type of information is extremely useful to establish the origin of income shocks on economic agents and institutions. Last, the calculation of the employment multiplier facilitated

knowledge of the capacity to generate employment of each of the bioeconomy accounts in Spain.

The contribution of this paper is to apply a methodology that facilitates the analysis of the bioeconomy products with the greatest impact on an economy in terms of growth, while also analysing their impact on employment generation. This methodology was applied specifically to the Spanish case to demonstrate its application and validity. The results provide a complete analysis of the bioeconomy in Spain, which will be useful to promote policies that focus on the future development of the bioeconomy.

2. Materials and methods

2.1. Data sources: SAM with bioeconomy accounts

A SAM is a matrix database that compiles economic and social information on every transaction made between agents in an economy over a period of time, generally one year, the origins of which are set out in the pioneering works by Stone (1978, 1962) and Pyatt and Round (1979), among others.

If the aim is to study the bioeconomy, it is essential to work with a SAM that separates the accounts related to biobased products from those that are not. Hence, the BioSAM were produced for the European Union (Mainar et al., 2018). For a better analysis, this work outlined the conversion of the BioSAM to a symmetric product-by-product matrix valued at basic prices, following the Eurostat Manual of Supply, Use and Input-Output Tables (Eurostat, 2008).

2.1.1. Construction of the symmetric bioeconomy social accounting matrix for Spain

2.1.1.1. Conversion to a supply-use matrix at basic prices. The supply-use matrix at basic prices must be obtained to be able to construct the symmetric product-by-product matrix. The valuation at basic prices values each product without considering its indirect net taxes and trade and transport margins. It is more suitable for analytical purposes given that it provides a more homogeneous valuation for a better interpretation of the technical coefficients and an accurate allocation of the trade and transport accounts (Eurostat, 2008; Rueda-Cantuche, 2011).

Considering that the original BioSAM has a supply-use framework, the transformation implied that the columns for trade and transport margins and net taxes on products were now irrelevant in the supply table, so the margins and non-deductible taxes minus subsidies on products were deducted from the use table. Given that the valuation matrix was not available, the transformation was based on the supply and use matrix for the Spanish economy published by the National Statistics Institute of Spain and was complemented with indirect information about the desegregation of the bioeconomy products. This information identified the taxes and margins associated with each product. Furthermore, the RAS method for balance was applied where there were small redistribution differences (Miller and Blair, 2009).

2.1.1.2. Conversion to a symmetric product-by-product matrix.

A symmetric matrix has the advantage of being easy to handle and suitable for macroeconomic analyses (Eurostat, 2008). Converting model B was chosen among the different options because it enabled the conversion to a product-by-product table under the assumption of industry technology (Eurostat, 2008).¹ A product-by-product

¹ Chosen due to the lack of data complementing a combined correction of methodologies. According to the Spanish statistics institute, it is better to use a combination method known as "hybrid" (INE, 2014).

	Products	Industries	Final Demand	Total
Products	U		Y	q
Industries	V	g		
Value added	W		w	
Total	q ^t	g ^t	y	

Fig. 1. Integrated supply-use matrix framework to explain the conversion to a symmetric matrix with product-by-product framework. Source: Eurostat (2008).

matrix describes the quantities of products used to produce each product, regardless of the sector that generates them (ten Raa and Rueda-Cantuche, 2013). The European System of Accounts (ESA) 1995 recommends their use because they are considered to be more homogeneous in their description of transactions and in practice they are more suitable for many types of analyses (Álvarez-Martínez and López-Cobo, 2018; Eurostat, 2008).

Industry technology considers that every product produced by one industry is produced with the same technology, which is characterized by its inputs and a cost structure common to all its outputs (ten Raa and Rueda-Cantuche, 2013). The input structure assigned to each industry in the use table at basic prices needed to be combined with the supply table to convert the matrix (Rueda-Cantuche, 2011).

Hence, considering the basic example of a supply-use matrix (Fig. 1), the matrix $D = V \times (diag(q))^{-1}$ was obtained from the make matrix at basic prices V and the column vector of product output q , representing each industry's contribution to the output of each product.² Matrix $Z = U \times (diag(g))^{-1}$ represented the product input needed produce one unit of industry output, with U the use matrix for intermediates at basic prices, and g the column vector of industry output. The value-added matrix W , $L = W \times (diag(g))^{-1}$ was also obtained, which represents the value-added inputs required to produce one unit of industry output.

The intermediates product-by-product matrix will be $S = (ZD)\hat{q}$ and the value-added matrix $E = (LD)\hat{q}$. Last, the rest of the accounts included in the BioSAM were added since they did not need to be converted, obtaining the SAM matrix for the bioeconomy at basic prices with its symmetrical product-by-product structure for Spain for the year 2010 (Fig. 2).

2.1.2. Description of the Spanish bioeconomy SAM

The symmetric bioeconomy SAM obtained above was presented with a partial aggregation of 36 products, of which 32 are part of the bioeconomy. Table 1 lists the accounts and details the total products and their aggregation.

The data analysis of the bioeconomy matrix for Spain for the year 2010 painted a picture of the characteristics of the Spanish economy and the bioeconomy sector, starting with total product supply (2,327,107 million euros), 10.5% of which belongs to the bioeconomy. Of the total product supply, production accounted for 2,038,315 (million euros) and imports represented 12.4%, of which 2.3% were bioeconomy products. Bioindustry imports stood out at 43% of supply. Focusing on productive factors, employment and capital represented 55% and 45%, respectively. Within the final demand, households and exports stood out at 24% and 12%, respectively. Considering exports within the bioeconomy, the food,

² $diag(q)$ [$diag(g)$]: diagonal matrix $n \times n$, with the elements of a vector q (g) on its main diagonal and all other entries equal to zero.

bioindustry, and agriculture sectors stood out at 7%, 4%, and 5%, respectively. Focusing on demand, intermediate consumption and final demand were 44% and 56%, respectively. The food sector stood out with its total supply destined mainly for intermediate demand, but with large values towards final demand. In the case of the bioindustry, the flow towards final demand was larger and was mainly destined for households and exports. The detail of product flows from supply to demand is shown in a Sankey diagram in Fig. 3, clearly showing the importance of imports in the food, bioindustry, and agriculture sectors.

2.2. Methodology

2.2.1. The linear SAM model and multipliers

The linear SAM models are a simple way to analyse the information provided by a SAM regarding the structure of an economy. They show the separate effects being generated in the economic activity of different agents due to the relationships of the circular flow of income.

The exogenous and endogenous accounts of the matrix were defined to explain the model. Exogenous accounts are the ones that can be used as potential economic policy instruments given that they are determined outside the economic system (the government, savings investment accounts, and the foreign sector). The endogenous accounts are the production sectors, factors (labour and capital), and private consumers. The starting point was Leontief's equilibrium equation, but applied to the case of a SAM (Pyatt and Round, 1985).

Thus, the initial equation was obtained:

$$Y_n = (I - A_{nn})^{-1} X_n = M_{nn} X_n \tag{1}$$

Where Y_n is the column matrix of endogenous income in each account, I is the identity matrix, A_{nn} is a matrix of technical coefficients, and X_n is a column matrix that represents the exogenous injections received by each endogenous account. $M_{nn} = (I - A_{nn})^{-1}$ is the matrix of accounting multipliers of the SAM model, whose number of rows and columns is determined by the endogenous accounts used. This matrix shows the overall effects on the endogenous accounts, of the unitary exogenous changes in the exogenous income of accounts. It is used as a tool to evaluate the capacity of each account to generate wealth in the rest of the economy through the analysis of two multipliers: the diffusion effect and the absorption effect.

The diffusion effect is obtained using the sum of each element in column M_{nn} . This multiplier indicates the income expansion effect generated in the endogenous accounts as a result of a unitary exogenous injection of income into the account in the column. A high value of this multiplier indicates an account with a large backward income expansion influence on the rest of the economy, given that its input requirements to cope with the increase when it receives an exogenous shock are transferred to its suppliers (Pulido and Fontela, 1993).

$$U_j = \sum_{i=1}^n m_{ij} \forall j = 1, 2, \dots, n$$

The sum of the rows of multipliers in matrix M_{nn} represents the absorption effect. This quantifies the increase in income in each sector due to a unit-income exogenous injection in the economy. The value obtained in the sum of row i indicates how much this sector must produce due to an increase in one exogenous monetary unit in final demand over all the other endogenous accounts. Therefore, a high value occurs in accounts that have a greater impact on the other accounts in the economy, absorbing most of the

		Production	Factors	Private Sectors	Public Sectors	Saving and Investment	Rest of the World (RoW)	Total
Production	Bioeconomy	Intermediate consumption (S)		Private sector Consumption	Public sector expenditure	Investment and stock changes	Exports	Demand
	Non-Bio							
Factors	Labour	Remuneration of factors (E)					Factor income from RoW	Factor income
	Capital							
Private Sectors	Households		Factor income to private sector	Transfers between private sector	Transfers to private sector		Transfers to private sector	Private income
	Corporations							
Public Sectors	Taxes	Taxes	Factor income to public sector	Private sector taxes			Transfers to government	Public income
	Government							
Saving and investment				Private sector savings	Public sector savings		Transfers from RoW	Saving
Rest of the world		Imports	Factor income to RoW	Transfers private sector to RoW	Transfers public sector to RoW			Payments to RoW
Total		Supply	Expenditure on factor	Private expenditure	Public expenditure	Investment	Income from RoW	

Fig. 2. Database basic structure: Bioeconomy SAM symmetric product-by-product.

Source: based on Mainar et al. (2018).

Table 1

Description and classification of the accounts in the Bioeconomy SAM database for Spain.

Account	Aggregated sectors	Partial disaggregation	Account	Aggregated sectors	Partial disaggregation
Products	Agriculture	Cereal	Products	Biomass	Pellet
		Vegetables			Energy crops
Fruits		Forestry			
Oilseeds		Bioelectricity			
Oil plant		Biofuel- 1st generation			
Industrial crops		Biofuel- 2nd generation			
Other crops		Biochemicals			
Extensive livestock and products		Textiles			
Intensive livestock and products		Wood			
Other live animals and animal products		Natural resources			
Food	Food	Raw milk	Others accounts	Factors of production	Manufacture
		Fishing			Energy
		Animal feed			Service
		Beverages and tobacco			Labour
		Red meat			Capital
		White meat			Net production taxes
		Olive oil			Net products taxes
		Vegetable oils			Direct taxes
		Dairy			Households
		Processing of rice, milled or husked			Enterprises/Corporations
		Sugar			Government
		Other food			Investment-savings
		Wine			Rest of the world
					Capital account
	External relations				

Source: based on Mainar et al. (2018).

global increase in income (Pulido and Fontela, 1993).

$$U_i = \sum_{j=1}^n m_{ij} \forall i = 1, 2, \dots, n$$

2.2.2. Decomposition of the matrix of accounting multipliers

The first works on the decomposition of the multiplier matrix were by Stone (1978) and Pyatt and Round (1985, 1979). The starting point is matrix A_{nn} with the average propensity of the endogenous accounts ordered by products, productive factors, and private institutions, represented by subscripts 1, 2, and 3, respectively. Matrix A_{11} has input-output coefficients; A_{13} contains the consumption coefficients of private institutions in the productive sectors; A_{21} includes the coefficients of the production factors of production; A_{32} contains the coefficients of the income consumers received from the factors; and A_{33} includes the transactions between households.

$$M2_{nn} = \begin{bmatrix} I & (I - A_{11})^{-1}A_{13}(I - A_{33})^{-1}A_{32} & (I - A_{11})^{-1}A_{13} \\ A_{21} & I & A_{21}(I - A_{11})^{-1}A_{13} \\ (I - A_{33})^{-1}A_{32}A_{21} & (I - A_{33})^{-1}A_{32} & I \end{bmatrix}$$

A_{nn} is decomposed into:

$$A_{nn} = \begin{bmatrix} A_{11} & 0 & A_{13} \\ A_{21} & 0 & 0 \\ 0 & A_{32} & A_{33} \end{bmatrix} \Rightarrow \tilde{A}_{nn} = \begin{bmatrix} A_{11} & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & A_{33} \end{bmatrix} \text{ and } A_{nn} = \begin{bmatrix} -\tilde{A}_{nn} & & \\ 0 & 0 & A_{13} \\ A_{21} & 0 & 0 \\ 0 & A_{32} & 0 \end{bmatrix}$$

$$M3_{nn} = \begin{bmatrix} [I - (I - A_{11})^{-1}A_{13}(I - A_{33})^{-1}A_{32}A_{21}]^{-1} & 0 & 0 \\ 0 & [I - A_{21}(I - A_{11})^{-1}A_{13}(I - A_{33})^{-1}A_{32}]^{-1} & 0 \\ 0 & 0 & [I - (I - A_{33})^{-1}A_{32}A_{21}(I - A_{11})^{-1}A_{13}]^{-1} \end{bmatrix}$$

Based on both matrices, Pyatt and Round (1979) proposed a methodology for the decomposition of matrix M_{nn} between different interdependence circuits.³

$$Y_n = (I - A_{nn}^*)^{-1} (I + A_{nn}^* + A_{nn}^{*2}) (I - \tilde{A}_{nn})^{-1} X_n$$

with $A_{nn}^* = (I - \tilde{A}_{nn})^{-1} (A_{nn} - \tilde{A}_{nn})$

Three sub-matrices with different economic meanings (Holland and Wyeth, 1993) are obtained (equation (2)), representing the

interrelationships between the endogenous accounts.

$$M1_{nn} = (I - \tilde{A}_{nn})^{-1} M2_{nn} = (I + A_{nn}^* + A_{nn}^{*2}) M3_{nn} = (I - A_{nn}^{*3})^{-1}$$

$$Y_n = M3_{nn} M2_{nn} M1_{nn} X_n \tag{2}$$

Matrix $M1_{nn}$, has the following elements:

$$M1_{nn} = \begin{bmatrix} (I - A_{11})^{-1} & 0 & 0 \\ 0 & I & 0 \\ 0 & 0 & (I - A_{33})^{-1} \end{bmatrix}$$

It is called the matrix of own effect and includes the effects of internal transfers among themselves in group accounts that belong to the same block as a consequence of an exogenous increase in income in some of the endogenous accounts.

Matrix $M2_{nn}$ has the following structure:

$M2_{nn}$ contains the open effects caused by the accounts belonging to a group on the accounts of the remaining groups. It captures the effects produced by an initial exogenous injection into an account from a certain block, which is transferred towards the endogenous accounts of another block, but without completing the circular effect.

Matrix $M3_{nn}$ has the following structure:

$M3_{nn}$ represents the circular multipliers. This matrix reveals the circular effects of an exogenous shock on the accounts due to their interdependence. It represents the effects of a group of accounts on themselves, considering the impact of an initial shock that completes the circuit passing through the three groups of accounts and culminating in the original account.

For a better interpretation, Stone (1978) suggested an additive decomposition, equation (3), which leads to the total net multiplier effect.

$$M_{nn} - I = (M1_{nn} - I) + (M2_{nn} - I)M1_{nn} + (M3_{nn} - I)M2_{nn}M1_{nn} \tag{3}$$

In this new expression (3), I represents the injection of income

³ For the details of the calculations see See Pyatt and Round (1979) and Stone (1978).

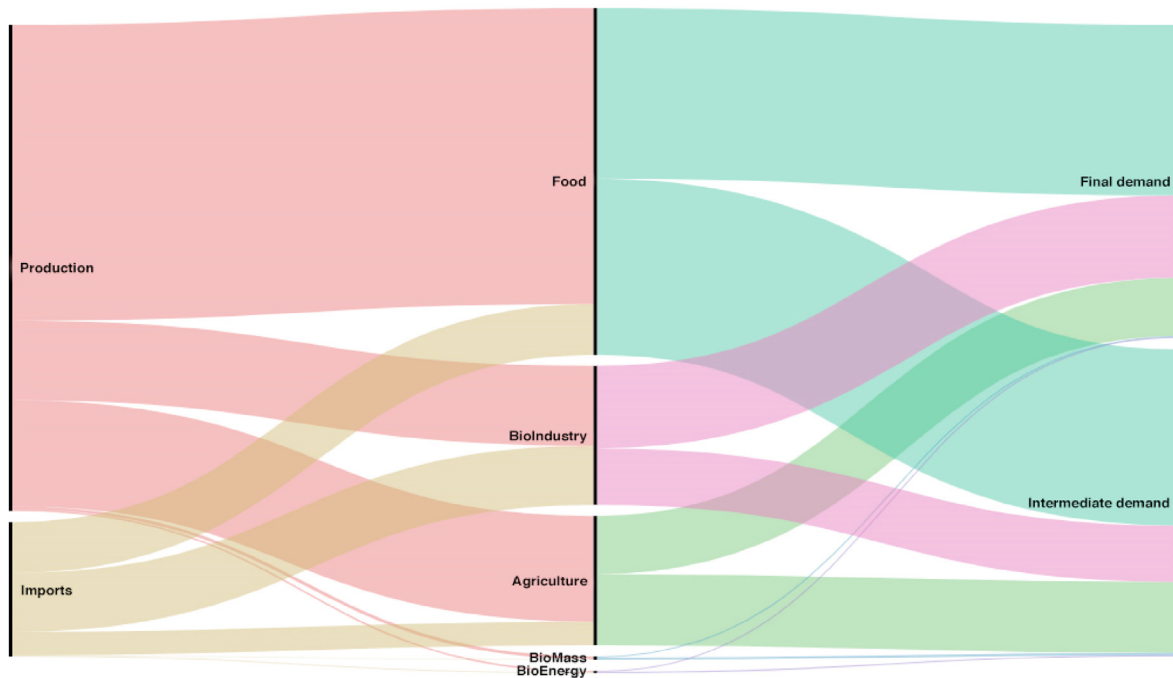


Fig. 3. Flow of bioeconomy total supply towards demand. Starting with the total production and imports for each bioeconomy product, towards each product group account, and ending with its distribution between intermediate and final demand. Source: own elaboration with Raw graphs (Mauri et al., 2017).

that starts the multiplier process. In $(M1_{nn} - I)$, own net effects derived from internal transfers were then shown, $(M2_{nn} - I)M1_{nn}$ quantifying the open net effects, and $(M3_{nn} - I)M2_{nn}M1_{nn}$ representing the net circular effects.

This SAM decomposition of multipliers enables the channels through which the effects of income can be produced and transmitted throughout the economy to be identified, while also showing the relevance of each effect. This type of information is obviously very useful to establish the origin of income shocks on economic agents and institutions.

2.2.3. Employment multiplier

The employment multiplier explains the effect of an exogenous demand side shock on employment in a sector. The transformed employment vector e contained the ratios between the number of jobs and the total output of each product (*per million euros of output value*).⁴ The employment matrix E_{nn} is a diagonal matrix whose elements are the vector e and is multiplied by the multiplier matrix (M_{nn}) .

$$ME_{nn} = E_{nn} \times M_{nn}$$

Each element in ME_{nn} , me_{ij} is the increment in the number of jobs in sector i when there is a unit exogenous injection into the endogenous account j . The sum of the columns in the matrix show the global effect on employment produced by the exogenous increase in demand.

3. Empirical application for the bioeconomy in Spain

3.1. Matrix of accounting multipliers

After obtaining the matrix of accounting multipliers of the

bioeconomy symmetric SAM for Spain for the year 2010, with order 40×40 , the diffusion and absorption effects for each account were calculated (Table 2). The calculations in this section were performed using the Python software developed by the University of Illinois (PyIO).

The results indicated that the diffusion multipliers are higher than the absorption multipliers for most products. The latter had very low values, which are even below those belonging to the non-bioeconomy group.

Taking the diffusion multipliers into account, the food and biomass groups showed a higher backward income generation capacity than the economy average. While the figure for agriculture was average, on removing two products with low diffusion multipliers (oil seeds and industrial crops) the results were above average. Therefore, the accounts related to the livestock, meat and dairy sector mainly stood out. Food stood out with above average results for most of the products, especially beverages and tobacco, read meat, white meat, vegetable oils, dairy, and other food and wine, which had multiplier effects greater than four. Within the biomass group, both forestry and energy crops had a greater than average diffusion effect, with energy crops standing out at 4.71. Regarding agriculture, extensive livestock and products, intensive livestock and products, other live animals and animal products, raw milk, and other crops had a multiplier higher than four, meaning that for each euro of income received the expansion over the whole economic activity will be greater than four.

The group of accounts that include bioenergy and the bio-industry had a below-average income diffusion effect, but bioelectricity and wood stood out, both with an approximate value of four. Of the 36 accounts belonging to the bioeconomy, 13 had a below average diffusion multiplier effect, whereas 5 had similar values to the average (vegetables, oil plant, sugar, pellet, and biofuel-2nd generation). The accounts with a low diffusion effect of below three were cereal, oil seeds, industrial crops, biochemical, and textiles.

⁴ See: https://datam.jrc.ec.europa.eu/datam/mashup/EU_SAM_JOBS/index.html.

Table 2
Results of diffusion and absorption multiplier effects by products for Spain 2010.

		Diffusion effects	Absorption effects	
Agriculture	Cereal	2.89	1.28	
	Vegetables	3.43	0.21	
	Fruits	3.73	0.28	
	Oilseeds	0.80	0.31	
	Oil plant	3.41	0.16	
	Industrial crops	1.57	0.13	
	Other crops	4.71	0.79	
	Extensive livestock and products	5.09	0.42	
	Intensive livestock and products	5.42	0.70	
	Other live animals and animal products	4.90	0.10	
	Raw milk	5.14	0.40	
	Fishing	3.13	0.16	
	Food	Animal feed	3.82	2.14
		Beverages and tobacco	4.29	0.81
Red meat		4.88	0.30	
White meat		5.20	0.53	
Olive oil		3.05	0.90	
Vegetable oils		4.15	0.12	
Dairy		4.67	2.56	
Processing of rice, milled or husked		3.80	0.20	
Sugar		3.45	0.14	
Other food		4.18	3.11	
Wine		4.05	0.44	
Biomass		Pellet	3.49	0.00
		Energy crops	4.71	0.00
Bioenergy		Forestry	3.96	0.16
	Bioelectricity	3.94	0.01	
	Biofuel-1st generation	3.07	0.02	
Bioindustry	Biofuel-2nd generation	3.45	0.00	
	Biochemicals	2.99	0.28	
Non Bioeconomy	Textiles	2.13	0.95	
	Wood	4.02	0.46	
	Natural resources	1.37	3.06	
	Energy	4.36	3.47	
	Manufactures	3.08	9.17	
Labour	Services	4.59	31.62	
	Labour	4.18	16.64	
Capital	Capital	2.62	21.04	
	Private institutions	Households	3.18	28.88
Corporations		0.88	13.87	
Average		3.64	3.64	

Note: Each value of the diffusion effect shows the income expansion effect generated in the endogenous accounts due to a unitary exogenous shock of income into the account. Each value of the absorption effect quantifies the increase in income in the account as a result of a unit-income exogenous injection in the economy. The average is represented to compare those below or above the average. Source: own elaboration.

The diffusion effect analysed showed significant differences between products related to agriculture, biomass and food, and the newer, more innovative sectors such as the bioindustry and biofuels. Regarding the latter, the results showed that they were not yet able to generate wealth above the overall economy average, but that the products bioelectricity and wood had a diffusion multiplier close to four (Philippidis and Sanjuán, 2018). Outside the bioeconomy, services and energy had substantially above average values.

Continuing with the analysis of the multiplier matrix, the absorption multiplier did not stand out for the bioeconomy sectors, showing extremely low values for the accounts related to biomass and bioenergy. The food and bioindustry groups had the highest absorption impact. Within food, dairy, animal feed, and other food had values greater than two, and were the only ones in the bioeconomy accounts. Additionally, cereal had the highest value within agriculture and textiles had the highest value within the bioindustry.

The main sectors not belonging to the bioeconomy were services and manufacturing, private institutions (households and corporations), and labour and capital. The significant impact on the labour and capital accounts and services was explained by this

multiplier analysing the impact of a supposed increase in all the other accounts in the economy. Therefore, given that these accounts are part of the inputs of almost every sector, a one-unit increase in each of them will generate a greater impact.

3.2. Decomposition of multipliers

Only the accounts that generate higher and lower effects on the rest of the economy and those that benefit most can be identified using the matrix of accounting multipliers. The decomposition of the multiplier matrix was carried out to obtain the impact of each effect and to be able to analyse the own, cross, and circular multiplier effects.

The analysis of the diffusion multiplier decomposition (Fig. 4) showed that the weights of the circular effects and the open effects stood out at 39% and 38%, respectively, demonstrating that the internal transfers in a group represented only a percentage of the total exogenous injection effect, and that the circular effect based on feedback predominated in most sectors.

Two situations with an above average diffusion effect were identified in the decomposition of the bioeconomy account. First, the accounts related to livestock, other food products, raw milk,

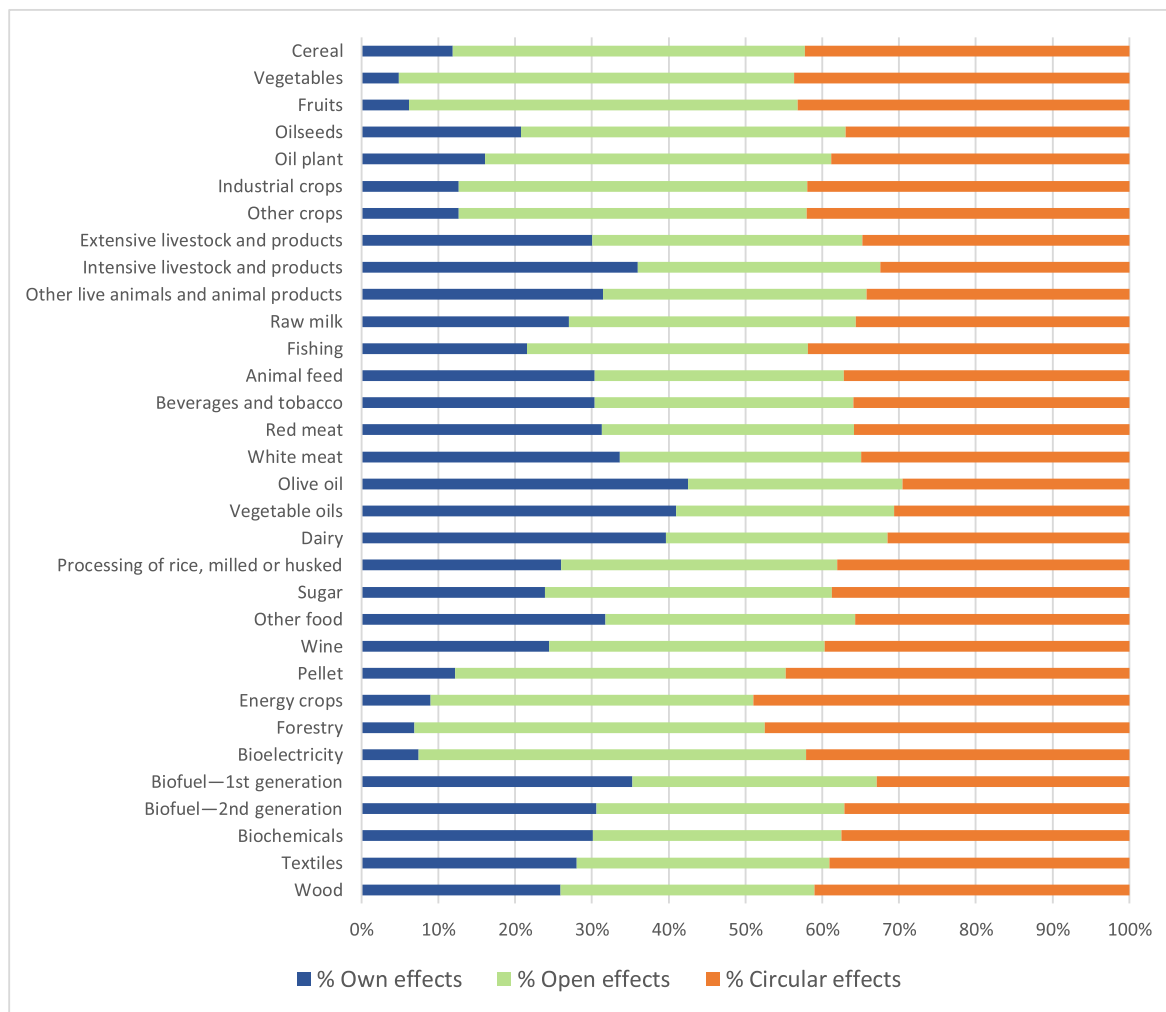


Fig. 4. Additive decomposition of the diffusion multiplier, illustrating the contribution (%) of each decomposition effect by products. Source: own elaboration.

animal feed, beverages and tobacco, meat products, dairy, other food, and to a lesser extent vegetable oils, rice, wine, and the wood bioindustry, distributed their multiplier impact among the three effects in a similar way. And second, there were some accounts that also had an above average diffusion effect but different decomposition effects. The main differences were identified in agriculture (other crops and fruits), biomass (energy crops and forestry), and bioelectricity, whose own effects were low and, in some cases, whose open effects stood out, indicating that the intersectoral relationship between the accounts is very low, and highlighting the influence of labour and capital.

This behaviour effect was also identified in the decomposition of some products with below average diffusion effects such as pellets, vegetables, cereals, industrial crops, and oil plant. However, the rest of the accounts with below average diffusion effects including biofuels, biochemicals, and textiles had a similar distribution between the three effects. The open effects were greater, mainly in the capital factors.

Like for the diffusion multiplier, the circular and open effects stood out in the absorption multiplier decomposition (Fig. 5).

However, a deeper analysis showed that these effects predominated for productive factors and private consumption and that in the rest of the accounts, with some exceptions, their own effects stood out. Therefore, the internal transfer effect is important to

determine the income absorbed by each account. Moreover, in most of the bioeconomy products the absorption effect focused almost entirely on their own effects, implying that these are products whose outputs are in high demand by other sectors and whose demand will also increase if there is an increase in the final production of each of the accounts. However, vegetables and fruit, meat, beverages and tobacco, biofuels, bioelectricity, textiles, and biochemicals distributed their absorption effect between their own and circular effects, due to the importance not only of their intersectoral intermediate consumption, but also of their final consumption.

3.3. Employment multiplier

The employment multiplier indicated the number of jobs generated per million euros of additional output (Fig. 6). The highest values were in the agriculture and biomass group given that they are labour-intensive sectors. Within the agriculture group extensive livestock, industrial and other crops, oil plants, and raw milk stood out. In the biomass group, energy crops and forestry had an employment multiplier of approximately 32, meaning that an average of 32 jobs will be generated in the sector per million euros of additional output (exogenous injection). In the case of food, only meat and rice could generate an above average number of jobs. The

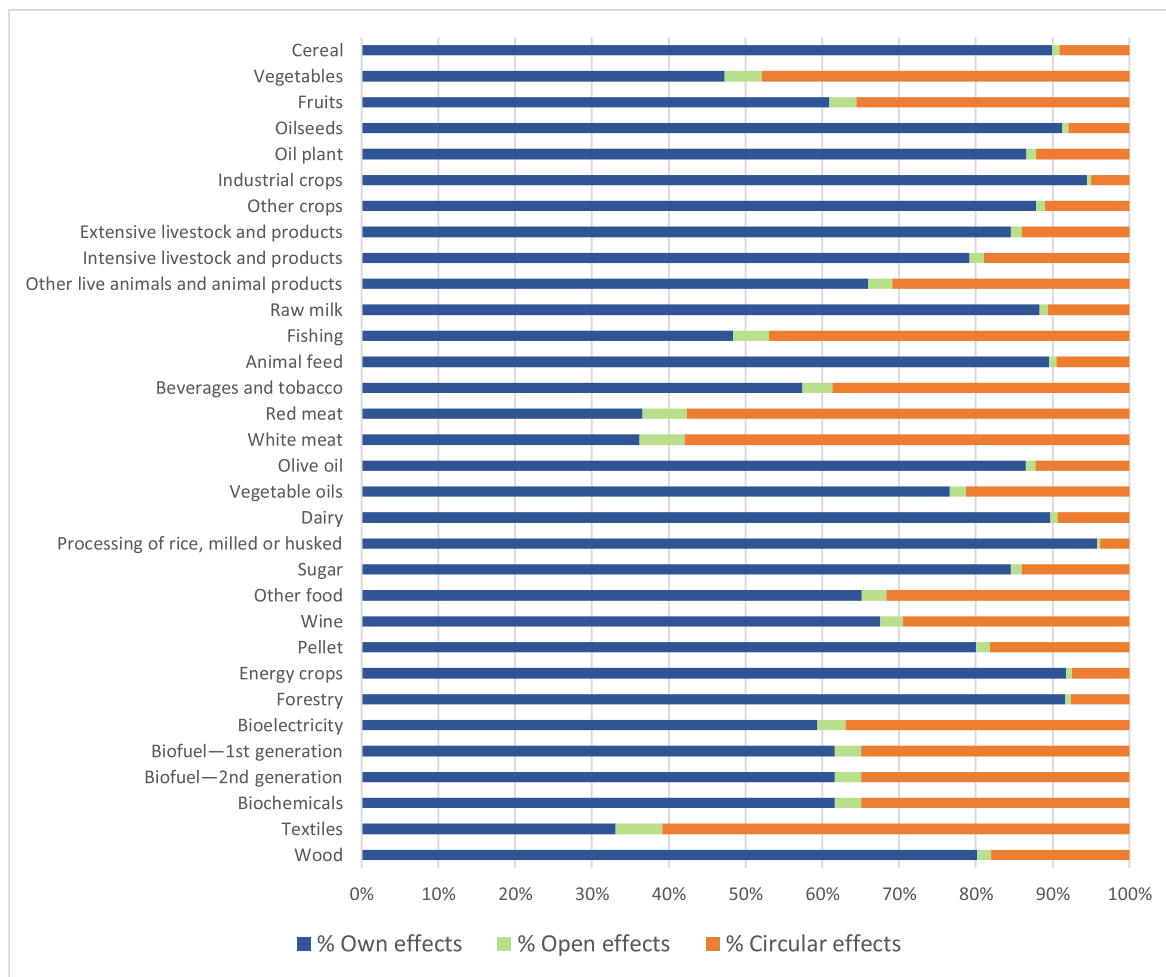


Fig. 5. Additive decomposition of the absorption multiplier, illustrating the contribution (%) of each decomposition effect by products. Source: own elaboration.

wood bioindustry was also highlighted to a lesser extent, the results indicating that the more innovative products such as bioelectricity, biofuels, and biochemicals had below average employment multipliers, which can be explained by the fact that they are capital intensive sectors.

On comparing the employment multiplier with products that have a higher diffusion effect it can be observed that within the agriculture group, extensive livestock, other crops, and raw milk, and within the biomass group, energy crops, and forestry, had high employment and diffusion multipliers. This was similar to the case of red meat within the food industry. However, the other accounts with a high diffusion effect had below average employment multipliers. Additionally, within the agriculture group, vegetables, fruit, oil plant, and industrial crops had a low diffusion multiplier but a high employment multiplier because they are intensive in the work factor. In the case of bioenergy, although its diffusion multiplier was slightly above average, its employment multiplier was very low, like for biofuels.

Notably, the results did not take social variables such as the quality of employment into account. Besides, the results should not be interpreted as an exact forecast of job creation due to exogenous shocks. Nonetheless, they are useful as an indicator of the economy accounts with a greater potential to generate jobs (Philippidis et al., 2014).

4. Discussion

The results showed the significance of many products that use various inputs of other products for their own production, measured by the diffusion effect. Among the most prominent were the food sector, biomass, and agriculture. Within these sectors, the accounts with the highest diffusion multiplier (greater than five) belonged to agriculture and food. This fact can be explained by the large consumption of inputs needed to meet certain standards due to production needs and legal requirements (Philippidis et al., 2014).

The diffusion effect decomposition showed that products with a significant diffusion effect also had an important influence on work and capital factors, mainly for the products related to livestock, meat, and energy crops due to their labour intensity. This was demonstrated by the fact that these products stood out for their employment multiplier.

The results also indicated that the non-traditional bioeconomy sectors, such as the bioindustry and bioenergy, had a low diffusion effect for most of their products. This situation was also observed when the employment multiplier was analysed, possibly because these sectors are capital intensive.

Regarding the absorption effect, the results showed low values for bioeconomy products with the focus on the intersectoral linkages due to the higher own effect. This meant that demand for

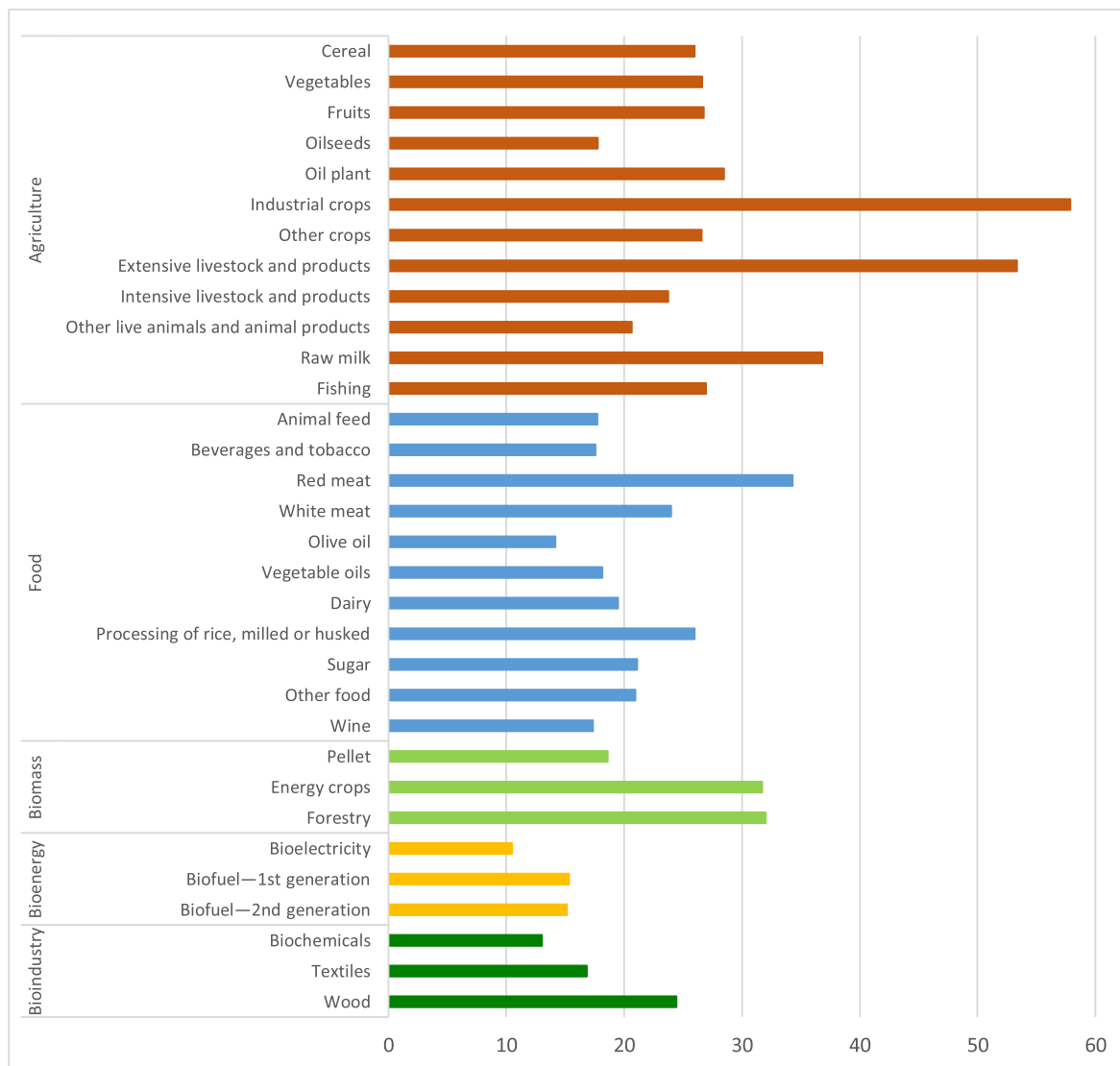


Fig. 6. Employment multipliers for bioeconomy products in Spain 2010. Number of people employed per million euros of output value. Source: own elaboration.

bioeconomy products was concentrated in a few sectors, which could be due to the characteristics of different products with little potential use as suppliers of other products given that they had hardly been processed and so had limited alternative uses, and also because they needed fewer of the other sectors to process and distribute a unit of product for the final users (Mainar et al., 2017). However, there were some cases within food, such as bioenergy and the bioindustry, where not only the importance of intermediate consumption stood out, but also the final demand mainly on households and exports.

According to the results, some sectors are important to promote the bioeconomy in Spain and, by promoting their final demand, they also can influence the rest of the economy. This study enabled the policies directed at these accounts to be analysed. Considering the linkages between the accounts and the most important output value, the bioeconomy in Spain is dominated by the food and agriculture sector. Additionally, low value multipliers in sectors that are partially bio, such as bioenergy and the bioindustry, determined the need to promote policies focused on these sectors. Furthermore, considering the output of each group, the accounts

included in bioenergy had low values compared with the rest of the Spanish economy, probably because they were recently innovative products with low market penetration (Fuentes et al., 2017; Loizou et al., 2019). Overall, this demonstrated that the Spanish bioeconomy is still focused on traditional sectors and has not yet developed its potential in more innovative sectors.

This research suggested that to achieve the Spanish bioeconomy strategy goals, the target sectors of the proposed strategy should be taken into account and strengthened through innovation and research, even if they are not considered relevant in this research.

Accordingly, the transition to a biobased economy requires knowledge creation, research, and innovation (Van Lancker et al., 2016). The main factor is the development of products that allow fossil-based products such as petrol to be replaced by renewable and plant-derived resources. To this end, several publications refer to the approach to be taken for innovation in the bioeconomy (Golembiewski et al., 2015; Lovrić et al., 2020; Van Lancker et al., 2016; Wydra, 2020). To promote the bioeconomy it is mainly important to focus innovation on new (biobased) production methods and value chains that can produce new (biobased)

products (Golembiewski et al., 2015; Lovrić et al., 2020; Wydra, 2020). This involves redesigning business models and reconfiguring supply chains (Golembiewski et al., 2015; Van Lancker et al., 2016). However, there must also be a focus on the commercialization and adoption of new bioeconomy technologies and biobased products that allow an increment in demand for biobased products, both in a business-to-business context and towards final consumers (Bröring et al., 2020; Golembiewski et al., 2015; Van Lancker et al., 2016). Further development of the bioeconomy must take new ways of stakeholder collaborations involving academic institutions, public authorities, industry and citizens into account (Bröring et al., 2020; Van Lancker et al., 2016).

Due to the growing concern about environmental issues and climate change, the progress of the bioeconomy and the development of other biobased sectors will gradually show more visible results (Heijman, 2016). The impact of innovation in the production of biobased products will be reflected in the multipliers of both the diffusion and the absorption effect. The diffusion effect takes the backward linkages (suppliers) of the product analysed into account, so new products or using new raw materials involved new chains of production. That will be reflected on the use of inputs from other sectors suppliers and employment. The absorption effect can be understood as a measure of forward expansion because it indicates the relationship with its customers, due to the distribution of its products in the rest of the economy. Thus, innovation will also impact on the market with more biobased products and consequently on the intermediate and final demand structure. This can serve as a guide for researchers, policy makers, and administrators for future research paths focused on design innovation strategies.

5. Conclusions

In recent years, there has been notably increased in concern about issues broadly related to environmental impact. The bioeconomy emerges with the main objective of focusing on a more sustainable economy.

To date, the BioSAM are the only official databases for the EU countries that detail the bioeconomy accounts. Considering this database, the first contribution of this paper was to construct a symmetrical bioeconomy database for Spain valued at basic prices. The bioeconomy was then studied using this matrix, by applying a multisectoral model. The bioeconomy products and their links with the rest of the accounts of the Spanish economy were analysed through calculating the multipliers. Some of the conclusions drawn in this paper are in line with results published previously for the EU and the member countries using similar methodologies (Fuentes et al., 2017; Mainar, 2019; Philippidis and Sanjuán, 2018).

The empirical application enabled the most important accounts in the bioeconomy in Spain to be identified, along with their impacts on economic growth and employment and the decomposition of each effect. The results showed the significance of many products that use various inputs of other products for their own production, mainly within food, biomass, and agriculture. In contrast, the accounts grouped under bioindustry and biofuels showed that the diffusion of income in the economy was below average.

One of the main conclusions of this research is that many bioeconomy products have the potential to promote the rest of the economy and employment and can be considered strategic to receive incentives through public policies aimed at promoting a positive impact on the economy and especially on biobased sectors. This type of analysis is a useful tool for policy makers in their decision-making processes related to the evolution of the Spanish bioeconomy. Taking into account that the analysis in this article is based on a macroeconomic approach, some aggregate products

could not stand out. However, it would be interesting to re consider the scale applying the concept of two-scale featured in Ain and He (2019) and He (2020). In order to be able to analyse whether these macroeconomic impacts could have other implications if the scale were microeconomic. As this study is beyond the scope of this article, we consider an interesting proposal for future research.

The bioeconomy in Spain still has a long way to go. It must promote sectors with future potential, encouraging research, innovation and capital investment (Lainez et al., 2018). The fact that the sectors with the greatest influence on economic development are not necessarily the most appropriate ones at the environmental level must also be considered. Since the goal is sustainable development, the bioeconomy must find a balance between analysing not only the economic but also the social and environmental impact (Ramcilovic-Suominen and Pülzl, 2018). From this perspective, and to be able to make complete policy recommendations, future lines of research should focus on evaluating the bioeconomy, while also considering the environmental impact (Fuentes et al., 2017).

The caveats and limitations of this research must be considered. Regarding the database, the conversion to a symmetric matrix at basic prices involved some difficulties and estimations. As for the linear SAM model, the limitations include the linear behaviour of economic agents, constant technical coefficients, fixed prices, and excess capacity (Defourny and Thorbecke, 1984). Furthermore, the employment multiplier analysed only considers the generation of jobs without considering their quality (Fuentes et al., 2017). Last, the matrix used has data for the year 2010, which was the last official database, published in 2018. Therefore, the results may be undervalued with respect to those obtained using more current data due to the growth in the bioeconomy sectors in recent years.

Funding

This project received funding from the European Union's Horizon 2020 research and innovation programme under Marie Skłodowska-Curie grant agreement No. 713679 and from the Universitat Rovira i Virgili (URV).

CRedit authorship contribution statement

Valeria Ferreira: Formal analysis, Investigation, Writing – original draft, and the resubmitted, Visualization. **Laia Pié:** Conceptualization, Methodology, Supervision, Writing – review & editing. **Antonio Terceño:** Conceptualization, Methodology, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

- Ain, Q., He, J.H., 2019. On two-scale dimension and its applications. *Therm. Sci.* 23, 1707–1712. <https://doi.org/10.2298/tsci190408138a>.
- Álvarez-Martínez, M., López-Cobo, M., 2018. WIOD SAMs adjusted with Eurostat data for the EU-27. *Econ. Syst. Res.* 30, 521–544. <https://doi.org/10.1080/09535314.2018.1448758>.
- Asada, R., Cardellini, G., Mair-Bauerfeind, C., Wenger, J., Haas, V., Holzer, D., Stern, T., 2020. Effective bioeconomy? a MRIO-based socioeconomic and environmental impact assessment of generic sectoral innovations. *Technol. Forecast. Soc. Change* 153, 119946. <https://doi.org/10.1016/j.techfore.2020.119946>.
- Becerril, J., Albornoz, L., 2010. Respuestas y opciones de los productores de subsistencia a las señales de política pública ambiental: un enfoque de análisis multisectorial. *Probl. Desarro.* 41, 85–102.
- Bracco, S., Calicioglu, O., Gomez, M., Flammini, A., 2018. Assessing the contribution

- of bioeconomy to the total economy: a review of national frameworks. *Sustain* 10. <https://doi.org/10.3390/su10061698>.
- Brizga, J., Miceikienė, A., Liobikienė, G., 2019. Environmental aspects of the implementation of bioeconomy in the Baltic Sea Region: an input-output approach. *J. Clean. Prod.* 240 <https://doi.org/10.1016/j.jclepro.2019.118238>.
- Bröring, S., Laibach, N., Wustmans, M., 2020. Innovation types in the bioeconomy. *J. Clean. Prod.* 266 <https://doi.org/10.1016/j.jclepro.2020.121939>.
- Bruckner, M., Wood, R., Moran, D., Kuschnig, N., Wieland, H., Maus, V., Börner, J., 2019. FABIO - the construction of the food and agriculture biomass input-output model. *Environ. Sci. Technol.* 53, 11302–11312. <https://doi.org/10.1021/acs.est.9b03554>.
- Budzinski, M., Bezama, A., Thrän, D., 2017. Monitoring the progress towards bioeconomy using multi-regional input-output analysis: the example of wood use in Germany. *J. Clean. Prod.* 161, 1–11. <https://doi.org/10.1016/j.jclepro.2017.05.090>.
- Çağatay, S., Taşdoğan, C., Özeş, R., 2017. Analysing the impact of targeted bioethanol blending ratio in Turkey. *Bio base Appl. Econ.* 6, 209–227. <https://doi.org/10.13128/BAE-16395>.
- Cardenete, M.A., Boulanger, P., Delgado, M.C., Ferrari, E., M'Barek, R., 2014. Agri-food and bio-based analysis in the Spanish economy using a key sector approach. *Rev. Urban Reg. Dev. Stud.* 26, 112–134. <https://doi.org/10.1111/rurd.12022>.
- D'Amato, D., Droste, N., Allen, B., Kettunen, M., Lähminen, K., Korhonen, J., Leskinen, P., Matthies, B., Toppinen, A., 2017. Green, circular, bio economy: a comparative analysis of sustainability avenues. *J. Clean. Prod.* 168, 716–734. <https://doi.org/10.1016/j.jclepro.2017.09.053>.
- Defourny, J., Thorbecke, E., 1984. Structural path analysis and multiplier decomposition within a social accounting matrix framework. *Econ. J.* 94, 111–136. <https://doi.org/10.2307/2232220>.
- Dietz, T., Börner, J., Förster, J., von Braun, J., 2018. Governance of the bioeconomy: a global comparative study of national bioeconomy strategies. *Sustain* 10. <https://doi.org/10.3390/su10091910>.
- European Commission, 2019. The European Green Deal. Communication European Parliament, Brussels. <https://doi.org/10.2307/j.ctvd1c6zh.7>.
- European Commission, 2018. A Sustainable Bioeconomy for Europe: Strengthening the Connection between Economy, society and the environment. Brussels. <https://doi.org/10.2777/792130>.
- Eurostat, 2008. Eurostat Manual of Supply, Use and Input-Output Tables. Luxembourg.
- Fuentes, P., Mainar, A., Ferrari, E., 2017. The role of bioeconomy sectors and natural resources in EU economies: a social accounting matrix-based analysis approach. *Sustain* 9. <https://doi.org/10.3390/su9122383>.
- German Bioeconomy Council, 2018. *Bioeconomy Policy (Part III) – Update Report of National Strategies Around the World*. Berlin.
- Golembiewski, B., Sick, N., Bröring, S., 2015. The emerging research landscape on bioeconomy: what has been done so far and what is essential from a technology and innovation management perspective? *Innovat. Food Sci. Emerg. Technol.* 29, 308–317. <https://doi.org/10.1016/j.ifset.2015.03.006>.
- He, J.H., 2020. Thermal science for the real world: reality and challenge. *Therm. Sci.* 24, 2289–2294. <https://doi.org/10.2298/TSCI191001177H>.
- Heijman, W., 2016. How big is the bio-business? Notes on measuring the size of the Dutch bio-economy. *NJAS - Wageningen J. Life Sci.* 77, 5–8. <https://doi.org/10.1016/j.njas.2016.03.004>.
- Holland, D., Wyeth, P., 1993. *SAM Multipliers: their decomposition, interpretation and relationship to input-output multipliers* Washington State University. Res. Bull. 13–31. XB1027.
- INE, 2014. a. Nota metodológica sobre las tablas Input - output de la economía español [WWW Document]. https://www.ine.es/daco/daco42/cne10/meto_tio_10.pdf (accessed 4.20.19).
- Joshi, O., Grebner, D., Henderson, J., Grado, S., Munn, I., 2012. Input-Output modeling of wood-based bioenergy industries in Mississippi. *For. Prod. J.* 62.
- Koukios, E., Monteleone, M., Teixeira, M., Charalambous, A., Girio, F., Hernández, E.L., Mannelli, S., Parajó, J., Polycarpou, P., Zabaniotou, A., 2018. Targeting sustainable bioeconomy: a new development strategy for Southern European countries. The Manifesto of the European Mezzogiorno. *J. Clean. Prod.* 172, 3931–3941. <https://doi.org/10.1016/j.jclepro.2017.05.020>.
- Lainez, M., González, J., Aguilar, A., Vela, C., 2018. Spanish strategy on bioeconomy: towards a knowledge based sustainable innovation. *N. Biotechnol.* 40, 87–95. <https://doi.org/10.1016/j.nbt.2017.05.006>.
- Lehtonen, O., Okkonen, L., 2013. Regional socio-economic impacts of decentralised bioeconomy: a case of Suutela wooden village, Finland. *Environ. Dev. Sustain.* 15, 245–256. <https://doi.org/10.1007/s10668-012-9372-6>.
- Loizou, E., Jurga, P., Rozakis, S., Faber, A., 2019. Assessing the potentials of bioeconomy sectors in Poland employing input-output modeling. *Sustain* 11, 1–12. <https://doi.org/10.3390/su11030594>.
- Lovrić, N., Lovrić, M., Mavsar, R., 2020. Factors behind development of innovations in European forest-based bioeconomy. *For. Policy Econ.* 111. <https://doi.org/10.1016/j.forpol.2019.102079>.
- Lusser, M., Sanchez Lopez, J., Landa, L., Avraamides, M., Motola, V., Zika, E., Mallorquin, P., 2018. Joint Survey on Bioeconomy Policy Developments in Different Countries.
- Machado, P., Cunha, M., Walter, A., Faaij, A., Guilhoto, J., 2019. The potential of a bioeconomy to reduce Brazilian GHG emissions towards 2030: a CGE-based life cycle analysis. *Biofuels, Bioprod. Biorefining* 1–21. <https://doi.org/10.1002/bbb.2064>.
- Mainar, A., 2019. Análisis de los sectores de Bioeconomía a través de matrices de contabilidad social específicas (BioSAMs): el caso de España. *Investig. Reg.* 3, 273–282.
- Mainar, A., Philippidis, G., Caivano, A., 2018. BioSAMs for the EU Member States: constructing Social Accounting Matrices with a Detailed Disaggregation of the Bio-economy. <https://doi.org/10.2760/811691>. Luxembourg.
- Mainar, A., Philippidis, G., Sanjuán, A.I., 2017. Analysis of Structural Patterns in Highly Disaggregated Bioeconomy Sectors by EU Member States Using SAM/IO Multipliers. <https://doi.org/10.2760/822918>.
- Mauri, M., Elli, T., Caviglia, G., Uboldi, G., Azzi, M., 2017. RAWGraphs. In: Proceedings of the 12th Biannual Conference on Italian SIGCHI Chapter - CHIItaly '17. ACM Press, New York, USA, pp. 1–5. <https://doi.org/10.1145/3125571.3125585>. New York.
- Miller, R., Blair, P., 2009. *Input-output Analysis: Foundations and Extensions, Second*. Cambridge University Press, Cambridge.
- Nakama, M., Romstad, E., 2020. Ethanol for an agriculture-based developing economy: a computable general equilibrium assessment for Uganda. *Energy Sustain. Dev.* 59, 160–169. <https://doi.org/10.1016/j.esd.2020.10.003>.
- Philippidis, G., Sanjuán, A.I., 2018. A Re-examination of the structural diversity of biobased activities and regions across the EU. *Sustain* 10, 4325. <https://doi.org/10.3390/su10114325>.
- Philippidis, G., Sanjuán, A.I., Ferrari, E., M'Barek, R., 2014. Employing social accounting matrix multipliers to profile the bioeconomy in the EU member states: is there a structural pattern? *Spanish J. Agric. Res.* 12, 913–926. <https://doi.org/10.5424/sjar/2014124-6192>.
- Pulido, A., Fontela, E., 1993. *Análisis Input-Output: Modelos, Datos Y Aplicaciones*. Pirámides, Madrid.
- Pyatt, G., Round, J., 1985. *Social accounting matrices for development planning*. In: Pyatt, G., Round, J. (Eds.), *World Bank Symposium*. The World Bank, Washington.
- Pyatt, G., Round, J., 1979. Accounting and fixed price multipliers in a social accounting matrix framework. *Econ. J.* 89, 850–873. <https://doi.org/10.2307/2231503>.
- Ramcilovic-Suominen, S., Püzl, H., 2018. Sustainable development – a 'selling point' of the emerging EU bioeconomy policy framework? *J. Clean. Prod.* 172, 4170–4180. <https://doi.org/10.1016/j.jclepro.2016.12.157>.
- Ronzon, T., M'Barek, R., 2018. Socioeconomic indicators to monitor the EU's bioeconomy in transition. *Sustain* 10. <https://doi.org/10.3390/su10061745>.
- Rueda-Cantuche, J., 2011. The choice of type of input-output table revisited: moving towards the use of supply-use tables in impact analysis. *SORT* 35, 21–38. <http://hdl.handle.net/2099/11410>.
- Smeets, E., van Leeuwen, M., Valin, H., Tsiropoulos, Y., Moiseyev, A., Lindner, M., O'Brien, M., Schutz, H., Schouten, M., Verburg, P., Verhagen, W., Junker, F., Msangi, S., 2014. *Annotated Bibliography on Qualitative and Quantitative Models for Analysing the Bio-Based Economy*. The Hague.
- Song, J., Yang, W., Higano, Y., Wang, X., 2015. Modeling the development and utilization of bioenergy and exploring the environmental economic benefits. *Energy Convers. Manag.* 103, 836–846. <https://doi.org/10.1016/j.enconman.2015.07.028>.
- Staffas, L., Gustavsson, M., McCormick, K., 2013. Strategies and policies for the bioeconomy and bio-based economy: an analysis of official national approaches. *Sustain* 5, 2751–2769. <https://doi.org/10.3390/su5062751>.
- Stone, R., 1978. The disaggregation of the household sector in the national accounts. In: *Social Accounting Matrices: A Basis for Planning-World Bank Conference on Social Accounting Methods in Developing Planning*. World Bank.
- Stone, R., 1962. A social accounting matrix for 1960. In: *A Programme for Growth*. Chapman and Hall Ltd, Londres.
- ten Raa, T., Rueda-Cantuche, J., 2013. The problem of negatives generated by the commodity technology model in input-output analysis: a review of the solutions. *J. Econ. Struct.* 2 <https://doi.org/10.1186/2193-2409-2-5>.
- Van Lancker, J., Wauters, E., Van Huylenbroeck, G., 2016. Managing innovation in the bioeconomy: an open innovation perspective. *Biomass Bioenergy* 90, 60–69. <https://doi.org/10.1016/j.biombioe.2016.03.017>.
- Wen, X., Quaoe, Daniel, Quaoe, Dinah, Appiah, K., Danso, B., 2019. Analysis on bioeconomy's contribution to GDP: evidence from Japan. *Sustain* 11, 1–17. <https://doi.org/10.3390/su11030712>.
- Wesseler, J., von Braun, J., 2017. Measuring the bioeconomy: economics and policies. *Annu. Rev. Resour. Econ.* 9, 275–298. <https://doi.org/10.1146/annurev-resource-100516-053701>.
- Wydra, S., 2020. Measuring innovation in the bioeconomy – conceptual discussion and empirical experiences. *Technol. Soc.* 61, 101242. <https://doi.org/10.1016/j.techsoc.2020.101242>.
- Zúñiga, C.A., Trejos, R., 2014. Medición de la contribución de la Bioeconomía: caso Nicaragua. *Univ. Rev. Científica la UNAN León* 5, 59–82. <https://doi.org/10.5377/universitas.v5i1.1479>.