

Zhu, Benz Xinqi; Vrachioli, Maria; Sauer, Johannes

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Regional Employment Impacts of Biorefineries in the EU

Impacts régionaux des bioraffineries sur l'emploi dans l'Union européenne

Regionale Beschäftigungseffekte von Bioraffinerien in der EU

Benz Xinqi Zhu, Maria Vrachlioli and Johannes Sauer

Introduction

In 2019, the European Commission adopted a set of proposals – the Green Deal – to make Europe the first climate neutral continent in the world. The European Green Deal sets the blueprint for reducing net greenhouse gas emissions by at least 55 per cent by 2030, compared to 1990 levels. This implies that the amount of greenhouse gas emitted into the environment will need to be counterbalanced by carbon sequestration, either through natural carbon sinks, such as forests, or by carbon offsetting among different sectors. In addition to reducing emissions, the Green Deal foresees new opportunities for innovation and investment that can lead to further economic growth and create job opportunities in the green economy (European Commission, 2019).

The transition towards a low-carbon economy can boost employment opportunities in the long term. However, some sectors will see job losses, such as coal mining and fossil fuel extraction, which leads to increasing concerns regarding economic growth deceleration in the short term. For example, the steel, chemicals and cement industries are indispensable to the European economy, as they supply several key value chains, and hence, provide the main source of employment and economic growth in Europe (European Commission, 2019). In order for these industries to deliver

on the Green Deal, they will need to replace fossil-based inputs with bio-based ones. However, given the different supply chains for fossil-based and bio-based products, the economic growth and employment opportunities of these production processes will be altered – ultimately involving different employment possibilities and pathways of economic development.

“ Les bioraffineries peuvent promouvoir la croissance économique dans les régions rurales et offrir des opportunités d'emploi au niveau régional. ”

Biorefineries are facilities that convert biomass into value-added products (biofuels, biochemicals, bioenergy and other biomaterials) with minimal waste and emissions. They are needed for the provision of bio-based products that can replace their fossil-based counterparts in any sector of the economy that is able to use bio-based inputs. Biorefineries can promote economic growth in rural regions and provide employment opportunities at the regional level, through the new value chains they create and the innovative technologies

that they attract (Lehtonen and Okkonen, 2013). However, the introduction of biorefineries might reduce the employment opportunities in other sectors that are involved in fossil-based production. Biofuel and bioplastics constitute examples of biorefinery outputs that aim to replace fossil-based outputs with bio-based ones. While these bio-based products may increase the labour demand for the bio-based value chains, at the same time, they might cause job losses in the fossil-based counterparts of these sectors. Hence, the overall impact of the establishment and operation of biorefineries at the local employment levels remains ambiguous.

This article presents the impact of biorefineries on regional employment in the EU using European regional data provided by EU Joint Research Centres (JRC) and the EU H2020 BioMonitor project. While most of the studies have so far focused on the local employment impact of specific biorefineries, this study adopts a broader geographical and biomass perspective. More specifically, all the types of biomass processing facilities throughout Europe in the last 10 years were considered to investigate the effect that biorefineries can have on regional employment growth. A linear regression model was estimated to empirically assess the determinants of employment and their impact over time at the regional level, comparing regions with and without biorefineries.

What we know so far

A few studies have attempted to investigate the potential employment impact of biorefineries in the EU. Heijman *et al.* (2019) investigated how a biorefinery that processes corn into bioethanol can have an impact on rural employment in Hungary using a regional input-output model. They found that the biorefinery created employment opportunities not only through direct employment at the facility, but also created and maintained jobs in farming and service industries in the surrounding areas. More specifically, the biorefinery employed 172 people directly and created more than 5,000 jobs indirectly. Heijman *et al.* (2019) concluded that biorefineries could make a significant contribution to rural development.

“ Bioraffinerien können das Wirtschaftswachstum in ländlichen Regionen fördern und Beschäftigungsmöglichkeiten auf regionaler Ebene schaffen. ”

Thornley *et al.* (2014) estimated the potential impact of biorefineries on employment in five EU Member States (Germany, the Netherlands, Poland, Spain and the United Kingdom). They focused on biomass facilities that process two types of biomass, straw and softwood, and estimated their employment impact from the design to the construction and to the operation stage of the biorefinery facility. Biorefineries that convert straw into surfactants and dry lignin products generate the highest employment potential, with up to almost 70,000 man-years per facility (dry lignin is a polymer used to produce plastics, drugs and paints). This number can be further disaggregated into the employment at the process plant (over 10,000

man-years), in agriculture (over 15,000 man-years), in the supply and logistics sector (roughly 10 man-years), and the indirect employment (around 30,000 man-years). Given the biomass availability, the authors estimated that up to 24 biorefineries could be established in the targeted regions, generating up to a total of 1.4 million man-years of employment. Thornley *et al.* (2014) concluded that biorefineries could significantly contribute to employment generation.

Studies targeting regions outside the EU also reached similar conclusions. Bailey *et al.* (2011) using both qualitative (in-depth interviews) and quantitative (input-output table) methods examined the impact from the establishment of lignocellulosic biorefineries on the local employment in Alabama (USA). Considering the establishment of six biorefineries, they found that in total 2,696 new employment opportunities would be created, with 891 of them sourced from the logging sector, 1,217 being indirect jobs sourced from other sectors that have a connection with the logging sector, and 588 more jobs to cover the worker's needs, such as food and services. Cambero and Sowlati (2016) assessed the potential impacts of constructing forest-based biorefineries in British Columbia, Canada. They found that the establishment of biorefineries could increase the employment opportunities from 203 up to 239 entry-level jobs, such as

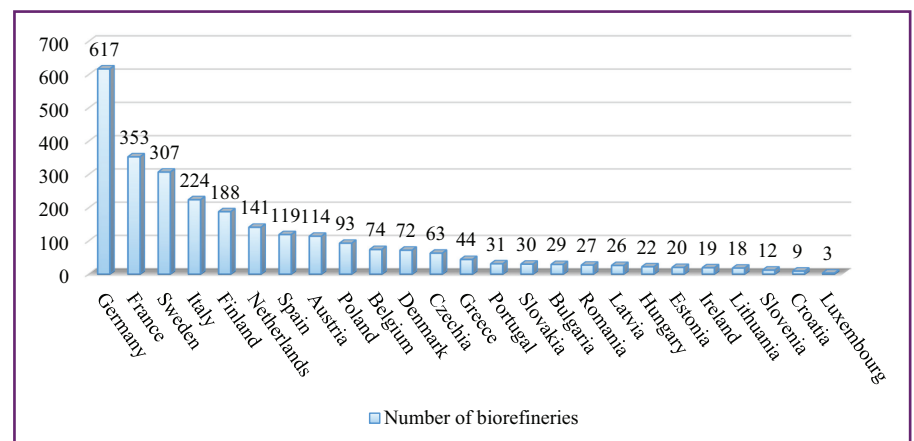
logging, truck drivers and machinery operators.

Biorefineries in the EU

By 2022, 2,655 biorefineries in the EU processed pulp and paper, biomethane, starch and sugar, bio-based chemical, timber, liquid biofuels, and composites and fibres (JRC DataM, 2022). The majority (92.5 per cent) are at commercial scale, with the remaining serving as pilot facilities. Figure 1 shows that Germany, France and Sweden have the highest number of biorefineries, while Figure 2 reveals that the Netherlands, Belgium and Germany exhibit the highest density of biorefineries per km².

According to the EU bioeconomy job and wealth data from the JRC DataM database, the EU bioeconomy sector employed 2.56 million workers, generated €136 billion value-added and over €462 billion turnover in 2017 (Ronzon *et al.*, 2020). Focusing on biorefineries that produce bioenergy, biomethane, biochemical, biofuel and bio-based components, Figure 3 presents the year of establishment of these biorefineries (dataset provided by Joint Research Centre (European Commission) in the context of the BioMonitor project). Before the concept of a bioeconomy was officially introduced and established in the 2000s, there was only a small number of biorefineries established in the EU, and their

Figure 1: Number of biorefineries in the EU, 2022



Source: Authors' own representation. JRC DataM Bio-based Industry: https://datam.jrc.ec.europa.eu/datam/mashup/BIOBASED_INDUSTRY/index.html

impact on regional employment was thus expected to be limited (Figure 3). From 2000 onwards, the number of biorefineries started to significantly increase, reaching a maximum of 74 newly established biorefineries in 2011. Therefore, to investigate the impact of biorefineries on employment in the EU, the period from 2009 until 2018 will be considered, when the great majority of the biorefineries had been established.

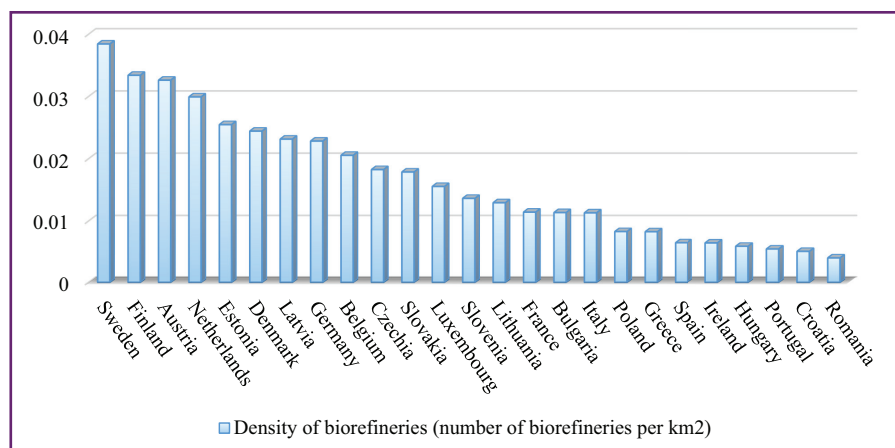
Estimated impact of biorefineries on employment growth in the EU

Transitioning from a fossil-based to a bio-based production setting might create competition for input resources and market shares in a region. Biorefineries might provide a certain amount of direct and indirect employment in a region, but they might also eliminate some employment that was previously related to fossil-based industries. Also, biorefineries can contribute to displacement of employment opportunities within the same sector, such as farmers shifting from the production of arable and feed crops to bioenergy crops. Thus, it is of great importance to understand how the establishment and operation of biorefineries in a region can affect local employment. To explore this research question further, we have identified two types of regions in the EU: the biorefinery-regions with at least one biorefinery facility being established, and the nonbiorefinery-regions with no biorefineries being established.

This study uses Eurostat regional data (NUTS-2 level) and data sourced from the JRC bio-based industry dashboard. The NUTS-2 location and year of establishment for each biorefinery were considered as the separating variables between biorefinery and nonbiorefinery regions. A total of 190 biorefineries across 94 NUTS-2 regions (12 EU Member States) were considered, covering the period from 2009 to 2018.

Figure 4 shows that biorefinery-regions exhibit employment growth

Figure 2: Number of biorefineries per km² in the EU, 2022



Source: Authors' own representation. JRC DataM Bio-based Industry and Eurostat https://datam.jrc.ec.europa.eu/datam/mashup/BIOBASED_INDUSTRY/index.html and https://ec.europa.eu/eurostat/databrowser/view/lan_lcv_ovw/default/table?lang=en

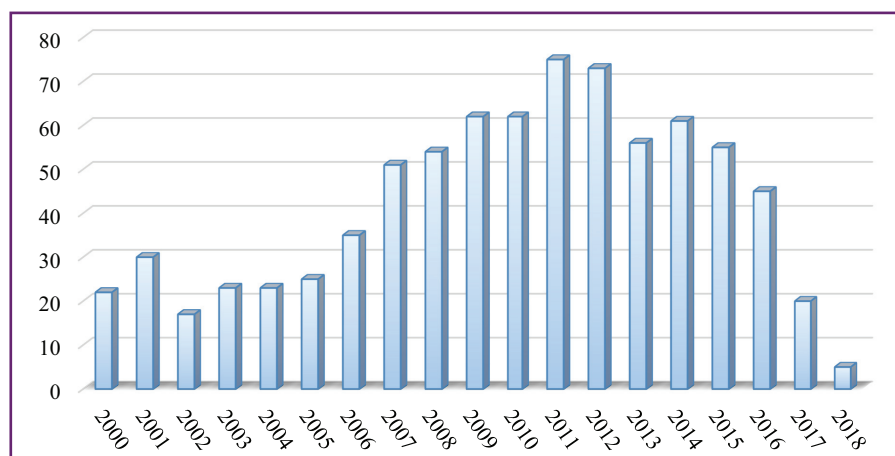
when the EU overall employment change decreases (from 2011 till 2013). In addition, nonbiorefinery-regions show a higher employment growth than biorefinery-regions when employment in the EU spikes.

Table 1 provides the definitions and descriptive statistics of all the variables used in the analysis. To ensure the stability of the estimated results and isolate the causal effect of biorefineries on regional employment, we control in our analysis for other regional characteristics that might influence regional employment. Population, disposable income and education can play an important positive role in determining employment growth in Europe (Biagi and Lucifora, 2008). In addition, the level of innovation activity in a region, such as business birth and survival rates, can have a

significant positive impact on employment (Fritsch and Schindele, 2011). Finally, the availability of important infrastructure for the operation of biorefinery establishments (i.e. motorways, railways etc.) can significantly affect the location of biorefineries, thus, introducing some degree of selection bias on the geographical placement of the biorefinery (Serrano-Hernandez *et al.*, 2017). The two types of regions are not different from each other at the population and education levels and when it comes to the number of birth and survival rates of businesses in the region. However, for the rest of the characteristics the two regions present statistically significant differences (Table 1).

We continue our analysis and investigate how the establishment of biorefineries correlates with regional

Figure 3: Number of biorefineries established per year in the EU, 2000 to 2018



Source: Joint Research Center, European Commission.

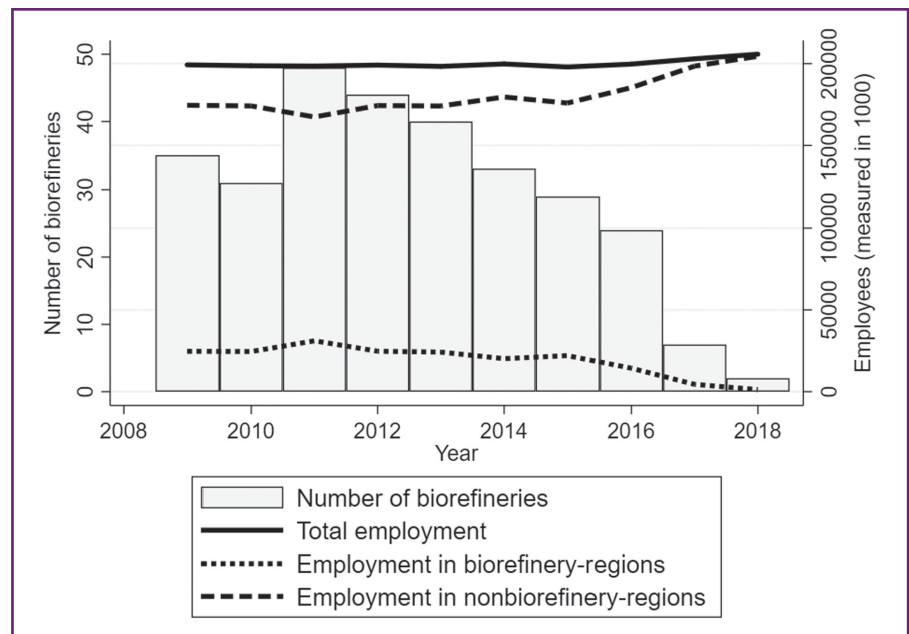
employment by running a linear regression model (Equation (1)).

$$\begin{aligned}
 \text{Employment} = & \beta_0 + \beta_1 \text{Biorefinery} \\
 & + \beta_2 \text{Population} + \beta_3 \text{Disposable income} \\
 & + \beta_4 \text{Education} + \beta_5 \text{Business birth} \\
 & + \beta_6 \text{Business survive} + \beta_7 \text{Motorways} \\
 & + \beta_8 \text{Railway} + \epsilon
 \end{aligned} \quad (1)$$

The estimated coefficient β_1 in Equation (1) shows how employment correlates with the number of biorefineries, while holding all other factors fixed. The other factors included in the analysis are population, disposable income, education, business birth and survival rates, motorways and railway as control variables. Also, a time dummy was added in Equation (1) to account for the impact of technical change in the relationship between employment and biorefineries. The results are presented in Table 2.

When the time dummy is not included in the model, the estimated coefficient for biorefinery is statistically significant and equal to 16.44 suggesting a positive correlation between employment and biorefineries. To account for the dynamic aspect of the biorefinery and employment relationship, we run a regression model including a time trend. The time trend is constructed as follows: if a region has at least one

Figure 4: Biorefineries and employment change in the EU, 2009 to 2018



Source: Authors' own calculations and Eurostat.

biorefinery established in 2009 and another one established in 2010, the number of biorefineries established will equal 0 before 2009; equal 1 in 2009; equal 2 from 2010 onward. The results in Table 2 show that the estimated coefficient for a biorefinery is still statistically significant and of almost the same magnitude, when the time trend is considered, revealing a positive connection between employment and biorefineries over time. This could be explained by the fact that the labour needs of a

biorefinery are higher around the time the biorefinery is established (construction, first years of operation, etc.) while later on these needs have decreased. The same story could be revealed by the negative estimated coefficients for the time trend, indicating that there is less employment needed as time passes. The rest of the control variables are statistically significant and exhibit the expected sign given the existing literature and initial hypotheses of this study. The only exception is the

Table 1: Regional characteristics (2009–2018)

	Unit	Description	Non-biorefinery region mean (SD)	Biorefinery region mean (SD)	p-value
Employment	1,000 employees	People employed for all NACE activities	822 (752)	1,009 (579)	***
Biorefinery	#	Number of biorefineries established	-	293	
Population	1,000 inhabitants	Average annual population	1,832 (1,647)	1,973 (1,037)	
Disposable income	€	Purchasing power index, per inhabitant	14,310 (4,053)	17,513 (2,819)	***
Education	%	% of economically active population with tertiary education (ISCED level 5-8)	3.82 (1.58)	4.22 (0.99)	***
Business birth rate	#	Number of enterprise births in t	982 (653)	1,057 (410)	
Business survival rate	#	Number of enterprises newly born in $t-3$ having survived to t	588 (390)	640 (234)	
Motorways	km	km per thousand km ²	34 (27)	40 (18)	***
Railway	km	km per thousand km ²	83 (67)	109 (63)	***
Observations			2,201	190	

Notes: We are using NUTS-2 level data covering the period from 2000–2018. We filled the missing data with multiple imputation methods using Stata. We imputed each observation 20 times and took the average of the results. The cleaned dataset contains 2,391 observations, which covers 94 NUTS-2 regions from 2009 to 2018. * p-value ≤ 0.05 ; ** p-value ≤ 0.01 ; *** p-value ≤ 0.001 .

Source: Authors' own calculations and Eurostat.

variable that controls for the impact of business birth rates revealing a statistically significant negative relationship between employment and number of enterprises established in a region.

Discussion, recommendations and limitations

This study assesses the impact of establishment of biorefineries on regional employment in the EU using a regression model. The results of the regression reveal that regions with biorefineries exhibit higher levels of regional employment, and characteristics such as population, income, education and transportation infrastructure, can further affect this relationship in a positive manner. It was also found that the dynamic relationship between the establishment of a biorefinery and regional employment is decreasing over time.

“ Biorefineries can promote economic growth in rural regions and provide employment opportunities at the regional level. ”

While there is a great interest at the European level in moving towards a more bio-based economy, there is still a lack of data regarding

Table 2: Linear regression results, 2009–2018

	Without time trend	With time trend
constant	-358.740***	-345.102***
Biorefinery	16.444***	15.348***
Population	0.434***	0.435***
Disposable income	0.016***	0.016***
Education	17.680***	17.790***
Motorways	0.646***	0.632***
Railways	0.523***	0.519***
Business birth rate	-0.025**	-0.020
Business survive	0.076***	0.069***
2010		-9.146
2011		-16.250
2012		-13.570
2013		-20.582
2014		-18.399
2015		-28.590*
2016		-27.505*
2017		-25.660*
2018		-20.720*
Obs.	2,131	2,131

Note: * p-value ≤ 0.05 ; ** p-value ≤ 0.01 ; *** p-value ≤ 0.001 .

biomass-processing facilities and the limited information that is available is scattered or not publicly available due to data confidentiality concerns. This study identified the impact of the biorefineries on regional employment growth by focusing only on the number of established biorefineries without considering their capacity, as data on the production capacity and costs of biorefineries were not available. In addition, this study assumes that the impact of biorefineries on regional employment and socio-economic composition remains constant over time. However, in reality, technology innovations and biorefinery market dynamics (i.e. exits, merges) can further influence the way that biorefineries (and bioeconomy, in general) are affecting the socio-economic environment of each region.

Technology, innovation, market organisation, demographics, economic development and consumer preferences represent some of the key bioeconomy drivers in the EU. A shift in these drivers might also affect the impact that biorefineries can have at the regional level, thus, accounting for them in bioeconomy related analyses would be of great importance. Technology and innovation can drive biorefineries' productivity, labour demand and labour-to-capital ratios. In the case that the technologies are capital-augmented, then less labour will be needed for the biorefinery processes. The market organisation can also drive the value chain of the biorefineries by shifting the employment multiplier. Demographic changes, economic development and consumer preferences can drive the



Biofuel and bioplastics constitute examples of biorefinery outputs that aim to replace fossil-based outputs with bio-based ones © Canva.

market demand for bio-based products leading to a change in the bio-based market equilibrium.

To better understand the regional impacts of biorefineries in the EU, data on the survival or market exit of established biorefineries are needed. In addition, information on the status of the biorefineries (e.g. constructing, operating, halting or out of business) will improve the results by enhancing the boundary of analysis. More details on bio-based shares and regional bio-based production capacities can further help in this regard. Improving biorefinery data availability and quality can assist further research in this area and promote the development of bioeconomy in Europe. Finally, data on small biorefineries are also important as they can help policymakers to make more informed decisions about governmental support. This study presents a very early picture on the impact that biorefineries can have on regional employment, and there is room for more in-depth analysis by using more informative econometric tools. For example, given that data are available, difference-in-difference in combination with propensity score matching or regression discontinuity models can be



Biorefineries are facilities that convert biomass into value-added products with minimal waste and emissions © Canva.

used to estimate in a more detailed and precise way the impact of biorefineries on regional employment and the role that policies such as the Green Deal can play in shaping this impact.

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Benz Xinqi Zhu, Production and Resource Economics, Technical University of Munich, Germany.
Email: benz.xinqi.zhu@tum.de

Maria Vracholi, Production and Resource Economics, Technical University of Munich, Germany.
Email: maria.vracholi@tum.de


Johannes Sauer, Production and Resource Economics, Technical University of Munich, Germany.
Email: jo.sauer@tum.de

Summary


Regional Employment Impacts of Biorefineries in the EU

 The European Commission aims to achieve a climate-neutral economy by 2050 and positively affect the employment growth rate while reducing fossil-based production activities. For that reason, according to the European Green Deal, decarbonisation and modernisation of fossil-based industries is essential. Thus, replacing fossil fuel-based inputs in these industries with bio-based inputs through the establishment of biorefineries can contribute towards this goal. This article reports the results of a study on the impact of biorefineries on the regional employment rate, and other regional socio-economic indicators. A unique regional level dataset provided by EU Joint Research Centre and the EU H2020 BioMonitor project is used to examine the impact of the biorefinery industry on local employment. This dataset covers multiple European Member States and enables us to account for regional characteristics over a 10-year period (2009–2018). Our results show that introducing biorefineries to a region can be associated with a higher regional employment growth compared to regions with no biorefineries. Improving biorefinery data availability and quality can assist further the research in this area and promote the development of bioeconomy in Europe.

Impacts régionaux des bioraffineries sur l'emploi dans l'Union européenne

 La Commission européenne vise à parvenir à une économie neutre pour le climat d'ici 2050 et à influencer positivement le taux de croissance de l'emploi tout en réduisant les activités de production basées sur les énergies fossiles. C'est pourquoi, selon le Pacte vert européen, la décarbonation et la modernisation des industries basées sur les énergies fossiles sont essentielles. Ainsi, le remplacement des intrants d'origine fossile dans ces industries par des intrants d'origine biologique grâce à la création de bioraffineries peut contribuer à cet objectif. Cet article rapporte les résultats d'une étude sur l'impact des bioraffineries sur le taux d'emploi régional et d'autres indicateurs socio-économiques régionaux. Un ensemble de données unique au niveau régional fourni par le Centre commun de recherche de l'Union européenne et le projet BioMonitor du programme européen H2020 est utilisé pour examiner l'impact de l'industrie de la bioraffinerie sur l'emploi local. Cet ensemble de données couvre plusieurs États membres européens et nous permet de prendre en compte les caractéristiques régionales sur une décennie (2009-2018). Nos résultats montrent que l'installation de bioraffineries dans une région peut être associée à une croissance de l'emploi régional plus élevée que dans les régions sans bioraffineries. L'amélioration de la disponibilité et de la qualité des données sur les bioraffineries peut contribuer à faire progresser la recherche dans ce domaine et promouvoir le développement de la bioéconomie en Europe.

Regionale Beschäftigungseffekte von Bioraffinerien in der EU

 Die Europäische Kommission hat sich zum Ziel gesetzt, bis 2050 eine klimaneutrale Wirtschaft zu erreichen und das Beschäftigungswachstum zu fördern, während gleichzeitig die auf fossilen Brennstoffen basierenden Produktionsaktivitäten reduziert werden. Gemäß dem europäischen Green Deal ist aus diesem Grund die Dekarbonisierung und Modernisierung fossil basierter Industrien unerlässlich. Dementsprechend können fossile Rohstoffe in diesen Industrien durch biobasierte Rohstoffe ersetzt werden. Zur Erreichung dieses Ziels kann die Errichtung von Bioraffinerien beitragen. Der vorliegende Artikel zeigt die Auswirkungen von Bioraffinerien auf die regionale Beschäftigungsquote und andere regionale sozioökonomische Indikatoren auf. Basierend auf einem umfangreichen Datensatz, der von der Gemeinsamen Forschungsstelle der EU und dem EU-H2020-Projekt BioMonitor bereitgestellt wurde, werden die Effekte von Bioraffinerien auf die lokale Beschäftigung untersucht. Der Datensatz deckt mehrere europäische Mitgliedstaaten ab und ermöglicht es uns, regionale Merkmale über einen Zeitraum von 10 Jahren (2009-2018) zu berücksichtigen. Unsere Ergebnisse zeigen, dass die Einführung von Bioraffinerien in einer Region im Vergleich zu Regionen ohne Bioraffinerien mit einem höheren regionalen Beschäftigungswachstum verbunden sein kann. Eine verbesserte Verfügbarkeit und Qualität von Daten zu Bioraffinerien kann die Forschung in diesem Bereich unterstützen und die Entwicklung der Bioökonomie in Europa fördern.