THE USE OF ECONOMETRIC MODELS IN STUDIES OF ELECTRICITY GENERATION FROM BIOMASS: a bibliometric analysis

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Abstract

The present research investigated the utilization of econometric models in studies related to the generation of electricity from biomass, through a bibliometric analysis. The general objective of the study was to analyze the publications, from 1987 to 2018, that explored the potential of econometric models involving biomass for electricity generation. Additionally, it was intended to investigate the most cited articles and authors, seeking to verify the most relevant themes and the main econometric techniques used in the analyses; verify the countries most engaged in these researches, drawing a parallel with their current energy strategies; identify future trends of studies in this area. For this, the SCOPUS database was used, selecting articles in English, from the keywords "Econometrics, biomass and Electricity". The data collected with the literature review were compiled on thematic maps, with the help of the Vosviewer software, which realized analysis of citation, co-citation, co-authorship and keywords. SciMat software was also used, which generated from key terms, longitudinal strategic maps that allowed identifying future trends on the theme discussed in this article. The results indicated that the main research fronts in this field are related to the use of econometrics to estimate the impacts of energy generation from biomass in variables such as economic growth, energy demand and greenhouse gas emissions.

Keywords: Econometric Models; Biomass. Energy; Electricity; Bibliometric Analysis; Keyword Analysis.

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1 Introduction

In the last decade, interest in understanding the relationships between economic and social variables associated with the production and use of electric energy through renewable resources, especially biomass, has grown significantly. (Arisoy & Ozturk 2014; Bhat 2018; Rehman, Deyuan, Chandio, & Hussain 2018). For energy related research, econometric models are versatile and can be used to analyze a multitude of problems, from issues related to energy efficiency and security (Alexander et al, 2006; Zhang et al. 2018), elasticities of energy products and inputs (Atalla, Bigerna, & Bollino 2018; Ko et al. 2010), climate change (Dong, Sun, & Dong 2018) as well as assisting in the development of long-term energy policies for countries. (Sinha, Shahbaz & Sengupta 2018).

Biomass has been considered one of the most promising inputs to be used as a primary energy source to replace traditional fossil fuels. The current scenario, marked by population growth, food and energy demand, and the need to develop new paradigms related to the mitigation of environmental impacts caused by human activities, is a strong challenge to be faced by countries (Bulut & Muratoglu 2018; Martins et al. 2019). One of the solutions is the use of renewable energy sources to reduce greenhouse gas (GHG) emissions from fossil sources such as oil, coal and natural gas and to diversify the global energy matrix. An example is biomass and its waste, which has a 9.7% share in primary energy generation as demonstrated by data from the International Energy Agency (IEA 2018), volume larger than traditional and technically sources better developed, like nuclear (4.9%) and hydraulic (2.5%).

Despite being used since the mid-1950s, econometric models, before the last decade, when studying the electricity market, basically concentrated on the relationships between economic growth and energy consumption (Darmstadter 1971; Mainguy 1967; Mason 1955). More recent studies, such as Hannesson (2009) have included other variables such as the price of oil, reaching more robust conclusions on the dependence on fossil fuels and broader geopolitical issues, such as energy security.

Only from 1983 began to emerge works with the use of more robust econometric models, such as (Bajracharya 1983) and Hosier & Dowd (1987), which analyzed the relationships of

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logging for energy purposes and deforestation for planting food with changes in consumption habits by more modern and sophisticated energy sources as the economic status of the population improves.

It is only from 2010 that one can observe the proliferation of studies involving simultaneously econometric models, electricity and biomass, with different interests: economic development (Kebede, Kagochi, & Jolly 2010; Munich, Hakim, & Abdullah-Al-Mamun 2010; Solarin & Ozturk 2015); climate change (J. B. Ang 2007; M. E. Bildirici 2014, 2017) and energy efficiency (Gasparatos, Doll, Esteban, Ahmed, & Olang 2017; Long, Wu, Zhang, & Zhang 2018), for example.

Thus, the general objective of this research is to analyze the publications, from 1987 until 2018, that exploited the potentialities of the econometric models in the studies involving biomass for electricity generation. Additionally, it was intended to investigate the most cited articles and authors, seeking to verify the most relevant themes and the main econometric techniques used in the analyses; verify the countries most engaged in these researches, drawing a parallel with their current energy strategies; identify future trends of studies in this area.

For this purpose, a bibliometric research was conducted using the keywords "Econometrics, Bio-mass and Electricity", with the help of VOSviewer and SciMat software, as well as an analysis of time intervals, using the SCOPUS database, establishing, quantitatively and qualitatively, the main results of the research on the use of econometric models in studies of electricity generation from biomass, as well as the main trends in this field of study, given the development seen in this area in recent years.

2 Methodology

This section presents the procedures adopted in the research. First, a brief explanation of the bibliometric research was presented. Subsequently, the choice of the database was justified and the process coding, indicators and bibliometric methods and the software used were presented, as well as the parameters established for the generation of the outputs.

2.1 Bibliometric analysis

The bibliometric research refers a wide range of studies that emerged at the beginning of the 20th century, as an alternative to the need for further studies and evaluations of scientific production and communication and its direction. Among many other purposes, it can be used as a quantitative tool to evaluate the past contribution to science by research entities and also to predict their future research potential. In other words, bibliometric studies aim to demonstrate the direction of science in a given field of knowledge. (Gautam 2017).

This paper is characterized as a systematic reviewing from literature and uses a bibliometric analysis of secondary data. This type of analysis generates useful information for researchers evaluating the evolution of scientific activity (Montero Díaz, Cobo, Gutiérrez, Segado Boj & Herrera Viedma 2018) examining bibliographic material from an objective and quantitative perspective that is useful in the organization of information within a specific field (Albort-Morant & Ribeiro-Soriano 2016). Thus, a bibliographic analysis using keywords allows the analysis of details in the main research topics within a defined relationship domain of a given research area (G. Chen & Xiao 2016).

Following criteria suggested by Castillo-Vergara, Alvarez-Marin, & Placencio-Hidalgo (2018), the current study followed the following steps: a) definition of the field of study; b) selection and processing of the database; c) adjustment of search criteria; d) coding of selected material and; e) analysis of generated information.

2.2 Database's selection

The selected articles, from the keywords used, were recovered from the SCOPUS database of Elsevier publisher. This database was chosen because of its multidisciplinary nature and scope. According to Thelwall (2018), the tool, indexes peer reviewed academic titles, free access titles, conference annals, among others. It has about 50 thousand academic books and 25 thousand scientific journals.

The research analyzed publications since 1987, first year in which the three keywords were detected together, until 2018. The choice for this last year was due to the fact that all

articles are already in the final stage of publication, that is, with the research finalized and disclosed. The keywords included in the survey were: “Econometrics”, “Biomass” and “Electricity”, to be researched in the title, abstract and in the keywords using the Boolean operator “And”. Only articles published in English were requested. Initially the research returned 1,222 articles, which were qualitatively analyzed. Of these, the publications which did not specifically contain the three terms were removed, as were research on other renewable energy sources, like wind and solar and publications that did not deal directly with electricity generation and its aspects.

In addition, articles dealing with issues related to the use of biomass for human and animal nutrition were eliminated. Although they used econometric models in their analysis, they were not related to the scope of the present study. After this filter, 912 articles were left, which were used in the bibliometric analysis. Review articles were also selected to compose the database. The study and collection of publications were conducted during the last two weeks of August 2019.

2.3 Codification process

After data collection, a single information base was created, composed of a simple file, in Excel, in format “CSV”, containing complete record of the variables used for analysis: author, language, year of publication, type of research, country of origin, field of research, keywords and references cited in each of the publications selected in the selection step of the database. Time intervals consistent with the number of publications per period were also defined in order to visualize the evolution of the number of publications among the three decades considered. The division into periods also assisted in the use of one of the software used in the bibliometric analysis, the SciMat, which will be duly presented in a later section.

A common problem in bibliometric and systematic literature review works is the way authors are identified. The same author can be cited in several ways, making the process of identifying citations difficult, causing, in some situations, problems of double counting. To avoid this difficulty, a thesaurus file was also formatted standardizing the authors' citation format.

2.4 Choice of bibliometric indicators and methods

Quantitative indicators were used to measure the productivity of a researcher, periodical or country in terms of number of publications and citations, according to the methodology established by Cadavid Higuita, Awad, & Franco Cardona (2012). These indicators aim to mediate the frequency with which a work, author or periodic is cited in other researches, relating works, authors, institutions, countries and keywords according to the chosen method, mapping the units of analysis, in this case the keywords, according to this metric.

For the present research, the selected bibliometric methods were: Citation Analysis, which uses citation as a measure of influence, assuming that the most cited authors, papers and journals are more influential; Co-citation Analysis, seeks to answer which group of authors is systematically cited by a determined group of papers and which researches are jointly referenced, using the joint citation as a measure of similarity. It assumes that the more two works are cited together, the more their content is related, deducing the most influential authors of the studied area; Co-Author Analysis, answer which authors work together, as well as, which institutions or countries collaborated in a given field of research, i.e. identifies the measure of collaboration between the publications; Co-word Analyses, which identifies which words-key has been used more in each period of time, which of them are used together and as interest in research has changed over time. (Cobo, López-Herrera, Herrera-Viedma, & Herrera 2012; Zupic & Čater 2015).

The four techniques employed allowed the mapping of the established research field, i.e., the use of econometric models in studies of electric energy generation from biomass, especially through the Co-Word analysis technique that identified the current research front and possible future trends of studies related to the theme discussed in this review.

2.5 Softwares used

Two softwares were used in the process. The first was VOSviewer, a free access information technology program developed by Waltman & Van Eck (2012) for the construction and visualization of bibliometric maps. The main advantage of this program over most information technology programs available for bibliometric mapping is that it focuses on the

graphical representations of the maps. This is particularly useful when viewing large maps, facilitating the interpretation and is mainly used in the creation of maps based on network data (Cobo, López-Herrera, Herrera-Viedma, & Herrera 2011; Jeong, Cho, Park, & Hong 2016). The second tool was the SciMAT: developed by the group "SECABA" of the University of Granada, which allows the construction of scientific maps, as well as a better visualization of evolution within a scientific area (Cobo et al. 2012).

VOSviewer is a computer program that has been developed to create, view and explore academic and scientific bibliometric maps. The program is available for free via the www.vosviewer.com web-site (C. Chen, Ibekwe-SanJuan, & Hou 2010; Van Eck, Waltman, Dekker, & Van Den Berg 2010). The software allows the creation of so-called terms maps. A map of terms is a two-dimensional map in which the frequency of occurrence of a specific term is defined by the size of the label. The distance between two terms can be interpreted as an indication of the relationship of these terms based on the number of co-occurrences between them (Castillo-Vergara et al. 2018). The analysis made in this program considered countries, authors and most cited articles and keywords.

The SciMat, also an open source program, is designed to perform scientific mapping analyses in a longitudinal structure. The system provides a diversity of resources that help the researcher to con-duct workflows that help in the mapping of science. For this research the following flows were established: the first dedicated to the management of the knowledge base and its specificities, such as year and number of publications and academic efficiency indices; the second dedicated to the analysis and mapping of science, identifying the main trends; and a third stream created to present the results and the maps generated.

Three strategic maps were constructed with SciMat, which incorporated the analysis by time interval: (1987 – 2000); (2001 – 2015) and (2016 – 2018), using centrality and density measures. The division into periods allowed to verify trends in the publication patterns in the area of study of interest.

SciMat works with an algorithm that scales science in four quadrants. The focal themes, or motor themes, are those well developed and important for the construction of the scientific

field, because they have strong centrality and high density. Peripheral themes are characterized by being internally important and well developed, but are isolated from other themes, having marginal importance in the evolution of academic research. Emerging themes are seminal, usually exploratory and discursive research and the basic themes are important for scientific development, but are still little studied (Martins et al. 2019). Figure 1 synthesizes the algorithm used by SciMat for mapping science.

Figure 1 - Division of themes by quadrants, according to SciMat algorithm

Source: Martins et al (2019)

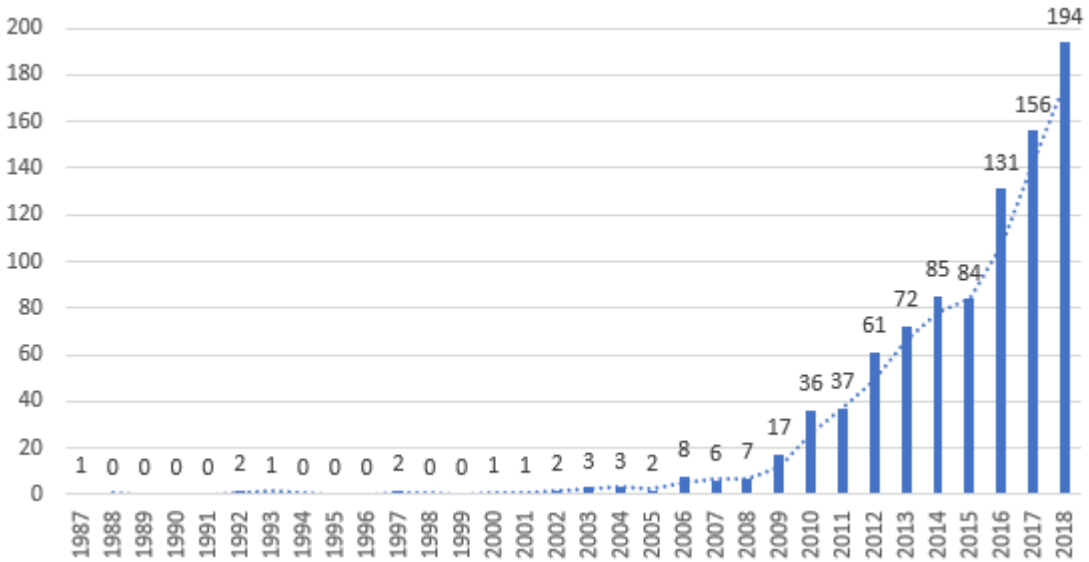
In the operational environment of SciMAT, the following configuration was established: word as analysis unit, co-occurrence analysis as a tool to build networks, equivalence index as a measure of similarity to normalize networks, and simple centers algorithm such as the algorithm used in the detection of clusters and creation of strategic diagrams, which are subdivided into the four quadrants reported. (Cobo et al. 2012). The mapping, according to these criteria, allowed the recognition of patterns in the publications and also revealed trends in research in the area of interest.

3 Results

As detailed in the methodological section, the basic body of publications identified in the literature did 912 articles. The distribution of publications in the period (1987 to 2018) is illustrated in Figure 2. In 1987, the first year of the series analyzed, only one article was

published on the subject, establishing a gap of four years without articles. The issue was not discussed again until 1992, remaining with discrete Song et academic interest until 2010, where from then on, until 2018 reached the average of 95 annual publications, culminating in a total of 194 articles in the last year of the series.

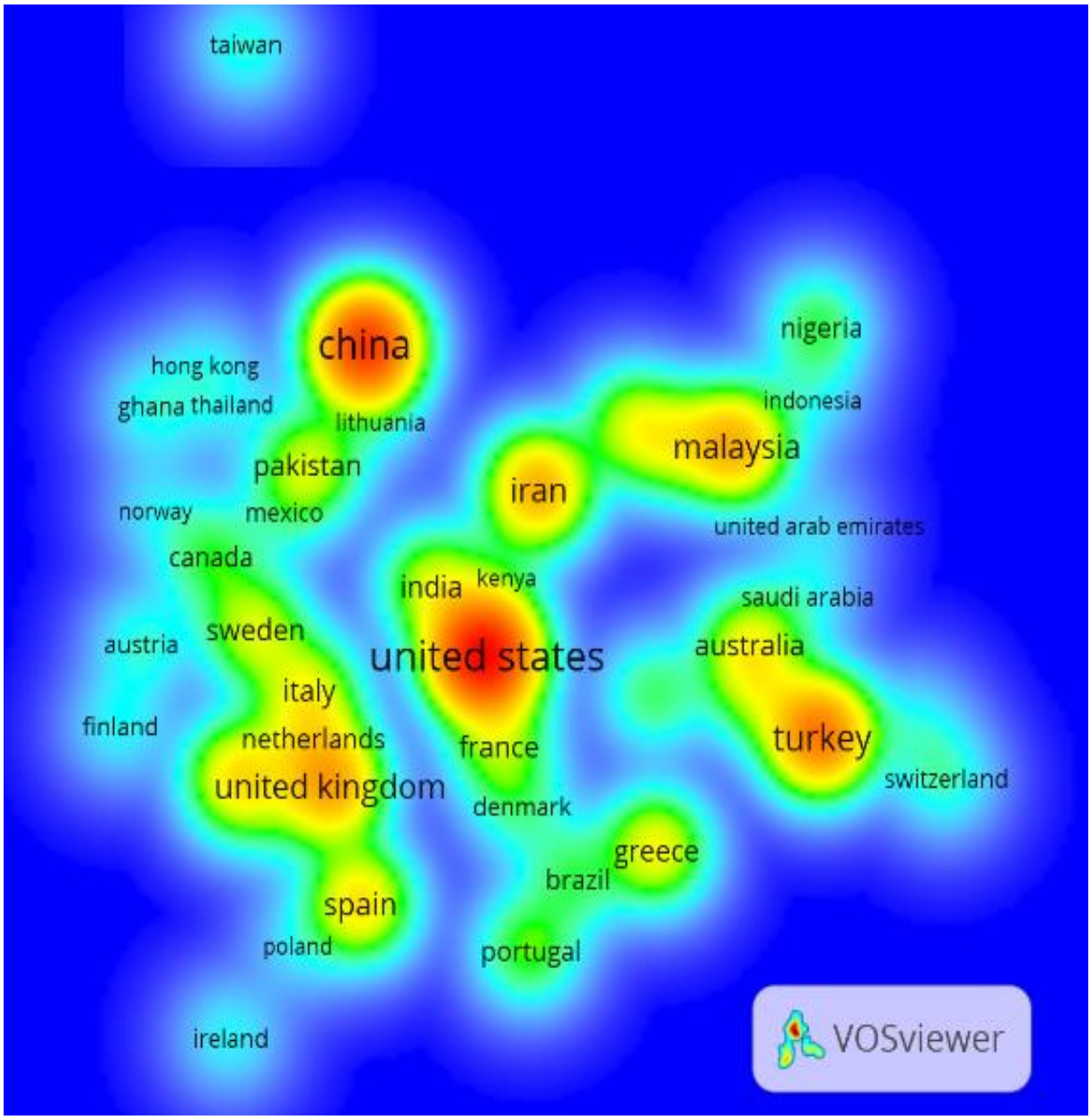
Figure 2 – Annual distribution of publications



Source: the authors

The country with the highest number of publications on the subject "Econometrics and Biomass and Electricity" are the United States (163), followed by China (129), Turkey (89) and the United Kingdom (66). The highest number of quotes also comes from the United States, with 5,044, which is the country that also has the highest number of links with other nations. The map in Figure 3 shows the countries that conduct research on the subject of interest. A total of 46 countries have been identified, forming nine clusters.

Figure 3 – Intensity of publications by country



Source: the authors

Regarding the number of publications by author, Lin, B. is that it has the largest number of articles with topic "Econometrics and Biomass and Electricity", with 17 works. However, Apergis, N. is the one with the highest number of quotes. Table 1 shows the 11 authors, who have at least 10 papers published on the subject of interest of a total of 2,121 authors. To earn the

quality of the publications, the Hirsch Index, or h-index, was included in the analysis. The index h is determined after sorting the publications of a researcher in decreasing order, according to their frequency of citation. Thus, the researcher or research group is classified according to its h level, which is equal to or less than the number of quotes for its articles (Schreiber 2015). That is, it is a proposal to quantify the productivity and impact of the researchers, based on their most cited researches. As a complement, the average citation per author was also inserted.

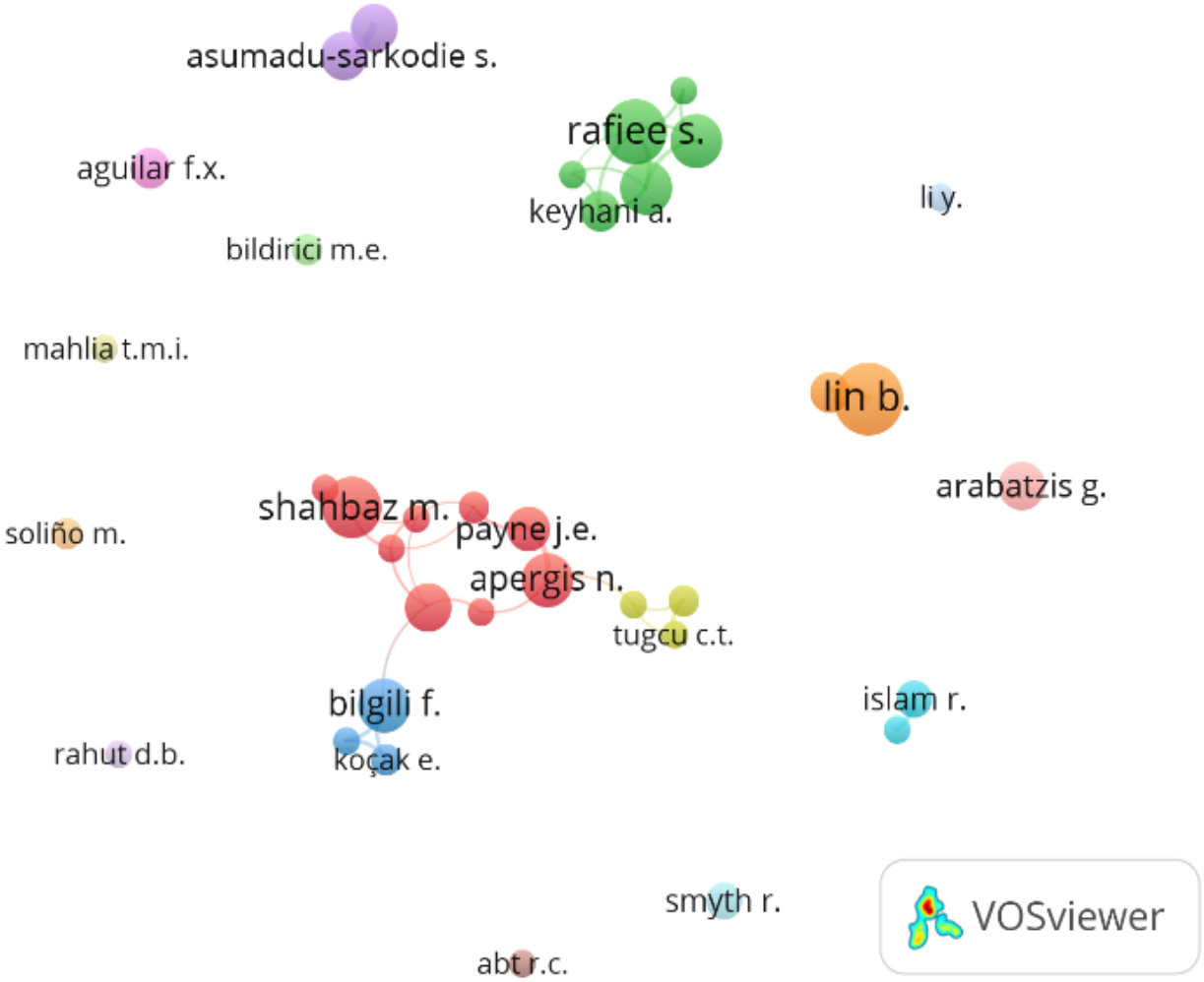
Table 1- Number of publications and citations of the main authors searched

Authors	Publications	Citations	h-index	Avarege
Lin B.	17	425	44	25,00
Rafiee S.	14	470	38	27,65
Shahbaz M.	12	430	42	25,29
Akram A.	11	365	19	21,47
Apergis N.	11	500	36	29,41
Bilgili F.	11	380	12	22,35
Omid M.	11	390	35	22,94
Arabatzis G.	10	176	18	10,35
Asumadu-Sarkodie S.	10	212	18	12,47
Owusu	10	182	13	10,71
Ozturk I.	10	423	42	24,88

Source: Scopus (2019)

Making simultaneous analysis among the main authors, in terms of number of publications, with the relevance of the works, that is, the number of citations, noticed that the main authors work, basically, in isolation, except for the clusters led by Shahbaz, M., Bilgili, F. and Tugcu, C. T. In the Vosviewer environment a minimum number of five publications and 25 citations were set up for each author, 36 authors were identified who composed 16 clusters. (Figure 4).

Figure 4 – Clusters of authors



Source: the authors

The cluster led by Assumadu-Sarkodie, S., works with the relationships and impacts of anthropic carbon emissions on various sectors and economic variables. Study, for example, the relationship of emissions with energy use, agriculture, Gross Domestic Product growth (GDP) and population growth (Asumadu-Sarkodie & Owusu 2016; 2017a, 2017b; Owusu & Asumadu-Sarkodie 2016). The main econometric techniques employed in these studies were linear regression and the Auto Regressive method of distributed lag.

The cluster highlighted by Rafiee, S., studies issues related to energy efficiency using computational modeling and neural networks on specific sectors, such as chicken and watermelon production (Amid, Mesri Gundoshmian, Shahgoli, & Rafiee 2016; Mousavi-Avval,

Rafiee, Jafari & Moham-Madi 2011a; Nabavi-Pelesaraei, Abdi & Rafiee 2016), using non-parametric methods of data analysis and the Levezanberg-Learning Algority-Marquardt, used for the training of input data in artificial neural networks (ANN). It also focuses on topics such as life cycle analysis (Rajaeifar, Akram, Ghobadian, Rafiee & Heidari 2014) and energy balance of biogas production among different biomass sources (Afazeli, Jafari, Rafiee, Nosrati & Almasi 2014; Beheshti Tabar, Keyhani & Rafiee 2010; Mousavi-Avval et al. 2011a).

One of the authors with the highest number of publications Lin, B., concentrates his studies on the evaluation of the intensive use of electricity in the agricultural and industrial sectors on CO2 emissions (Lin, Omoju & Okonkwo 2016; Lin & Xu 2018; Nejat, Jomehzadeh, Taheri, Gohari & Abd. Majid 2015). The group also turns its research to the area of energy security and implementation of new electricity production technologies, highlighting the various biomass sources as strategic factors in this process of replacing fossil fuels with renewable energy sources (Bloch, Rafiq & Salim 2015; Lin & Atsagli 2017; Lin & Tian 2017; Suh 2016). Interestingly, this cluster could be working together with the group led by Assumadu-Sarkodie, since both research lines the impacts of carbon emissions on economic variables, including similar econometric models shall be used. However, as can be seen in Figure 4, the clusters are far apart and without links.

Another common and relatively well-cited author is Arabatzis G. The works carried out in the cluster led by him are interested in understanding the relationships between the use of biomass, specifically wood, and energy generation and economic growth using econometric models based on generalized Linear Model regression (OLS) techniques, Tobit and Heckman and Auto Regressive moving average models (Arabatzis, Petridis, Galatsidas, & Ioannou 2013; Koutroumanidis, Ioannou, & Arabatzis, 2009; Ntanos et al. 2018).

The only clusters that interact are those led by Shahbaz, M. and Apergis, N., Bilgili, F. and Tugcuc, T. The group of authors work on broader issues, emphasizing the use of econometrics to establish macro-energy and regulatory relations between countries or groups of countries (Apergis, Eleftheriou, & Voliotis 2017; Balcilar, Ozdemir, Ozdemir & Shahbaz 2018; Bilgili, Koçak, Bulut & Kuşkaya 2017; Bilgili & Ozturk 2015; Shahbaz, Rasool, Ahmed & Mahalik 2016; Sinha et al. 2018; Tugcu & Tiwari 2016). Because they are comparative analyses

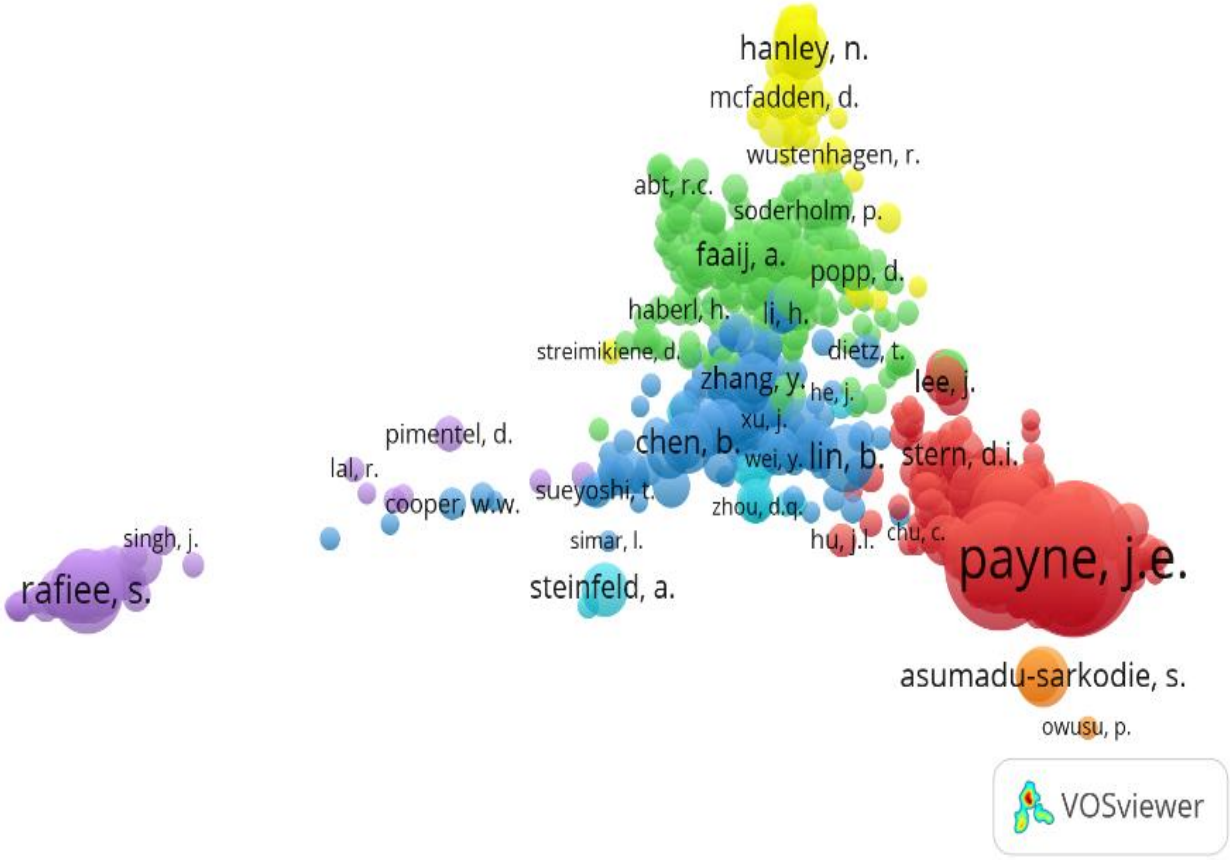
between regions or countries, the methodology used by these studies focuses on panel analysis and time series analysis.

The other clusters are composed of authors who have at most eight publications on the subject of interest. They work, practically alone, with the exception of the cluster led by Islam, A. They largely deal with articles that establish relationships on the use of biomass for electricity generation with climate mitigation factors and economic variables such as GDP and population growth, using a co-integration approach using Auto Regressive distribution model (M. Bildirici 2017; M. E. Bildirici 2014). They also work with analysis of the effectiveness of public policies to encourage the use of biomass using panel analysis (Lean & Smyth 2013) and some literature reviews involving biomass energy generation (Shafie, Mahlia, Masjuki & Ahmad-Yazid 2012; Smith & Shively 2018).

With a little more emphasis on the relevance of the authors' area and influence, a co-citation analysis was performed, which identifies which authors are most frequently cited simultaneously in a given study. Following the same parameters of the coauthor analysis, i.e., selection of a minimum of five articles, with 25 citations each, 395 authors were selected, divided into five clusters (Figure 5).

The co-citation analysis´s demonstrates that despite a low joint production, but at the same time with several authors researching the same object, as seen in the analysis of co-authorship, the theme “Econometrics, Biomass and Electricity” shows similarity between the mentioned works, at least within the clusters. Figure 5 allows us to observe a reduction in the number of clusters, when com-pared with the analysis of co-authors (16 to five), demonstrating approximation of the studies.

Figure 5 – Co-Citation Analysis



Source: the authors

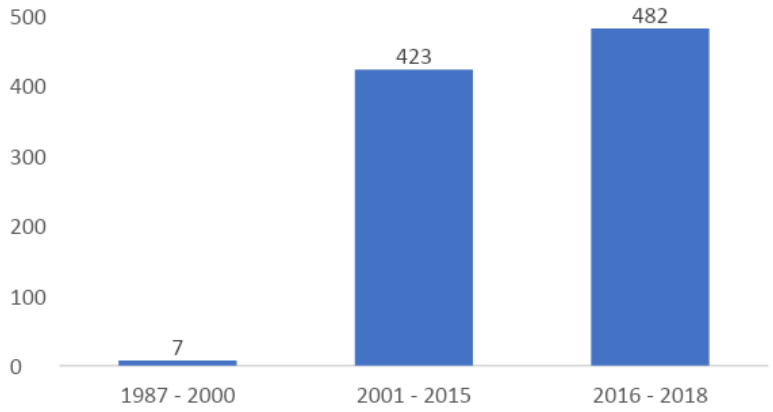
Rafiee, S., for example, who is one of the authors with the highest number of publications and citations, 14 and 470 respectively, works on issues related to energy efficiency and the use of cleaner technologies and sources for electricity generation, is commonly quoted jointly with Pimentel, D., Cooper, W. and Singh, S.. Payne, J. E. The latter has nine articles on the subject of interest, two of which, in collaboration with Apergis N., the most cited. The first is “Renewable Energy Consumption and Economic Growth: Evidence from a panel OECD countries” (Apergis & Payne 2010), with 367 citations, published in Energy Policy, The authors discuss the relationship between economic growth and the use of renewable energies, including wood, in OECD countries. Using the unit root test for panel data, which allows for heterogeneous Auto Regressive coefficients, they discover that there is a long-term equilibrium relationship between

real GDP and renewable energy consumption, indicating that an increase of 1% in the latter would lead to an increase of 0.76% in GDP.

The second work of the duo, with 242 citations, titled “Renewable and non-renewable Consumption-Growth Nexus: Evidence from a panel error Correction model” (Apergis & Payne, 2012), re-leased by Energy Economics, the authors showed, also by means of panel analysis, using unitary root test, the relationship between economic growth and the total consumption of renewable energy and non-renewable energy and their impacts on the formation of fixed capital and labor. The results of the panel showed that there is bidirectional causality between renewable energy consumption and economic growth, as well as between non-renewable energy consumption and economic growth, both in the short and long term. Moreover, the results also show that renewable and non-renewable energy consumption can serve as a substitute for each other.

For the purposes of a systematized analysis by keywords, and using the SciMat software, in an attempt to capture the main trends for the field of study of interest, the initial analysis period was di-vided into three blocks: 1987 to 2000, with seven publications; 2001 to 2015, 423 articles and 2016 to 2018, with 482 papers published. Since the 2000s, it is possible to observe the increase in the number of publications, and only in 2018 were published 194 articles that share the keywords “Econometrics and Biomass and Electricity”. Figure 6 demonstrates the number of articles published and analyzed for each time period.

Figure 6 – Number of articles by time period

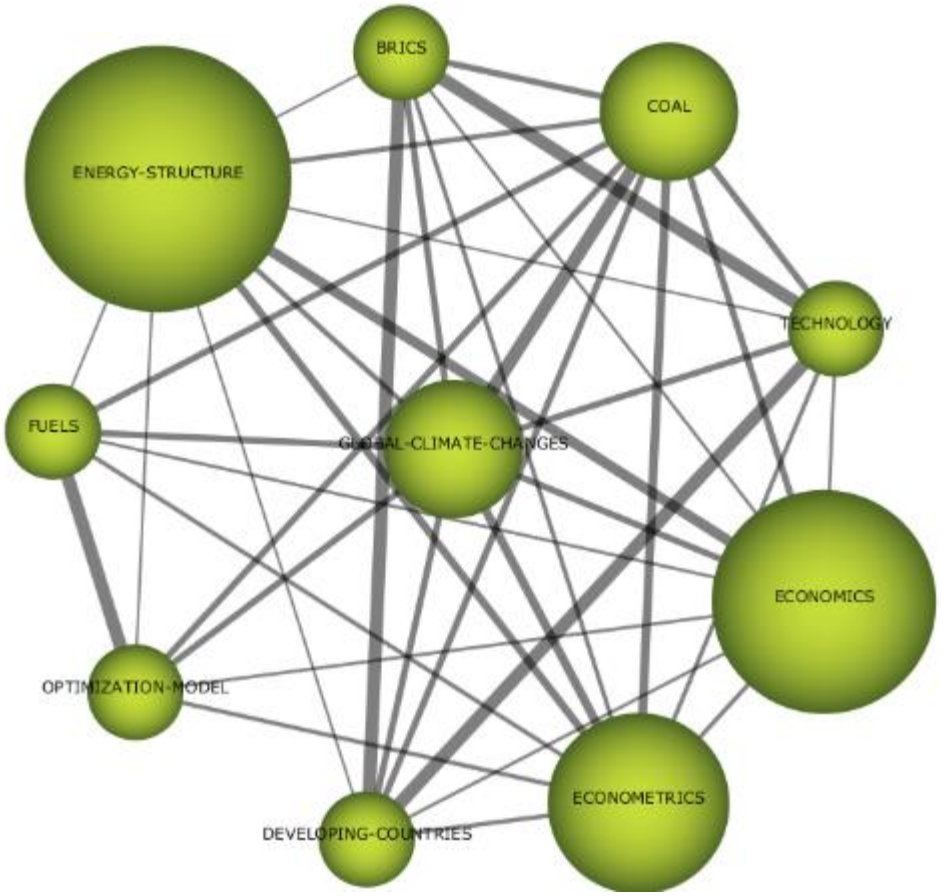


Source: the authors

The first strategic diagram, 1987 to 2000, represented by Figure 7, presented only one focal theme: “Global-Climate-change”, which had high density and centrality. The scarcity of themes captured by the SciMat algorithm was due to the limited number of articles of the period, only seven. As far as the term highlighted is concerned, the time factor has to be considered. In 1988 the Intergovernmental Panel on Climate Change (IPCC) was established and endorsed at the General Assembly of the United Nations (UN). The IPCC’s main objective at that time was to prepare a comprehensive review and recommendations regarding the state of knowledge of climate change science and what would be the impact of human action on that issue. This new phase of the climate study provided publications that were concerned with the impacts of anthropic actions on the planet’s climate, projecting scenarios, through econometric models, of the use of available sources, as well as substitution of these by alternative energy sources such as wood waste, municipal solid waste and other biomass sources (Bajracharya 1983; Hosier & Dowd 1987).

Despite the scarcity of topics in the period, when the analysis is visualized through the links of the cluster, it is observed that “Global-Climate-changes” has strong relationships with themes that would become focal in later periods, illustrating that the area’s development would be due to terms related to the energy structure of the sector, development of new technologies, econometric models, developing countries and computer optimization programs (Figure 7).

Figure 7 – Strategic map and cluster´s network (1987 – 2001)



Source: the authors

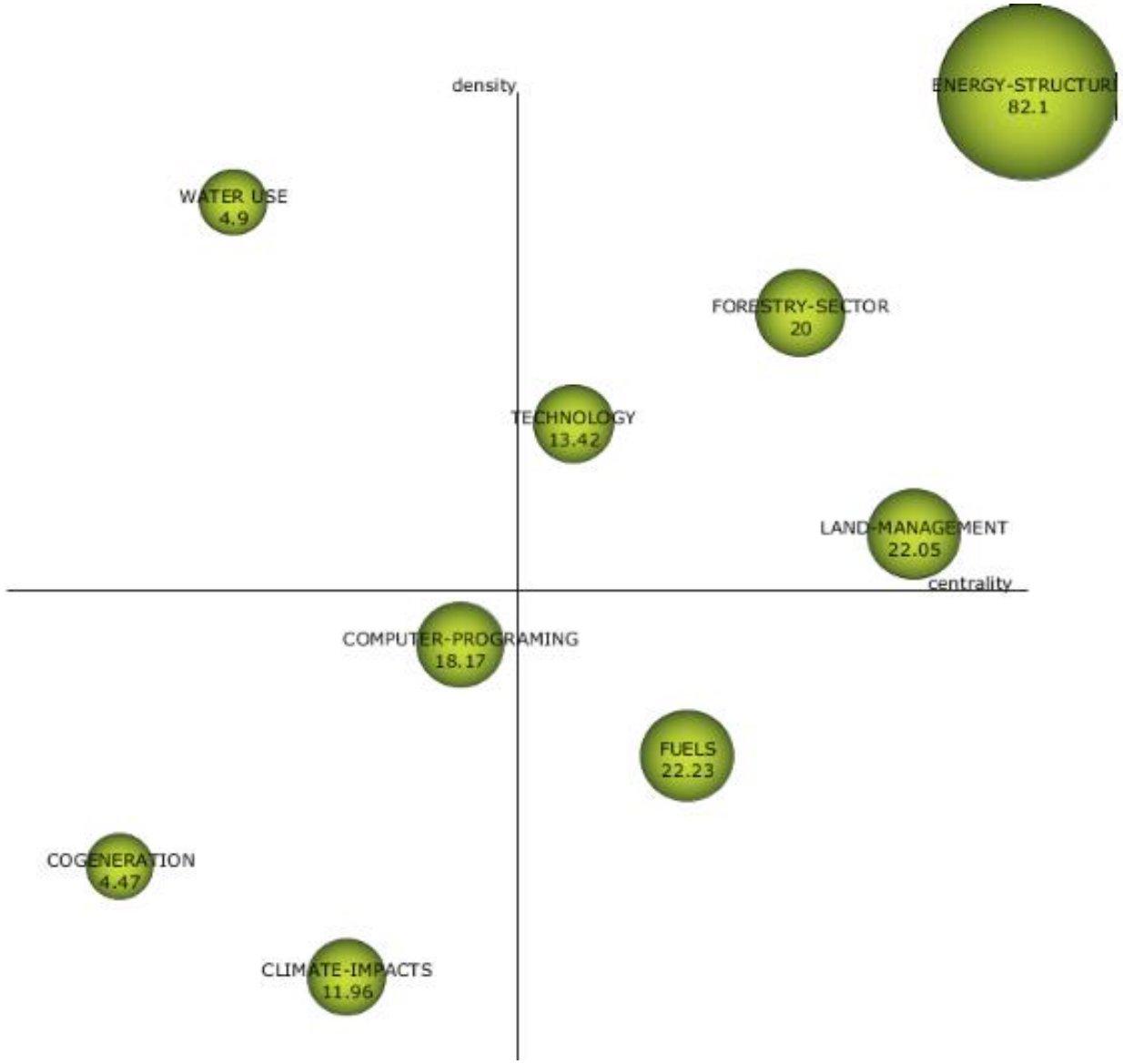
For the second analysis block, 2001-2015, topics of interest increased substantially. The focal themes identified through the keywords, in the upper right quadrant (Figure 8), were: “Energy-structure”, “Forestry-sector”, “Technology” and “Land-management”. For energy structure, theme of higher density and centrality, with 374 documents and index h of 63, the issues discussed focused on the relations between economic growth, climate change and agro food production systems (Bakhtiari, Hematian & Sharifi 2015), just as about on the efficient use of energy in European Un-ion countries and its relation to economic growth (Apergis & Payne 2012; Krausmann et al. 2009; Serrenho, Sousa, Warr, Ayres & Domingos 2014).

Forest sector, another focal theme of this period, presented 26 documents with index h of 16. The main interests of this theme were the relationships between the increased demand for energy inputs from wood and their impacts on the dynamics of land use (Abt & Abt 2013; Gan & Smith 2006; Lamers, Junginger, Hamelinck & Faaij 2012) and changes in infrastructure and logistics sector with increased interest in the use of wood for power generation (Bohlin 2002; Conrad, Bolding, Aust & Smith 2010; Lundmark 2006).

The only peripheral theme highlighted was “Water Use”, which according to research is related to “sugarcane”, “Resource Consumption”, “groundwater”, “anabic digester. The main publications are bibliometric researches developed separately, mainly by the authors highlighted in Figure 4 (Cluster of authors), such as Danlami, Islam & Applanaidu (2014) which discussing the determinants of energy choices and consumption in households in developing countries and Batstone, Hülsen, Mehta & Keller (2015) and Zheng, Li, Shi & Liu (2017) who have researched more energy-efficient ways of water treatment and waste from sewage for electricity generation.

The emerging themes, located in the lower left quadrant, were “Computer Programing”, “Cogeneration”, with high density and centrality, and “Climate Impacts”. In this quadrant, the econometric models were used to simulate the urban use of energy from renewable sources, calculation of energy intensity from different sources and comparison between them, in addition to biomass consumption impact studies on CO2 emissions. (Bilgili 2012; Katircioglu 2015; Mikkola & Lund 2014; C. Wang, Liao, Pan, Zhao & Wei 2014). Figure 8 illustrates the keywords highlighted, highlighting the h index of the topics of interest for the period 2001 a 2015.

Figure 8 - Strategic Map (2001 - 2015)

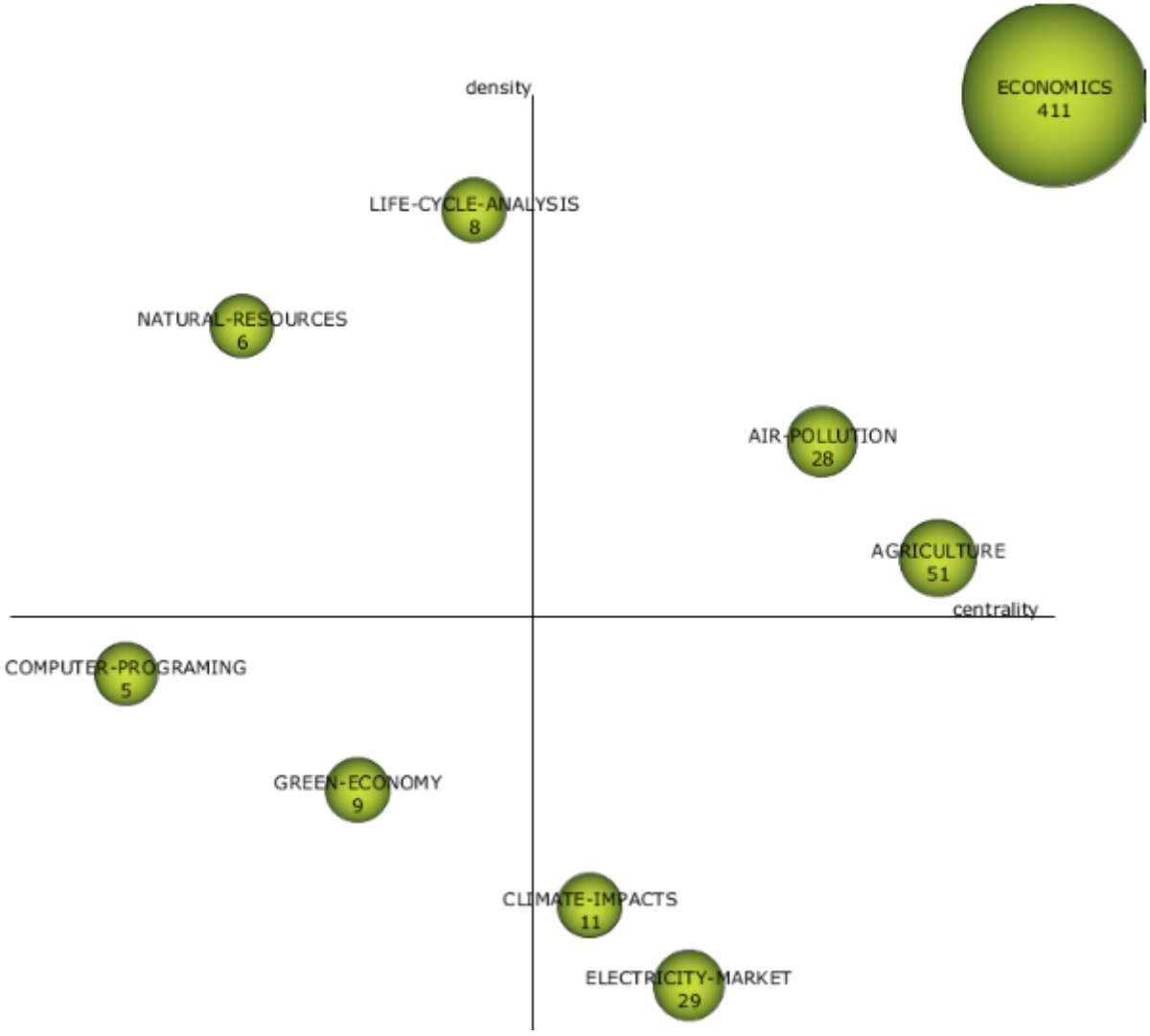


Source: the authors

The last period of study (2016 – 2018), was the one with the highest number of publications (482). The most commonly used keywords were “Economics”, “Air Polution”, “Agriculture” (Temas focais); “Life Cycle Analysis”, “Natural Resources” (Temas periféricos); “Computer Programing” e “Green Economy” (Tópicos emergentes) e “Climate Impacts” e “Electricity Market” (Basic topics). It is interesting to highlight during this period the evolution of the themes, showing trends of future studies, concentrated in areas of interest such as Circular

Economy and Waste of Energy. At the same time, important themes are perceived, but already studied exhaustively, such as impacts on the climate, losing the role of topics of interest in the most current researches. Figure 9 portrays this new reality, also showing peripheral themes, but still developed separately as Life Cycle Analysis, along with the amount of research that focus the terms in prominence.

Figure 9. Strategic Map (2016 - 2018)



Source: the authors

Fifteen of the 20 most cited articles in the area of interest of this research were published in the interval from 2001 to 2015, with relevant values of h – index, reflecting the growth of

publications in the period 2016 to 2018. The most cited researches have a direct relationship with the application of econometric models to relate the production and consumption of electricity, especially from bio-mass, about the economic growth of countries or group of countries (Ahmad et al. 2017; Bekhet & Othman 2018; Botelho, Lourenço-Gomes, Pinto, Sousa, & Valente 2018; Sinha et al. 2018; S. Wang, Wang & Zhou 2018), or on specific sectors, such as the agricultural sector (Britz & Delzeit 2013; Lajdova, Lajda & Bielik 2016), indicating the importance and concern of the academy in answering more precisely questions that worry society, such as environmental conservation for future generations and production of sufficient food to meet the population demand.

4 Discussion

The research showed that the countries with the highest number of publications on the subject of interest were the United States (163), followed by China (129), Turkey (89) and the United Kingdom (66). In the United States and China, the most recent works sought to understand the relationships between energy and electricity production from renewable sources and their impact on carbon emissions, climate mitigation and economic growth (Campbell, Venn, & Anderson 2018; Dong et al. 2018; Roberts, Musango, Brent & Heun 2018; Suh 2016). However, despite the magnitude of the number of publications, it has been noted in recent years that there has been a departure from American public policies interested in combating global warming. Evidence of this can be noted by the tone of speech in defense of domestic resources, be they traditional or alternative, emphasizing the importance of jobs created in the energy industry and the energy security of the country, which has estimated reserves of about 480 billion tons of coal. (IEA 2018).

Chinese behavior is similar. Despite its interest in renewable energy sources, China, which has the largest population in the world, approximately 1.3 billion inhabitants, and whose economic growth from 2000 to 2014 exceeded 250%, with a 150% increase in energy consumption (IEA, 2018), emphasizes energy security. The Chinese energy matrix also has massive participation of coal (66%) and oil (20%). The estimates of the IEA (2018), show a gradual reduction in the use of coal until 2035 (42%), due to the natural reduction of reserves,

but the trend is to be replaced, gradually, by natural gas, which today has participation of 5% in the matrix, but it could be as much as 11%, according to the agency's predictions.

Despite leading the list of major researchers on econometric relations between electricity generation and biomass, the United States and China are the largest emitters of CO2 in the atmosphere. Data from the Global Carbon Atlas of 2018 show that China emitted 10,065 tonnes of petroleum equivalents (MtCO2), while the United States was responsible for 5,416 MtCO2, demonstrating a different discourse between academic research and the market practice ("CO2 Emissions | Global Carbon Atlas," n. d.)

In Turkey, of the 89 works identified, only nine focused on the country's energy interests. Of these, the main topics of interest were related to energy analysis and the level of emissions and the impacts of biomass energy cultivation and relations with food production (Ozalp, Yilmaz, Ertekin, & Yil-maz 2018) in addition to economic concerns, relating the use of renewable energy, focusing on urban solid waste, with the growth of GDP (Baris & Kucukali 2012; Bulut & Muratoglu 2018).

The United Kingdom which produced 66 papers on the subject of interest and was the first country to use coal to generate electricity, as well as other European nations, has been implementing emission reduction policies, through the use of less polluting energy sources. According to the DRAX Annual Report (2018), combined renewable energy capacity in the UK reached 42 GW, while fossil fuels reached 40.6 GW in the third quarter of 2018. According to the report, it was the first time that alternative sources had a greater share in electricity generation in Britain.

As regards the analysis of the periods, from 1987 to 2000, the seven studies presented focused on the theme related to global climate change, but were not limited to this scope. Examples of this are the works of B. Ang (1992) and Meade (1984), which use growth curve methodology for energy studies, involving mathematical models, energy demand and studies of substitution of non-renewable fuel sources by renewables.

The main associated terms were energy structure, economy, econometrics, developing countries, BRICS, coal, technology, fuels and optimization models. Despite the scarcity of

research associating the three terms of interest, “Econometrics”, “Biomass” and “Electricity”, it was possible to identify some emerging future trends from the connections of the focal themes, for example, energy structure and economy, which became focal themes in the periods 2001 to 2015 and 2016 to 2018, respectively. The most widely used models were linear regression analysis (Dowlatabadi, Hahn, Kopp, Palmer & DeWitt 1993; Gupta & Hall 1997), logistic regression (B. Ang 1992) and multinomial Logit model (Hosier & Dowd 1987).

The scarcity of studies on the subject of interest is possibly related to macro-economic factors. At the end of the eighties, the price of the barrel of oil was stabilized after the second oil crisis between 1982 and 1983, ranging between US$ 28.00 and US$ 30.00, the ton, in this period. In addition, the price of coal was also at levels acceptable to the foreign market, being in the amount of US$ 30.00 a ton in the period, removing the incentive for financial and academic investments in alternative energy.

In 1987, for example, the overall energy consumption was 92,593 TWh, and the biomass was 91,64 TWh. Even in 2000, world consumption didn't overtake 112.416.26 TWh, and biomass accounted for 185.27 TWh. Despite having doubled its participation in energy consumption, it was still far be-hind sources such as oil and coal, which had participation in the matrix 38,28% and 24,38% in the year 2000 (IEA 2018).

In the second period, 2001 to 2015, 423 publications were identified. The focal themes were: “Energy-Structure”, “Forestry-sector”, “Land-Management” and “Technology”. The term with higher density and centrality was “Energy-Structure”. This comprehensive cluster was associated with terms like “Economics”, “Econometrics”, “Renewable-Energy”, “Fossil Fuels”, “Electricity-Market”, “Green House Emissions The most cited works of this period associated with the cluster addressed the dynamics between the consumption of renewable energy, its production, emissions and price comparisons with other sources, especially oil. (Bowden & Payne 2010; Payne 2012).

Forest-sector was a cluster that caught attention in this period. There were 26 publications that addressed this topic related to energy production and analyzed from the perspective of econometric models. The most prominent works were by Di Corato, Gazheli, & Lagerkvist

(2013), who discussed, from the perspective of costs, of return on investment and incentives for policies of induction of the decision of the farmer to replace part of agriculture by energy forestry and Aguilar, Cai & D'Amato (2014) which estimated the impacts of timber and woody biomass prices in relation to owners' predisposition to harvesting the input by means of a Bayesian multinomial model.

An emerging theme caught the attention: "Water use". This cluster was associated with "Global Climate changes", "sugar Cane", "Resource-Consumption" and "health Risks". Although it did not become, specifically, a focal theme in the later analyzed period (2016 a 2018), it amplified the discussion on the use of biomass for energy generation and its impacts on the conservation of water resources. The publications explored the relationship between electricity consumption and water for food production (Asgharipour, Mondani & Riahinia 2012; Gündoğmuş 2006; Thankappan, Mid-more & Jenkins 2006) and the impacts of climate change on water demand for electricity production (Arnell 2004; Ncube, Zikhali & Musango 2013).

From 2001 to 2010 the most widely used econometric models were estimates by OLS, used especially for decision-making in relation to the energy policy to be adopted (Cormio, Dicorato, Minoia & Trovato 2003; Sundqvist 2004). The estimates by OLS were also used to evaluate problems of energy demand, associated with the analysis of its substitution by alternative energy sources, in particular biomass from forest waste and municipal solid waste (Chambwera & Folmer 2007; Edwards & Langpap 2005; Jebaraj & Iniyan 2006). Another common technique in this sub period was the Logit models associated with optimization models. This technique was especially used in the analysis of choice problems between producing food or energy biomass (Johansson & Azar 2007; Ouedraogo 2006).

From 2011 on, the publications used more systematic and modern econometric techniques, such as instrumental variables, minimum two-stage squares (2SLS) and intensified the use of time series. Susaeta, Lal, Alavalapati & Mercer (2011), conducted an experiment of choice among individuals to evaluate electricity preferences based on woody biomass in the states of Arkansas, Florida and Virginia, in the United States, considering the likes and preferences of individuals as exogenous variables to the model, i.e., as not belonging to the

equation, but correlated to the explanatory variables, characterizing the method of instrumental variables.

The relation of electricity production through biomass and its analogy with poverty and social inequality was the focus of studies by Mousavi-Avval, Rafiee, Jafari & Mohammadi (2011b) that through a two-stage error correction model, estimated the impact of the production of electricity from forest biomass on these social variables, reaching the conclusion that when the management for the energy exploitation of wood is implemented, its use tends to decrease social inequalities. The same method was used by Song, Aguilar, Shifley & Goerndt (2012), associated with analysis by cointegrated panels to study the North American residential demand for energy from wood.

The articles published in this period focus their weightings and concerns on the diversification of the energy and electricity matrix. It was a time marked by unfolding events focusing on environmental preservation and reduction of greenhouse gas emissions (GHG), as for example, the River "92", the Kyoto Protocol and the launch of the eight Millennium Development Goals of the United Nations (UN). In addition, social issues were also incorporated into the Environmental Agenda by launching, at the end of 2015, the UN's 17 Sustainable Development Goals (ODS), which aimed, above all, the eradication of poverty, through the minimization of social inequalities, this being an indispensable requirement for directing the planet to the path of sustainable development.

This whole scenario for sustainable development culminated in December 2015 in the largest emission reduction agreement ever signed by all member nations, the 21st United Nations Climate Change Conference, better known as COP 21. In this event, which took place in the city of Paris, the 192 participating countries committed themselves to reduce their greenhouse gas emissions in order to keep global warming below 2o C (UN Climate Change Annual Report 2018 n. d.). Thus, the publications on the subject of interest increased and had the need to improve the econometric models used in order to capture a less biased possible the effects of biomass use for electricity generation in the economic and social variables previously mentioned.

If in the period 2001 a 2015, the concerns of the publications focused on specific sources of bio-mass, especially wood, in the last period analyzed, 2016 a 2018, the attention turned to global economic issues, such as economic growth, energy security and greenhouse gas emissions, being the production of electricity by means of biomass and its analysis through econometric parameters as the central focus of research.

The term '"Economics" presented high density and centrality (Figure 9), establishing itself as the main focal theme of this period. The main Journals of the triennium, listed in the SCOPUS database, were the Economics, Economics and Finance area, totaling 91 publications, or 18.87% of the total research published in this period. Of these, 23 publications are related to the consumption of bio-mass for electricity generation in China, analyzing different sectors, such as the rural, commercial and industry sector of this country and its impacts on CO2 emissions, using time series and data analysis in panels (Han & Wu 2018; S. Wang et al. 2018; Wen & Yan 2018).

In the triennium also highlighted the studies of biomass energy production and its relations with the economic development of developing countries (Ali, Law, Yusop & Chin 2017; M. Bildirici & Özaksoy 2018; Mousavi-Avval et al. 2011b), also highlighting the potential and restrictions for electricity production from biomass in developed countries (Barbose et al. 2016; Hamburger & Harangozó 2018; Jacqmin 2018), all using estimates of Auto Regressive vectors and panel analysis.

The longitudinal analysis, illustrated by the choice of keywords and their coding in the SciMat software, showed that research trends in this field of interest converge in the study of the impacts of energy biomass use on economic variables, such as demand for electricity and economic growth, in addition to environmental concerns in comparative studies between alternative and traditional sources and their relation to greenhouse gas emissions.

From the understanding of much of the scientific community that human action can influence the climate, as consolidated in the period 2001 a 2015, it was natural the migration of the interest this of the researches, especially from 2016 to global economic themes. In the name of energy security, the interests turned to understand the impacts of the use of energy biomass in

variables such as economic growth, agricultural production, in focus on food safety and scenario estimation to test whether electricity generation through different types of biomass, effectively has the ability to decrease greenhouse gas emissions, consolidating, so far, future trends in studies in this area.

5 Final Considerations

The bibliometric study revealed that there is an extensive and diverse field of study associated with keywords “Econometrics, Biomass and Electricity”. In a period of only three decades, it was possible to identify 912 articles dealing, exclusively, directly and indirectly, with the use of biomass for energy and electricity generation, analyzed from the economic point of view, with the aid of econometric models.

The research also found that although most publications are concentrated in the area of energy and environment production, 31.5% and 26.2%, respectively, the field of study Economics, Econometrics and Finance, has been standing out (10.2%)especially with researches led by China, which according to what has been published, wants to understand the impacts of the use of biomass energy in its most diverse economic sectors, as well as knowing the emission potential of this type of energy compared to traditional sources.

As regards the use of econometric models in this type of study, the research demonstrated that each year, the interests of the researchers became more complex, requiring the use of increasingly structured models. In particular, in the first period (1987 to 2000) and in part of the second period (2001 to 2010), the prevalence of regression analysis models by the linear method, where the equations were mostly presented in a reduced form, and estimated by means of OLS. From 2011, it was possible to observe more interesting models such as instrumental variables, generalized moment methods and two-stage minimum square methods. Interestingly, no articles were identified with estimation methodology for maximum likelihood, and only one by means of Bayesian estimation, which are common in strict research in the area of economics and finance.

Future research should be focused on the development of studies that associate terms such as biomass energy and its costs, waste from biomass and its relation to electricity demand and impacts of biomass use for electricity generation on economic and social variables such as

GDP, GDP per capita and social well-being. In addition, there is a need for further deepening on the cultivation of energy biomass and its impacts on food production, especially in countries with low supply of arable land, as well research to test the effective reduction of greenhouse gases from biomass-intensive energy processes, in detriment of processes based on traditional energy sources.

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Appendix – Corpus Analysis References

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