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Circular Economy and Economic Development in the European Union: A Review and Bibliometric Analysis

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Abstract: Increased changes in the climate and ecosystems call for a sustainable economic development, where economic growth should be compatible with the environment goals. In order to do this, it is urgent to find new ways of life and new production systems that make our ecological footprint compatible with global sustainability. The concept of the circular economy has brought relevant contributions to this problem. The central objective of the study presented here is to highlight the main insights presented through scientific literature about the concept of the circular economy within the European Union. In practice, the intention is to show what has already been done about this topic and what can/should be implemented in the future. To achieve these objectives, 144 articles were considered from the Web of Science (Core Collection) for the topics "circular economy" and "European Union". These documents were, firstly, analysed through a proper literature review and later explored through bibliometric analysis, considering bibliographic data and the VOSviewer software. As the main findings have revealed, the increased importance of this concept within the European Union is recognized. However, this paper also identifies several challenges in the literature, namely the concentration of the identified publications in certain countries, organizations, and authors.

Keywords: sustainability; reuse; recycling; literature gaps

1. Introduction

The social, economic, environmental, and technological contexts, amongst others, change at a great velocity around the world, and these frameworks call for new concepts, approaches, and perspectives concerning how multiple stakeholders play their role in society and in economic activities. The concept of circular economy, especially in countries having great environmental impacts, appears to have its importance widely recognized among the policymakers and the scientific community. The number of scientific documents available on the main scientific platforms (WOS, for example) confirms this perspective [1,2].

In fact, the interest shown by the scientific community towards the topics related with the circular economy has increased over the last decades, namely, in domains related with the economy and management. This is highlighted by the number of publications from European, Chinese, and North American authors. On the other hand, new ecological concepts may be interlinked with other new concepts from other socioeconomic fields, such as innovation and entrepreneurship [1].

In any case, the topics associated with the circular economy seem to arouse great curiosity within the Chinese and the European Union scientific community, namely, after changes in related policy instruments [2]. These fields have motivated researchers around the world. On the other hand, it is worth stressing the diversity of realities within each country, as well as inside the European Union. Since the concerns around the circular economy are global, the opportunities and the potential to cooperate across nations is enormous, as well as the interlinkages among several scientific domains and the different dimensions of society [2].

In this perspective, the core objective of this study is to highlight the main insights related to the concept of circular economy in the specific context of the European Union, showing what has been researched and presenting what must be done in the future, outlining scientific and socioeconomic gaps. For this purpose, a total of 144 articles (excluding proceeding papers) were obtained, in December 2019, from the Web of Science Core Collection [3] for the topics "circular economy" and "European Union" considered simultaneously. These documents were first analysed considering literature review and later explored further through bibliometric analysis (bibliographic data), considering the VOSviewer [4] software. Other topics could be considered, such as bioeconomy, or green economy [1], or "*circular* *econom*" to allow for a wider search [2]. However, considering the relevance of the concept "circular economy" to the European Union scientific community [1], the focus of this study was specifically on this topic ("circular economy").

A search on the Web of Science All Databases [5] shows that when it comes to the topics "circular economy", "European Union", and "bibliometric", simultaneously, there are only three documents; the research from Gregorio et al. [1] and Turkeli et al. [2], and a conference paper, revealing the potential of work to be explored in these fields. In turn, the research developed here has the novelty of being focused on the topics "circular economy" and "European Union", complementing the literature review of the 144 documents with the bibliometric analysis.

Bibliometric analyses have been considered by several authors from different scientific fields, as highlighted by Martinho [6,7] and Mourao and Martinho [8]. A relevant aspect in bibliometric analysis, is the choice of topics to perform the search on scientific platforms. As stressed before, many works have already been done for the "circular economy" domain, but there are still challenges emerging from searching simultaneously the terms "circular economy" and "European Union". In fact, as shown by Gregorio et al. [1] and Turkeli et al. [2], several search topics have already been considered in these domains, but here, considering the works as a basis, the aim is to explore the "circular economy" dimension in the "European Union". The 144 articles obtained from the Web of Science (WOS) platform were the only found in December 2019 for these two topics considered simultaneously. In this way, the conclusions obtained in this work are representative for these two domains.

In turn, the literature review performed in this research, complemented with the bibliometric analysis, follows authors such as Takey and Carvalho [9] and Xu et al. [10].

The Rationale behind the Selection of the Topics "Circular Economy" and "European Union"

There are several studies on the different dimensions related to the topic "circular economy" as shown, for example, by the researches of Gregorio et al. [1] and Turkeli et al. [2]. But there is still an opportunity to explore the researches about circular economy associated with the European Union context. In fact, the European Union framework is specific and has a great diversity between the different member-states, which creates relevant dimensions to be explored and analysed. On the other hand, the continuous changes in European policies and specifically the definition of an Action Plan for the Circular Economy, by the European Commission, make the European Union a fertile domain to be addressed. In this way, our aim is to bring insights from the literature about these domains through literature review and bibliometric analysis, considering, for instance, the developments of Takey and Carvalho [9] and Xu et al. [10].

The remaining sections of the paper are as follows. Section 2 revisits the most used keywords in the published materials about 'circular economy'. Section 3 details the exhaustive effort done in our bibliometric approach to the topic. Section 4 discusses the major findings and concludes the paper.

2. Literature Review—Revisiting the Most Frequent Keywords around "Circular Economy"

The literature was previously surveyed and analysed bibliometrically. This approach has its own contribution towards highlighting the main indicators from the scientific literature related with the topics addressed in this study. However, it was also possible to identify a set of dimensions that may be interesting to explore in the literature review, such as those related to management, efficiency, recycling, waste, innovation, and policies.

In this way, considering the insights obtained from the previous assessment, this section will be structured into the following subsections: Efficiency and sustainability; policies, governance, and management; product life cycle; resources and waste; innovation and opportunities; economic sectors; bio-economy. These topics were addressed because they were highlighted by the literature survey and bibliometric analysis as relevant in the domains related to the circular economy, but not significantly explored by the scientific literature as shown in the list for the co-occurrence keywords.

2.1. Efficiency and Sustainability

Sustainability, reuse, recycling, and integration have become current terms around the world, including the efficiency in the use of resources [11], namely in developed and developing countries, due to global warming and climate change [12]. In practice, the main objective of the multiple stakeholders is to promote economic growth [13] and competitiveness [14] without compromising the environment. One of the main challenges will be to provide societies with adjusted and sufficient resources [15]. The efficiency, productivity, and circular economy are, in general, viewed as interesting contributions for sustainable development; however, there are some specificities, namely macroeconomic, that should be considered more carefully [16]. In any case, more efficient resource utilization may bring about relevant outcomes for sustainability [17]. Quality of life and human health are, in general, interconnected with environmental sustainability [18], and there is a global concern with the environment [19], although sustainable developments are not easy goals [20]. The involvement of the several stakeholders may facilitate the evolution towards a greener economy and society [21], considering the great expectations in the European Union about the dimensions of the circular economy [22] and its local acknowledgement [23]. In this involvement, it is also important to understand the social dynamics [24]. Eco-efficiency is an aspect to take into account in the use of renewable sources of energy [25].

2.2. Policies, Governance, and Management

Public institutions, and their respective policies, play a determinant role in promoting a balanced relationship between socioeconomic activities and the environment, for example in the promotion of a renewable source of resource use [26]. In order to design efficient strategies, it is crucial to identify adjusted models [27] and indicators so as to perform pertinent assessments that support well-structured plans [28]. The indicators may be macro (country level), meso (industrial ecology), and micro (firm level) [29] and should be incorporated into the several policies, including regional strategies [30]. The discussion about the indicators to be considered so as to assess the circular economy is extensive [31]. Approaches which include the several institutions, the several levels of governance, and the complex policy framework, may bring to light relevant insights for policy design in an efficient evolution for a circular economy [32]. In this context, the European Union needs to rethink its policy framework for an effective decarbonisation [33], claiming, in some circumstances, for more robust frameworks [34]. This is also true for external cooperation, namely with developing countries [35]. For example, concerning the use of urban waste as agricultural fertilizers, the European legislation could be more specific about some aspects, namely those related with the potential contaminants [36]. The same deeper specificity could be helpful for plastics recyclers [37]. Another question concerning effective policy implementation is related with the unintended conflict amongst legislative instruments [38]. There is not yet, in fact, a consensus about the concept of circular economy [39], related strategies/options/alternatives [40], and methods for it to be properly assessed [41]. The policy dimension is one of the most important factors towards achieving levels of a circular economy [42], as well as, the governance dynamics and the respective adjustments [43]. Planned obsolescence is another question which legislation needs to address [44]. In general, the circular economy policies should address the following dimensions: Reuse, repair, and recycling; innovation; and promoting secondary material utilization [45]. The questions related with eco-design, fiscal policies, and public procurement should be addressed, and the obstacles should be explored for an effective policy implementation.

2.3. Product Life Cycle

The concept of circular economy has appeared these days from a perspective of increasing a product's life cycle through an approach of reuse, recirculation, and recycling [46], or reduce, reuse, and recycle [47]. This approach improves the efficiency of the resources used and promotes sustainable consumption models [48]. One of the greatest concerns related with product life cycles is related to plastic, due to the complexities associated with its composition [49], namely for the European Union [50]. A great part of plastic used is for packaging [51] and agro-food processes [52]. The production of plastic increased significantly in the last decades, and China is among the main polluters in this field [53]. The alternatives considered for packaging have, consequently, relationships with human health and sustainability [54]. Recovering aluminium is another concern with packaging [55]. The cascading use of waste, in some sectors, may be an interesting solution to mitigate the environmental impacts from the life cycle of some products [56]. Another example could be the use of plastic waste to be incorporated into transportation fuel production [57]. Another motive of concern is the electric and electronic waste [58], as a relevant challenge around the world [59] with a rapid increase in the European Union [60], or vehicles and tires [61], amongst the major sectors of the European economic activities [62], or lithium ion batteries [63,64], or the textile and clothing industry [65], or waste cooking oils [66], or baby diapers [67], or the forestry industry [68], or tablet, computer, and smartphone batteries [69]. A good end of life management mitigates the environmental impacts from the socioeconomic waste and residues [70].

2.4. Resources and Waste

The consideration of renewable resources for economic and social activities is determinant in order to decarbonise the planet [71], namely for energy inputs. In these cases, it is important, also, to minimize the environmental impacts from these alternatives [72]. The bio-based plastics may be an option for consideration in these contexts of renewable resources [73]. However, the increased stream of these products calls for further research into these alternatives, namely in terms of end of life [74]. The dependency of the European Union on raw materials from external markets is one further reason for an adjusted circular economy approach [75]. Only a small part of the waste materials produced are recycled around the world [76], and specifically in the Austrian context [77], sometimes caused by the use of waste and residues in bioenergy production [78]. This calls for adjusted measures, where waste reporting could provide its contribution [79]. In some contexts, the more efficient countries are, also, those with higher rates of recycling [80]. Recycling is, depending on the alternatives, always an interesting way to manage waste [81] from a sustainable perspective [82], as is reuse [83]. However, in these streams there are still some aspects that need more assessments [84] to make waste management and human health preservation compatible [85]. This is true across many dimensions of circular economy [86]. In these contexts, urban areas are those mainly responsible for solid waste generation [87], making solid municipal waste a real problem [88]. However, these are not the only sources [89] and the structure is diverse amongst different global regions [90], depending on their specific characteristics [91]. For example, Croatia recycled about 15% of its municipal solid waste [92]. In waste management, reuse and recycling contribute towards the circular economy, instead of incineration and landfills [93]. These authors highlighted the advantages of recycling and reuse towards economic circularity, due to the extension of a product's life cycle, and the disadvantages of traditional technologies such as landfills and incineration. These solid waste management techniques have their negative impacts on the environment, as have the liquid waste management technologies, such as sewage and chemical treatment. To avoid practices which are not compatible with the environment, other alternatives may be considered, such as the following: Detoxification; industry use; carbon sequestration; materials recovery [94]. Waste management may prove to be particularly problematic amongst the new European Union members [95]. The reality across the several European Union states is, in fact, extremely diverse [96].

2.5. Innovation and Opportunities

New technologies and innovative approaches are great opportunities to increase the sustainability of socioeconomic activities through a more circular economy [97], from a perspective of eco-innovation. In fact, the technological advances verified in the last few decades, such as autonomous robots, allow for the creation of new products and to redesign the productive processes. These evolutions may be great contributions in improving the circularity in socioeconomic activities, because they will help in the reduction of waste from raw materials. Circular economy is a broader concept that contains several dimensions [98]. However, there are also interesting opportunities in the development of new approaches and in the implementation of new ways of thinking about the several socioeconomic interrelationships [99], where recycling has its significance. The growing awareness of the several stakeholders about environmental problems and for the importance of a circular economy within current frameworks allow for these changes of socioeconomic paradigms. Considering the importance of the stakeholders' involvement and compliance with innovative strategies, these new ways of thinking are determinant for an effective eco-innovation implementation. For example, a deeper understanding of the several interconnections between energy, water, and food may bring additional insights [100], or new feed alternatives [101]. The applied scientific research brings about new opportunities to make the economic sectors more sustainable, namely those with more negative environmental impacts [102]. Research and innovation activities, as well as educational institutions, may bring forward relevant outcomes for the technological, governance, and social innovation that would provide an interesting support for the carbonization mitigation in cities [103]. Indeed, the research units and the institutions of higher education have a fundamental role to promote innovation and sustainable developments [104]. Reinforcing the network between business–higher education–research is an interesting pathway towards the circular economy [105]. The European Union promoted and created several initiatives, such as the Bio-based Industries Joint Undertaking, towards a more innovative and sustainable development in several member-states [106]. Sometimes changing old practices, with risks for sustainability, is not an easy task, which often requires adjusted approaches [107]. Some innovations in the commercialization chains, such as the agro-food short circuits, may promote a more circular economy in rural areas and improve the short profit margins of the farmers (for instance) [108]. In general, there is still a great need for significant steps to be taken in order to achieve the intended levels of sustainability [109], namely in waste management [110]. The 2030 Agenda for Sustainable Development, from the United Nations, and the European Union Action Plan for the Circular Economy, from the European Commission, are examples of these global concerns about sustainability [111], referred to in literature by several authors [112]. Recycling and innovation seem to be two determinant key words for a more circular economy [113].

2.6. Economic Sectors

The heterogeneity of the economic sectors across the European Union countries implies an existence of great heterogeneity in existing and applied circular economy strategies [114], including that for Electrical Waste and Electronic Equipment [115]. The industrial ecology (industrial networking to exchange resources and materials) and the related eco-industrial parks are adjusted approaches for a more sustainable planning [116], with interesting returns in some contexts [117], as shows an example from a Swedish region [118]. Nonetheless the exchange of data between industries may be a barrier for an effective industrial symbiosis [119]. Circular economy approaches may promote positive externalities [120] and economic growth [121]. The reverse is also true, where the economic and financial stabilities may create conditions for a more sustainable development [122]. These positive impacts are, for example, particularly relevant in agriculture, where the reuse of agro-waste [123] or waste from other sectors and activities [124] may improve the narrow margins of profit of the sector and bring alternatives for waste management [125]. Agricultural fertilizers appear to be an interesting alternative for several natural and anthropogenic wastes [126], having several applications [127] around the world [128], as well as the production of feed supplements [129] or in the construction industry [130], including end-of-life vehicle waste [131]. Circular economy activities in small and medium enterprises are interrelated and form a hierarchical structure where waste reduction is a priority [132], as well as product design [133].

2.7. Bioeconomy

The bioeconomy may contribute to a more sustainable and efficient development with positive externalities across several dimensions of society and the economy [134]. Buzzwords like bioeconomy, eco-innovation, or green economy, seem to have been replaced over recent years by the expression "circular economy" [135], which seems, in some circumstances (indeed), more comprehensive [136]. In any case, the concept of green (green houses or green buildings) seems to have its place [137], as well as the concept of bioeconomy [138] and green economy [1]. In some researches, the bioeconomy is viewed as a strategic approach for the European Union's development [139]. Other studies stress the need to interconnect these concepts in the debates about sustainability [140] and the importance of these approaches for the creation of new jobs, namely green [141], and economic growth [142]. Collaborative economy is another concept that appears in literature related with the circular economy [143], in amongst, for example, small and large companies [144], as well as the concept of ecodesign [145], where durability matters in the environmental tasks [146]. On the other hand, the circular economy has more than an economic and technological dimension, and should include social, behavioural [147], and cultural fields [148]. In fact, the behaviour and perceptions of the population about recycling, for instance, influence the effective implementation of circular economy strategies and plans [149]. The strategies adopted to promote the circular economy are different around the world. For example, China adopts more of a top-down strategy instead of the USA, European Union, and Japan [150]. In turn, China considers the circular economy as a response to the environmental problems from industrialization, and Europe has a perspective about this concept as an opportunity to make money and specifically to manage waste [151], focusing on innovation and business [152].

3. Bibliometric Analysis with Bibliographic Data

The bibliometric analysis allows us to highlight several pieces of interesting information available in the literature and may support an organized literature survey. For example, the studies developed by Martinho [6,7] produced relevant insights into the researches identified here. Following this, bibliometric dimensions related with the co-authorship, co-occurrence, citation, bibliographic coupling, and co-citation have been explored. Exploring these dimensions, in the above domains, contributes towards identifying gaps in the literature and to produce indicators which may support the several interested stakeholders, including the scientific researchers working on economic development compatible with the environmental and social dimensions, as referred by Mourao and Martinho [8]. The analysis performed in this section is based on the outputs obtained from the VOSviewer software through maps and tables.

3.1. Co-Authorship

Figure 1 shows three network visualization maps for the co-authorship related with the number of documents of an author, organization, and country. In this bibliometric field, the dimension of the respective circle represents the number of documents [153] and the proximity between circles presents the relatedness for the respective items (in this case the relatedness is about the number of co-authored documents). In addition to this, Table 1 provides complementary information.

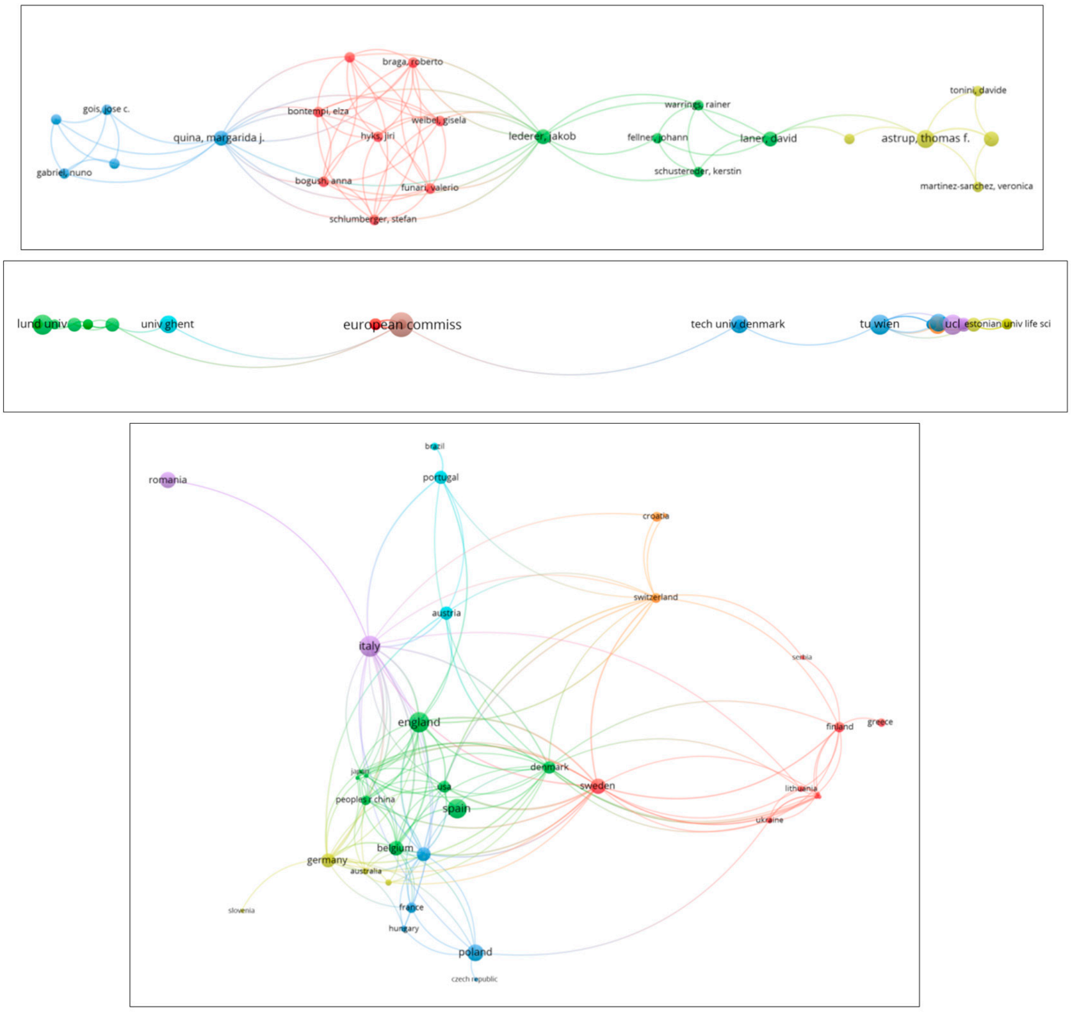

Figure 1. Co-authorship network visualization maps (1 as minimum number of documents of an author, of an organization and of a country)—the circle's dimension represents the number of documents.

In this way, the authors Astrup, Thomas F. and Faraca, Giorgia are those having more documents (the first with 3 documents and the second with 2 studies). Figure 1 also reveals a significant relatedness, because these authors' names are significantly close and belong to the same cluster. In general, the authors presented in Figure 1 and Table 1 published their work related with topics of circular economy and European Union in the average years 2018–2019 (before the search did not consider any year range). This shows that these fields have recently aroused the curiosity of the scientific community, noting that the "average publication year" is the average publication year of the documents published. It is also relevant to observe that there are many works related to the topic "circular economy", but not so much when the topic "European Union" is considered simultaneously.

The organization with more documents in these topics is the European Commission (with 6 documents), followed by the Lund Univ, Tu Wien, and UCL (all having 4 studies). For this item, the average year of publication begins in 2011, showing, again, a relatively new interest from the scientific community for these issues. The results presented in these figures and tables are only for the networked items. This explains some differences found, for example, in the average year of publication among the authors and the organizations. Finally, the documents published by Beijing Normal Univ, Dalarna Univ, Parthenope Univ Naples and Univ Bologna are the most cited, including on average.

Table 1. Co-authorship statistics (1 as minimum number of documents of an author, of an organization and of a country).

id	Authors	Cluster	Documents	Citations	Avg. pub. Year	Avg. Citations
22	astrup, thomas f.	4	3	15	2019	5
57	bogush, anna	1	1	24	2018	24
60	bontempi, elza	1	1	24	2018	24
66	braga, roberto	1	1	24	2018	24
131	faraca, giorgia	4	2	8	2019	4
134	fellner, johann	2	1	0	2018	0
154	funari, valerio	1	1	24	2018	24
155	gabriel, nuno	3	1	0	2019	0
161	gando-ferreira, licinio m.	3	1	0	2019	0
175	gois, jose c.	3	1	0	2019	0
176	gomes, luciano a.	3	1	0	2019	0
209	hyks, jiri	1	1	24	2018	24
253	laner, david	2	2	7	2018	4
256	lederer, jakob	2	2	24	2018	12
280	martinez-sanchez, veronica	4	1	6	2019	6
347	pivnenko, kostyantyn	4	1	7	2018	7
354	quina, margarida j.	3	2	24	2019	12
358	rasmussen, erik	1	1	24	2018	24
388	schlumberger, stefan	1	1	24	2018	24
392	schustereder, kerstin	2	1	0	2018	0
426	tonini, davide	4	1	2	2019	2
464	warrings, rainer	2	1	0	2018	0
465	weibel, gisela	1	1	24	2018	24
id	Organizations	Cluster	Documents	Citations	Avg. pub. Year	Avg. Citations
8	aix marseille univ	6	1	0	2020	0
9	akaki tsereteli state univ	4	1	18	2017	18
13	beijing normal univ	3	1	559	2016	559
20	china eu sch law	2	1	2	2018	2
23	city pozega	8	1	2	2017	2
31	dalarna univ	3	1	559	2016	559
32	danish waste solut aps	4	2	42	2018	21
35	dept environm food & rural affairs	1	1	64	2011	64
37	dev ctr sustainable management recyclable waste &	3	1	24	2018	24
38	ehime univ	1	1	64	2011	64
39	ellen macarthur fdn	5	1	62	2017	62
42	enervee	2	1	3	2019	3
44	estonian univ life sci	4	1	18	2017	18
45	european commiss	8	6	87	2017	15
49	european top ctr sustainable consumpt & prod	1	1	64	2011	64
50	fac chem technol	4	1	18	2017	18
53	fdn ent	3	1	6	2019	6
54	fed inst educ sci & technol brasilia ifb	7	1	0	2019	0
55	fed minist environm	1	1	64	2011	64
64	hasselt univ	2	1	2	2018	2
69	ineos technol france	6	1	0	2020	0
78	itrb consulting	8	1	0	2019	0
82	japan environm safety corp	1	1	64	2011	64
83	katholieke univ leuven	2	2	11	2019	6
84	kings coll london	2	1	2	2018	2
86	kyoto univ	1	1	64	2011	64
91	linnaeus univ	4	1	18	2017	18
93	loughborough univ	2	1	1	2019	1
95	lund univ	2	4	28	2018	7
96	maastricht univ	5	1	7	2018	7
97	maastricht univ unu merit	5	1	62	2017	62
102	minist environm land & sea	1	1	64	2011	64
103	monash univ	2	1	2	2018	2
106	natl inst environm res	1	1	64	2011	64
107	natl inst environm studies	1	1	64	2011	64
112	nottingham trent univ	2	1	1	2019	1
117	parthenope univ naples	3	1	559	2016	559
125	shanghai jiao tong univ	5	1	62	2017	62
130	ss bioenergias	7	1	0	2019	0
131	stena recycling as	3	1	24	2018	24
132	swedish energy agcy	2	1	3	2019	3

Table 1. *Cont.*

id	Authors	Cluster	Documents	Citations	Avg. pub. Year	Avg. Citations
135	taras shevchenko natl univ kyiv	4	1	18	2017	18
136	tech univ denmark	3	3	15	2019	5
140	towa technol	1	1	64	2011	64
141	tsinghua univ	1	1	64	2011	64
142	tu wien	3	4	31	2018	8
143	ucl	5	4	95	2018	24
157	univ bologna	3	3	584	2018	195
158	univ brescia	3	1	24	2018	24
162	univ cambridge	6	1	0	2018	0
163	univ coimbra	7	3	24	2019	8
167	univ eastern finland	4	1	18	2017	18
168	univ estado santa catarina udesc oeste	7	1	0	2019	0
173	univ ghent	6	3	9	2019	3
179	univ latvia	4	1	18	2017	18
181	univ leuven	2	2	16	2017	8
199	univ oslo	2	1	14	2016	14
214	univ shanghai sci & technol	5	2	69	2018	35
230	uppsala univ	1	1	64	2011	64
231	vast	1	1	64	2011	64
236	washington state dept ecol	1	1	64	2011	64
id	Countries	Custer	Documents	Citations	Avg. pub. Year	Avg. Citations
1	australia	4	2	44	2018	22
2	austria	6	9	228	2018	25
3	belgium	2	11	99	2017	9
4	bolivia	5	1	13	2019	13
5	brazil	6	3	0	2019	0
6	croatia	7	5	19	2017	4
7	czech republic	3	1	0	2019	0
8	denmark	2	8	163	2017	20
9	england	2	21	199	1922	9
10	estonia	1	1	18	2017	18
11	finland	1	6	55	2018	9
12	france	3	6	26	2019	4
13	georgia	1	1	18	2017	18
14	germany	4	10	156	2018	16
15	greece	1	4	12	2019	3
16	hungary	3	2	1	2019	1
18	italy	5	22	709	2018	32
19	japan	2	1	64	2011	64
20	latvia	1	1	18	2017	18
21	lithuania	1	2	18	2018	9
23	netherlands	3	10	189	2018	19
24	north ireland	7	1	1	2018	1
25	norway	4	2	56	2017	28
26	peoples r china	2	5	694	2016	139
27	poland	3	15	188	2018	13
28	portugal	6	9	30	1794	3
29	romania	5	13	34	2018	3
30	serbia	1	1	1	2019	1
32	slovenia	4	1	2	2019	2
33	south korea	2	1	64	2011	64
34	spain	2	20	89	1917	4
35	sweden	1	12	719	2017	60
36	switzerland	7	5	39	2019	8
38	ukraine	1	2	50	2017	25
39	usa	2	7	114	2017	16
40	vietnam	2	1	64	2011	64

For the item country, Italy is the country with the highest number of documents (22), followed by England and Spain (with 21 and 20 studies, respectively). In addition, England and Spain have great relatedness, considering the proximity of the respective labels. Excluding residual exceptions, again in this item, it is observable that the average year of publication begins in 2011. Documents published by China have more average citations and are amongst those having more total citations.

It is important to stress here that, if for the authors and organizations there is not a great difference between the number of documents published by the leaders and the remaining items, for the item country these differences are more visible. This seems to show that there do not yet exist specialised teams of researchers and organizations/Universities in these fields, having an international network. However, there are countries that are publishing more about these subjects, such as Italy, Spain, and England, with great networking between England and Spain. Finally, the international impact is higher for the documents published by the Chinese community.

3.2. Co-Occurrence

Figure 2 and Table 2 present the results for the co-occurrence links. Table 2 only exhibits the items with more occurrences. In Figure 2, the dimension of the circles/labels represents the number of occurrences of the keywords and the proximity (relatedness) is connected with the number of documents where these keywords appear together.

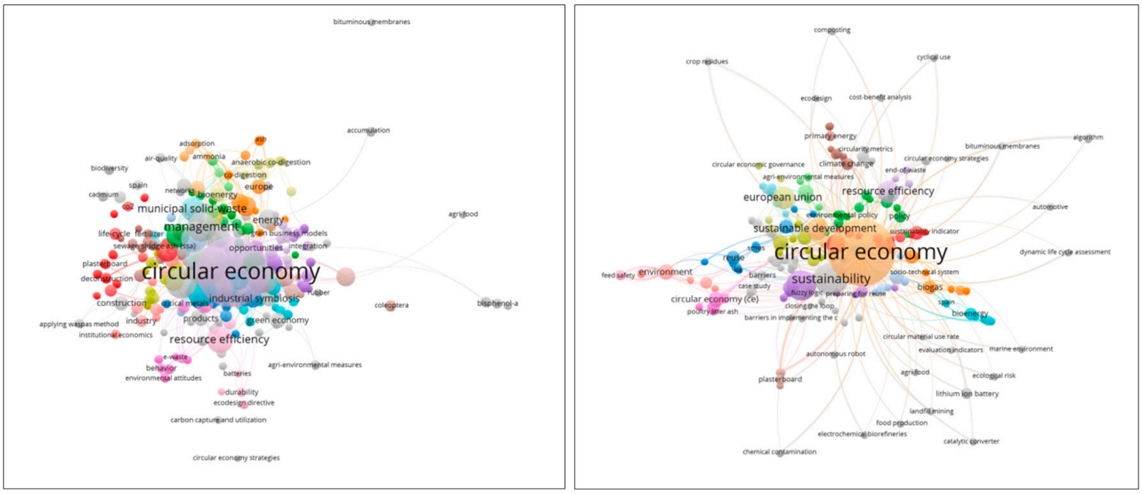

Figure 2. Co-occurrence network visualization maps (all keywords, 1 as minimum number of occurrences of a keyword; author keywords, 1 as minimum number of occurrences of a keyword)—the circle's dimension represents the number of occurrences.

Considering all keywords, the items with more occurrences, beyond circular economy, are 'sustainability, recycling, China, management, efficiency, and waste'. The average citations are greater in documents with the following keywords: Waste management, recycling, resource efficiency, and China.

Considering only the author keywords, the documents with more average citations are those where the following items appear: Reuse, resource efficiency, industrial ecology, recycling, and sustainability. This framework stresses the interest for the scientific community related with circular economy in the European Union, in aspects particularly related with sustainability, efficiency, ecology, recycling, and waste management. This shows that the concepts of management, efficiency, and recycling are the main focus, and that waste seems to be the main concern. However, the circular economy concept is broader, as is shown, amongst others, in the work of Alhola et al. [154].

Table 2. Co-occurrence statistics (all keywords, 1 as minimum number of occurrences of a keyword; author keywords, 1 as minimum number of occurrences of a keyword).

id	All Keywords	Cluster	Occurrences	Avg. pub. Year	Avg. Citations
115	circular economy	14	97	1998	13
825	sustainability	32	29	1949	27
688	recycling	23	18	2017	47
109	china	6	17	2018	40
501	management	27	17	2019	5
835	sustainable development	24	16	1892	6
719	resource efficiency	18	14	2018	45
686	recovery	12	13	2018	5
555	municipal solid-waste	15	12	2019	6
902	waste	2	11	2018	4
912	waste management	23	11	2018	60
306	european union	2	10	1816	15
311	european-union	1	9	2018	2
879	transition	31	9	2018	13
60	bioeconomy	7	8	2018	7
268	energy	22	8	2019	4
434	innovation	14	8	1766	8
479	life-cycle assessment	4	8	2018	12
539	model	27	8	2019	2
848	system	6	8	2019	15
40	barriers	31	7	2019	9
276	environment	17	7	2019	5
432	industrial symbiosis	3	7	2018	3
66	biomass	7	6	2018	4
206	design	5	6	1682	4
225	eco-innovation	17	6	2019	14
428	indicators	20	6	1346	5
851	systems	9	6	2018	5
id	Author keywords	Cluster	Occurrences	Avg. pub. year	Avg. citations
66	circular economy	16	87	2018	14
451	sustainability	20	21	1922	29
372	recycling	5	18	2017	47
172	european union	13	10	1816	15
392	resource efficiency	14	10	2018	60
461	sustainable development	16	10	1816	5
35	bioeconomy	1	7	2018	7
67	circular economy (ce)	9	5	1614	23
147	environment	10	5	2019	5
209	green economy	11	5	2018	2
230	industrial ecology	4	5	2017	58
500	waste management	5	5	2017	16
39	biogas	7	4	2018	5
118	eco-innovation	1	4	2019	10
232	industrial symbiosis	3	4	2019	1
255	life cycle assessment	12	4	2019	3
293	municipal solid waste	4	4	2018	17
401	reuse	3	4	2018	141
478	transition	7	4	2018	14
36	bioenergy	6	3	2019	13
77	climate change	8	3	2017	5
228	indicators	10	3	1346	3
258	life cycle thinking	44	3	2018	4
334	policy	2	3	2018	4
370	recovery	4	3	2018	9
407	secondary raw materials	22	3	2018	4
490	waste	2	3	2019	1
507	waste-to-energy	5	3	2019	2

3.3. Citation

For the filter related to citations, Figure 3 and Table 3 (for the items with more documents) exhibit the outputs obtained with the VOSviewer. In this case, the dimension of circles/labels represents the number of citations for the first map and the number of documents for the remaining maps. The proximity indicates the number of times they cite each other.

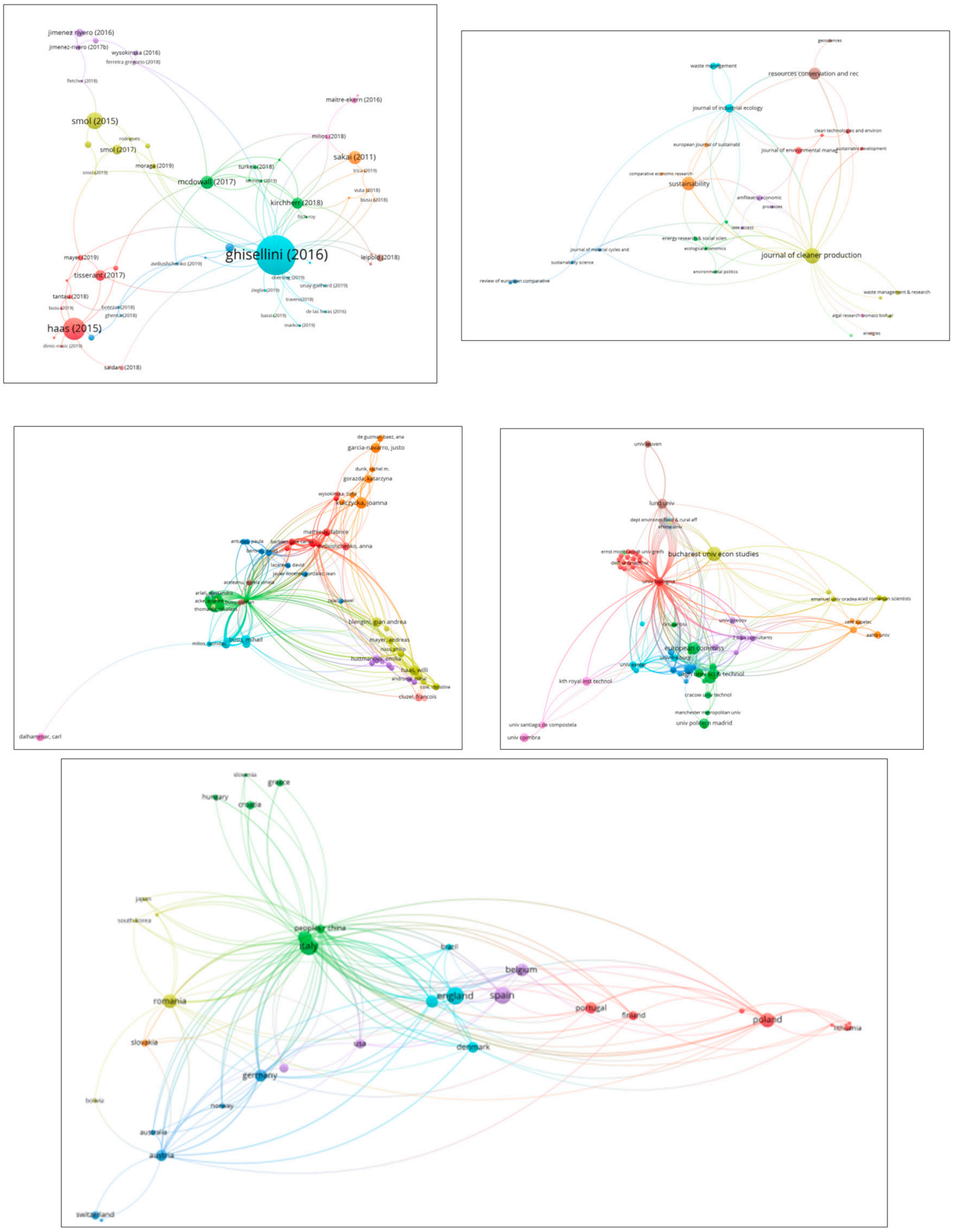

Figure 3. Citation network visualization maps (0 as minimum number of citations of a document (circle's dimension represents the number of citations), 1 as minimum number of documents of a source (circle's dimension represents the number of documents), 1 as minimum number of documents of an author (circle's dimension represents the number of documents), 1 as minimum number of documents of an organization (circle's dimension represents the number of documents), 1 as minimum number of documents of a country (circle's dimension represents the number of documents).

Table 3. Citation statistics (1 as minimum number of documents of a source, 1 as minimum number of documents of an author, 1 as minimum number of documents of an organization, 1 as minimum number of documents of a country).

id	Sources	Cluster	Documents	Citations	Avg. pub. Year	Avg. Citations
36	journal of cleaner production	4	20	746	2018	37
63	sustainability	7	15	26	2019	2
55	resources conservation and recycling	8	12	101	2018	8
41	journal of industrial ecology	6	6	297	2017	50
39	journal of environmental management	1	4	42	2018	11
69	waste management	6	4	8	2018	2
4	amfiteatru economic	5	3	6	2018	2
13	clean technologies and environmental policy	1	2	34	2018	17
20	energy research & social science	2	2	34	2017	17
28	european journal of sustainable development	7	2	0	2019	0
58	review of european comparative & international environmental law	3	2	16	2017	8
70	waste management & research	4	2	0	2019	0
3	algal research-biomass biofuels and bioproducts	9	1	0	2019	0
14	comparative economic research-central and eastern europe	7	1	9	2016	9
17	ecological economics	2	1	46	2018	46
18	energies	10	1	1	2019	1
19	energy efficiency	3	1	3	2019	3
23	environmental politics	2	1	0		0
29	fme transactions	6	1	1	2019	1
31	geosciences	8	1	0	2019	0
33	ieee access	5	1	0	2019	0
42	journal of material cycles and waste management	3	1	64	2011	64
51	processes	5	1	3	2018	3
53	rege-revista de gestao	2	1	0	2019	0
56	resources policy	1	1	0	2019	0
59	revista de derecho comunitario europeo	11	1	1	2016	1
64	sustainability science	3	1	10	2018	10
65	sustainable development	1	1	0		0
67	urban planning	4	1	1	2019	1
71	water alternatives-an interdisciplinary journal on water politics and development	4	1	0	2019	0
id	Authors	Cluster	Documents	Citations	Avg. pub. Year	Avg. Citations
248	kulczycka, joanna	7	4	146	2017	37
404	smol, marzena	7	4	146	2017	37
55	blengini, gian andrea	4	3	22	2018	7
76	busu, mihail	6	3	3	2019	1
165	garcia-navarro, justo	7	3	23	2017	8
185	haas, willi	4	3	192	2017	64
219	jimenez-rivero, ana	7	3	23	2017	8
467	wiedenhofer, dominik	4	3	192	2017	64
23	avdiushchenko, anna	1	2	34	2018	17
54	bleischwitz, raimund	1	2	69	2018	35
90	cluzel, francois	10	2	10	2019	5
101	dalhammar, carl	9	2	17	2018	9
178	gorazda, katarzyna	7	2	104	2017	52
203	huang, beijia	1	2	69	2018	35
206	huttmanova, emilia	5	2	0	2019	0
228	kemp, rene	1	2	69	2018	35
241	krausmann, fridolin	4	2	183	2017	92
259	leroy, yann	10	2	10	2019	5
284	mathieux, fabrice	1	2	19	2018	10
285	mayer, andreas	4	2	21	2019	11
286	mcdowall, will	1	2	69	2018	35
378	saidani, michael	10	2	10	2019	5
431	trica, carmen lenuta	6	2	0	2019	0
435	turkeli, serdar	1	2	69	2018	35
441	valentiny, tomas	5	2	0	2019	0
476	wzorek, zbigniew	7	2	104	2017	52
478	yannou, bernard	10	2	10	2019	5
id	Organizations	Cluster	Documents	Citations	Avg. pub. Year	Avg. Citations
16	bucharest univ econ studies	4	8	16	2019	2
45	european commiss	2	6	87	2017	15
5	agh univ sci & technol	2	5	148	2017	30
119	polish acad sci	2	5	147	2017	29
95	lund univ	8	4	28	2018	7
143	ucl	3	4	95	2018	24
204	univ politecn madrid	2	4	48	2017	12

Table 3. *Cont.*

id	Sources	Cluster	Documents	Citations	Avg. pub. Year	Avg. Citations
85	kth royal inst technol	9	3	37	2018	12
157	univ bologna	1	3	584	2018	195
163	univ coimbra	9	3	24	2019	8
173	univ ghent	2	3	9	2019	3
2	aalborg univ	5	2	42	2019	21
3	aalto univ	7	2	7	2018	4
10	alpen adria univ	7	2	180	2017	90
29	cracow univ technol	2	2	104	2017	52
81	jagiellonian univ	2	2	34	2018	17
83	katholieke univ leuven	2	2	11	2019	6
169	univ exeter	6	2	4	1009	2
171	univ freiburg	6	2	60	2018	30
181	univ leuven	8	2	16	2017	8
184	univ lodz	3	2	10	2018	5
207	univ presov	5	2	0	2019	0
212	univ santiago de compostela	9	2	8	2018	4
214	univ shanghai sci & technol	3	2	69	2018	35
id	Countries	Cluster	Documents	Citations	Avg. pub. Year	Avg. Citations
18	italy	2	22	709	2018	32
9	england	6	21	199	1922	9
34	spain	5	20	89	1917	4
27	poland	1	15	188	2018	13
29	romania	4	13	34	2018	3
35	sweden	2	12	719	2017	60
3	belgium	5	11	99	2017	9
14	germany	3	10	156	2018	16
23	netherlands	6	10	189	2018	19
2	austria	3	9	228	2018	25
28	portugal	1	9	30	1794	3
8	denmark	6	8	163	2017	20
39	usa	5	7	114	2017	16
11	finland	1	6	55	2018	9
12	france	5	6	26	2019	4
6	croatia	2	5	19	2017	4
26	peoples r china	2	5	694	2016	139
36	switzerland	3	5	39	2019	8
15	greece	2	4	12	2019	3
31	slovakia	7	4	0	2019	0
5	brazil	6	3	0	2019	0
1	australia	3	2	44	2018	22
16	hungary	2	2	1	2019	1
21	lithuania	1	2	18	2018	9
25	norway	3	2	56	2017	28
38	ukraine	1	2	50	2017	25
4	bolivia	4	1	13	2019	13
7	czech republic	1	1	0	2019	0
10	estonia	1	1	18	2017	18
13	georgia	1	1	18	2017	18
19	japan	4	1	64	2011	64
20	latvia	1	1	18	2017	18
30	serbia	3	1	1	2019	1
32	slovenia	2	1	2	2019	2
33	south korea	4	1	64	2011	64
40	vietnam	4	1	64	2011	64

The sources with most documents, in Table 3, are the following: Journal of Cleaner Production (20), Sustainability (15), and Resources Conservation and Recycling (12). On the other hand, the Journal of Cleaner Production is that with more citations, and the Journal of Material Cycles and Waste Management is that which has more average citations. There is a significant difference between the number of documents published by these sources and those remaining. However, together these journals published 47 documents, showing that there is a particular concentration of the filtered documents in 3 journals.

The authors Joanna Kulczycka and Marzena Smol are those with more documents also showing a significant relatedness, having worked together on the same documents. The authors with more total citations are the following: Willi Haas; Dominik Wiedenhofer; and Fridolin Krausmann. These authors also belong to the same cluster. In general, the authors with more documents and citations in this link also have more relatedness, having also worked together, showing that, when there are specialised teams for these topics, in general, they are small and come from the same organization, or at least, from the same country.

The Bucharest Univ Econ Studies is that which has more documents (8), but Univ Bologna is where the published documents received more total and average citations. As stressed before, the more productive organizations are not the same with greater international impact.

3.4. Bibliographic Coupling

Figure 4 shows the output for the links in bibliographic coupling where the relatedness is based on the number of references they share. This figure highlights that the document "ghisellini (2016)" is the most cited. Considering sources/journals, there is a relevant relatedness between the Journal of Cleaner Production and the following publications: Business Strategy and the Environment; Energies; and Marketing and Management of Innovations. The same happens for the Sustainability journal and the following publications: New Biotechnology; Autex Research Journal; or Journal of Food and Nutrition Research. However, there is a significant difference between the leading publication in these two clusters and other journals for several indicators (number of documents and citations). On the other hand, the Journal of Cleaner Production shares references with journals from the business, environment, energies, marketing, and innovation areas, and the Sustainability journal shares references with sources from the biotechnology, food, and nutrition issues. This reveals the relationships, for these topics, between sustainability and business aspects, namely those related with innovation. It also shows the interlinkages between sustainable development and new biotechnological approaches.

The organization that has more documents (Bucharest Univ Econ Studies) also shares publications containing references with a relevant number of organizations around the world. However, the organization with more citations (Univ Bologna) shares references with a more limited number of organizations. Finally, Australia and Norway are clustered together (this means that the authors from these countries usually share references). Brazil, England, Austria, and Portugal are grouped in another cluster, and Croatia, Serbia, Switzerland, and Northern Ireland compose another cluster. Some countries from the Asian Continent and the USA form another group, and the remaining countries are clustered into two bigger groups. It seems that, in general, there are more references shared between authors from countries with some closer affinities. In any case, the fields related to circular economy in the European Union create curiosity amongst researchers around the world.

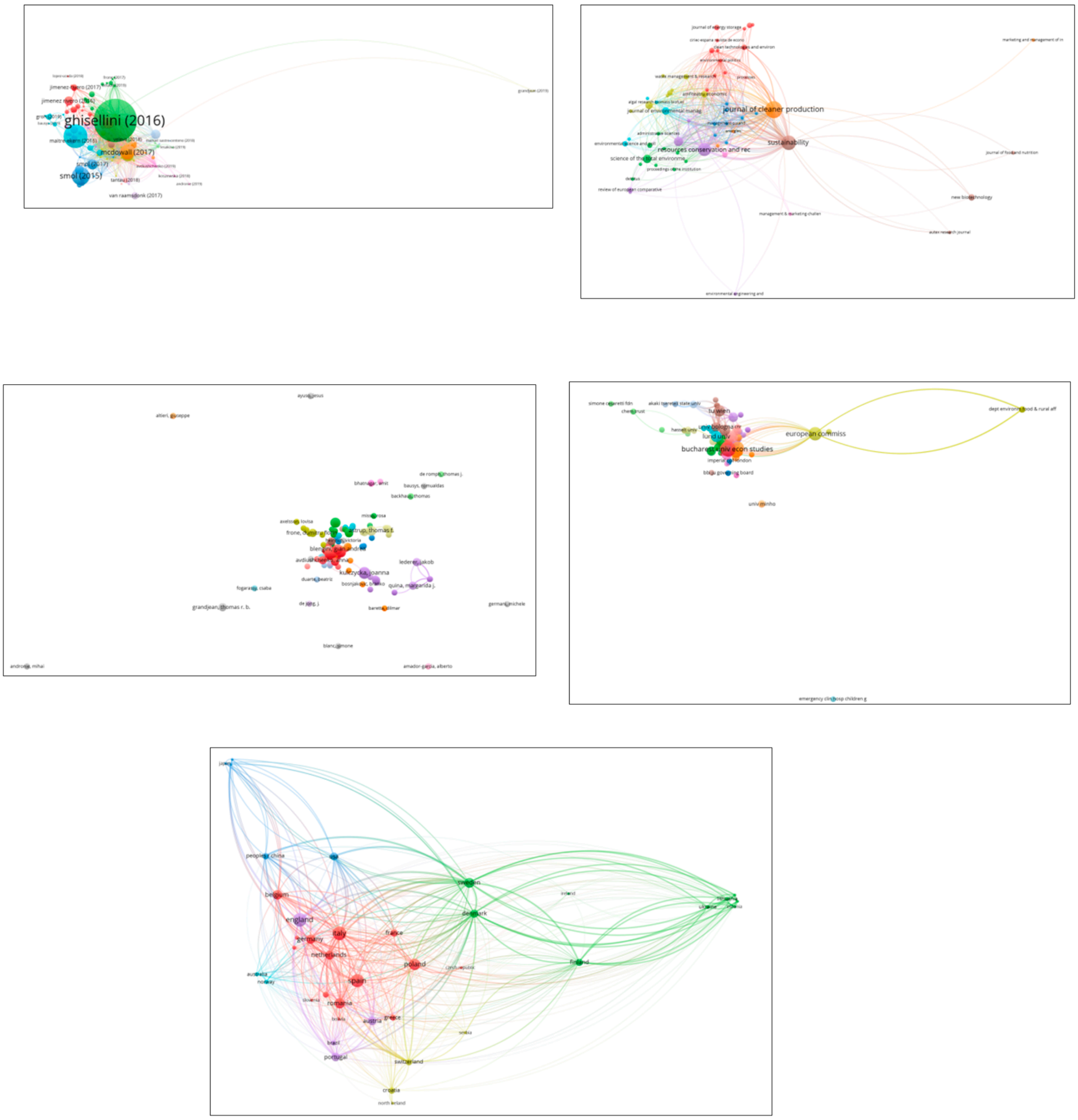

Figure 4. Bibliographic coupling network visualization maps (0 as minimum number of citations of a document (circle's dimension represents the number of citations), 1 as minimum number of documents of a source (circle's dimension represents the number of documents), 1 as minimum number of documents of an author (circle's dimension represents the number of documents), 1 as minimum number of documents of an organization (circle's dimension represents the number of documents), 1 as minimum number of documents of a country (circle's dimension represents the number of documents).

3.5. Co-Citation

In these filters the relatedness is based on the number of times the items are cited together (Figure 5). For instance, the Journal of Cleaner Production is co-cited with the following publications (amongst others): J Ind Ecol; Ecol Econ; Nature; Clean Technol Envir; Res Policy; Technol Forecast Soc. For the item author, the European Commission is co-cited with the following authors: OECD; Bleischwitz, R; Howlett, M; Wilts, H; Eco-Innovation, Observatory; Winans, K; Zavadskas, Ek; Ekvall, T. In general, the most co-cited sources are from the same fields, and the authors who are more cited together have some affinity (in this case three organizations appear, the European Commission, OECD, and the Eco-Innovation Observatory).

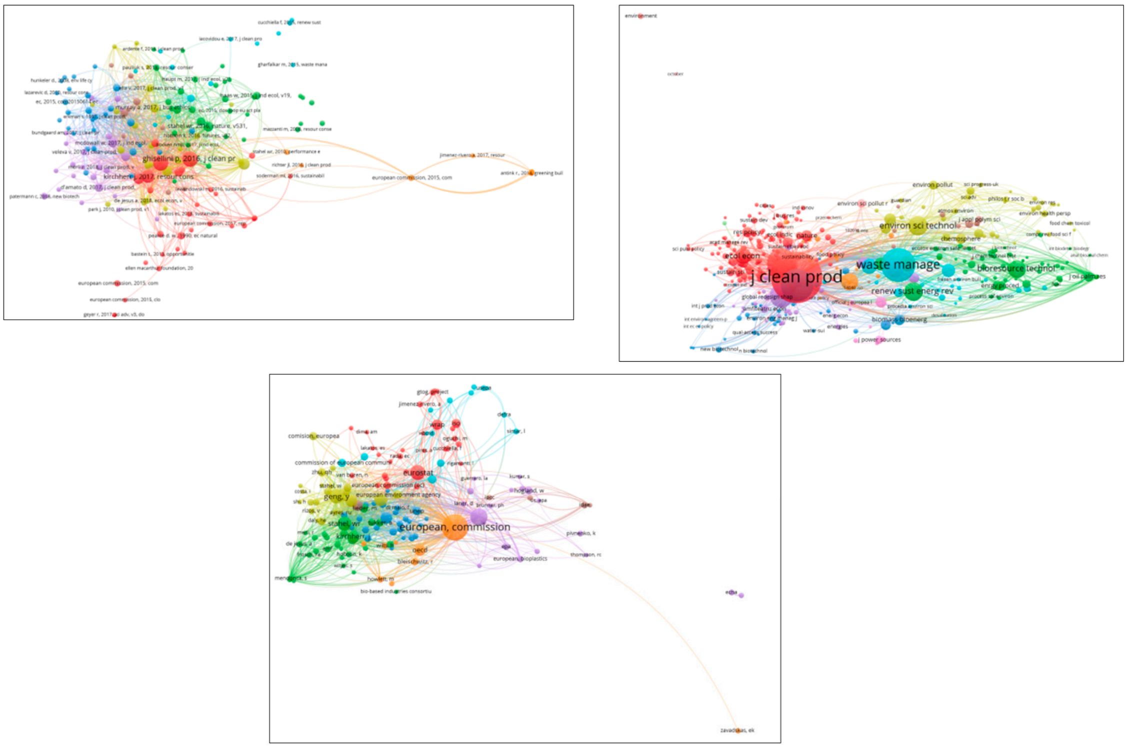

Figure 5. Co-citation network visualization maps (3 as minimum number of citations of a cited reference (circle's dimension represents the number of citations), 3 as minimum number of citations of a source (circles dimension represents the number of citations); 5 as minimum number of citations of an author (circle's dimension represents the number of citations).

4. Discussion and Conclusions

This research was aimed to perform a literature review, complemented by a bibliometric analysis, about the topics "circular economy" and "European Union". We referred to VOSviewer software for the bibliometric analysis and to the platform Web of Science (as the major source of our observed references). From this scientific platform, 144 studies were identified.

The bibliometric effort identified that several issues related to the circular economy have attracted the attention amongst researchers [76,82,103,122]. This identification has shown the relevance of studies performed in these fields and the enormous potential to be explored in future work. On the other hand, it is also worth highlighting the great number of documents produced by international institutions such as the European Commission, revealing institutional concerns about circularity in the European economy [14,88,103]. In addition, within these frameworks another question is raised about the international impact from scientific production and, in this dimension, the studies published by Chinese authors have had a greater impact in the scientific community. Keywords like sustainability, recycling, reuse, management, efficiency, waste, and industrial ecology stress the concerns with waste management.

The bibliometric analysis has also shown that the more productive authors are those with more relatedness, since, in general, they had worked together. However, it seems that there are some specialised teams in these fields, usually involving a small number of members and from the same institution, or, at least, from the same country. This framework shows that it is important to promote further networking and more specialised teams around the world for these domains. These are interesting insights, presenting that the organizations with more impact seem to be more focused on positive returns across the scientific community. Finally, the authors from Australia and Norway tend to share references more likely, as well as those from Brazil, England, Austria, and Portugal.

In terms of practical implications, there is a great potential to be highlighted in the domains related with the circular economy in the European Union, because they are still emerging areas. In general, the authors who publish on these topics have undergone very little networking. In turn, the findings obtained stress that the scientific community, related with these topics, focused their research, namely, on waste recycling and on business interrelationships. There are some fields' gaps here that may be addressed by the literature in future research.

In future studies, there are some topics, related with circular economy dimensions, that could be further addressed, as, for instance, the following: The design of companies' supply chains [155]; the indices, indicators, and assessment approaches [156]; the technological dimensions supporting the circular economy [157]; the circularity assessment in companies [158]; the relationships regarding human presence in organizations [159]; and implementation suggestions for recycling [160].

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Conflicts of Interest: The authors declare no conflict of interest.

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