
A MAPPING OF THE LITERATURE ON ECONOPHYSICS

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Abstract: *Econophysics is a relatively young discipline, being an interdisciplinary approach that applies methods and tools from physics in the economics, for studying the financial markets, or other economical phenomena. The objective is to create a mapping of the most used keywords in this topic, as well as the connections between countries and authors, based on citations. This article studies the literature on the topic of econophysics, using the Web of Science database. Bibliometric analysis was made with the free software VOSviewer, after extracting the data from 1364 articles, since the conception of the topic in 1996 until the year 2020. The software offered a useful network representation between the main keywords used in the field, or between countries and citations, and finally between authors, based on citations. The results evidenced a constant interest on the topic, with main keywords: "econophysics", "financial markets", "dynamics", "model" and "stock market", and the relationships between countries and authors were shown, with the United States, China and Italy being the leading ones. We also found that the most cited authors are H.E. Stanley, the inventor of the word econophysics, Wei-Xing Zhou and Didier Sornette. This article shows the main concepts used in econophysics, which can serve as an indicator of its directions of research, as well as the top contributors in the field, since its inception. Future directions include expanding the analysis to other databases, or to concepts relevant to econophysics, to identify trends in research and the growth of the field.*

Keywords: *econophysics, VOSviewer, bibliometric mapping, network.*

JEL Classification: *C45, D85, C38*

1. Introduction

Bibliometric mapping has developed over the last decades as a new tool of exploring literature. Beginning from the broad literature, it has asserted itself as a new means of examining the core literature on particular themes, and analyzing them. A simple method of finding important and relevant studies is offered by the citation reports of different databases, for example Web of Science. These platforms give a complex reading of bibliometric analysis, therefore there have been developed different methods and even software programs in order to construct bibliometric maps.

The aim of this paper is to analyze the framework of the research on econophysics. It is a relatively young branch of physics and economics, that established itself in the last few decades. It started developing because many of the statistical tools and data analysis used in physics can be successfully implemented in economy, as models that try to describe the fluctuating financial markets. The complexity of many models in physics, especially in statistical mechanics, also translates well in the topic of economics.

The VOSviewer software is used to provide the bibliometric analysis, this paper presenting a broad overview of the main topics addressed in research papers on the subject of econophysics, and its application. We also study which authors produced important research in this field, based on the citations of their papers. The countries which have contributed to this field will also be evidenced in the bibliometric analysis, as well as the apparent collaborations between research teams from different countries.

The paper is structured as follows: in section 2 we present the literature review, with a succinct history of econophysics, as well as other bibliometric analysis realized on this topic. Section 3 describes the research methodology and section 4 is structured in 3 subsections, containing the analysis in VOSviewer. In section 4.1 the network between keywords is studied, in section 4.2 we analyze citations by countries, and in section 4.3 the citations by author are processed in VOSviewer. Finally, section 5 shows the conclusions and the final results.

2. Literature review

Econophysics is a new discipline that uses various tools and methods from physics in order to contribute to the advancement of economy (Stanley & Mantegna, 2004). Physics has influenced economy from the beginning, since Adam Smith claimed he was inspired by Newton's ideas and successes in describing the natural world. The term econophysics was first coined by Eugene Stanley and his collaborators at a conference in 1995 in Calcutta, being a neologism for this new branch of physics that was developing at the time (Stanley et al., 1995), based on studying the financial markets as a complex system and utilizing the methods of statistical physics, such as power laws and random walks.

In the 1990s econophysics mostly studied the distribution of financial returns using tools from physics, and since the 2000s, the field started expanding by studying other phenomena occurring in the financial markets as well as in the economy in general. Econophysics also studies extreme events in the financial markets, such as crashes, which were little considered by economists at first, who based most of their results on assumptions that large deviations were not possible, and that the normal distribution would always apply (Perreira et al., 2017).

Bibliometric analysis uses statistical methods to analyze publications and to construct a network of representation of various useful characteristics of said publications, such as citations or keywords. This type of analysis is used to investigate trends of collaboration, emerging concepts as evidenced by most used keywords and the growth of the field by means of citation analysis. Citations and keywords play a large role in finding future directions of research and can also be used in finding the growth of the discipline and researchers specialized in it (Tahamtan & Bornmann, 2019).

There have been some studies on the econophysics collaboration network based on bibliometric analysis (Fan et al. 2004; Li et al. 2007, Sharma and Khurana 2021), mostly analyzing co-citation and co-authorship, as well as the development of citations in the field over the years. These results have shown that researchers from the USA, China, Japan, Italy and Germany to be the countries with researchers that collaborate the most, based on their bibliometric analysis. Other results evidenced some contributors belonging in these teams to be H.E. Stanley from USA, Wei-Xing Zhou from China (Jiang et al. 2010), H. Takayasu from Japan, R. N. Mantegna from Italy (Song et al., 2011) and D. Sornette from Switzerland (Jiang et al. 2010), among others.

3. Research methodology

In order to study the biggest trends in the field of econophysics, as well as studying which authors and countries have the most impact in this field, a bibliometric analysis was considered appropriate. The free software VOSviewer was used in order to identify the relationships between keywords used in econophysics articles, or between authors and their citations and the collaborations between different authors from different countries.

At first, we searched on the Web of Science – Clarivate Analytics data base on the topic of “econophysics”, in the years 1996-2020, and only articles as a document type were selected. The database evidenced a number of 1364 papers, and the list was saved as a .txt file, and a thesaurus file was provided to merge almost identical terms. Afterwards, this file was processed through the VOSviewer software, providing an analysis of keywords and citations based on individual authors and countries.

4. Findings

In figure 1 we present how the number of papers varies yearly in the studied period. It can be noticed that five years after the first mentions of the concept there has appeared a pronounced growth in the number of papers, and from the year 2004 the interest of the authors remained almost constant with a maximum of 80 articles in the years 2008, 2009 and 2016. In the last four years there has been a slightly smaller amount of articles, following the maximum in 2016.

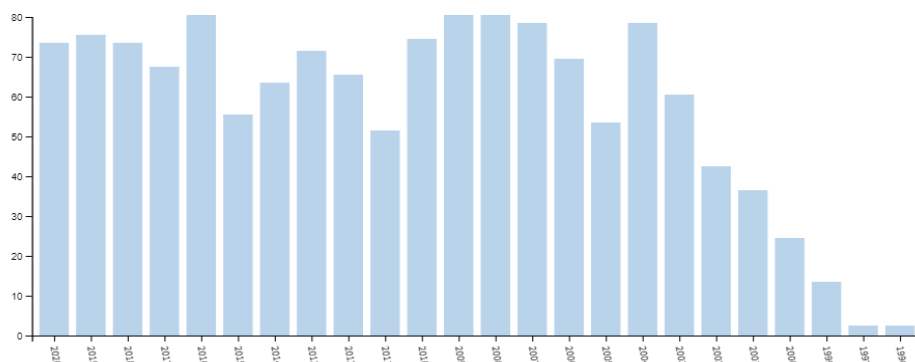


Figure 1: Number of papers published yearly
Source: Generated by the Web of Science analysis report

4.1. Analysis by keywords

In this section, the analysis by keywords is made, presenting how the most frequent keywords appear together in the articles studied. The VOSviewer software evidenced 3543 keywords. Some of them were very similar, therefore a thesaurus was used in the analysis, replacing keywords such as “stock-market” and “stock-markets” by “stock market”. This gave a total of 3530 keywords, and by setting the minimum rate of occurrence at 20, the software found 58 keywords.

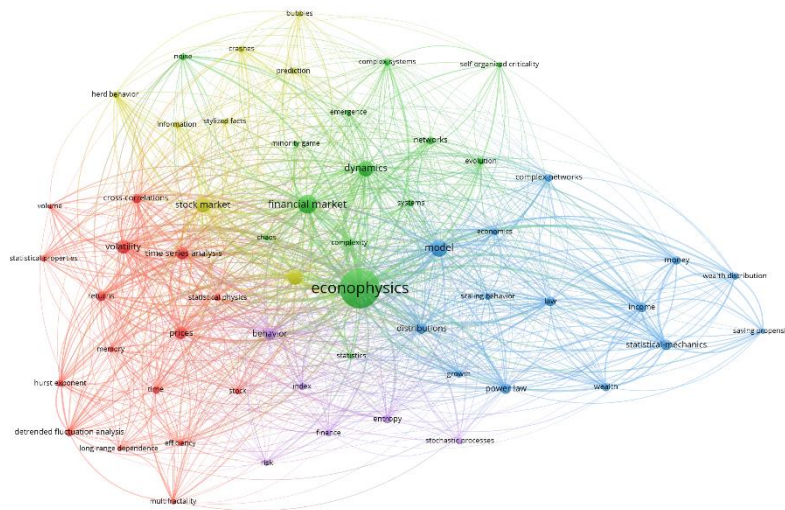


Figure 2: Keywords visualized
 Source: Computed in VOSviewer by the author

Their relationship is evidenced in Figure 2. The figure created in VOSviewer has the following structure: larger dots represent keywords mentioned more often, thicker lines represent how often the keywords are found together, and the distance between dots represents the strength of the relationship between keywords. The colors represent the clusters identified in the analysis by VOSviewer.

In our data, by choosing a minimum rate of 20 occurrences of keywords, and keeping the default resolution of 1.00, five clusters were found. These clusters are detailed in the following table, and also in Figure 1, by the colors red, yellow, green, blue and violet.

The top keywords in the articles analyzed are “econophysics” (with 1095 occurrences), “financial market” (246 occurrences, also considering the alternative forms “financial-markets”, “financial-market”, “financial markets”, “market”, “markets” which we considered to be equivalent to it). Other important keywords by occurrence are “model” (199 occurrences), “dynamics” (168 occurrences), “stock market” (163 occurrences, including “stock-market”, “stock markets”, “stock-markets”), “fluctuations” (160 occurrences). Of interest are also the keywords “volatility” with 137 occurrences, “time series analysis” and its alternate form “time series” with 110 occurrences, “prices” (including “price”) with 106 occurrences and “behavior” with 99 occurrences.

The central cluster, colored green, relates the field of econophysics (present also as a keyword) with the financial market, and its essential idea of studying the dynamics of said market.

Table 1: Keywords clusters

Cluster 1 (red)	Cluster 2 (green)	Cluster 3 (blue)	Cluster 4 (yellow)	Cluster 5 (violet)
volatility	econophysics	model	stock market	behavior
time series analysis	financial market	power law	fluctuations	entropy
prices	dynamics	statistical-mechanics	information	index

returns	networks	distributions	crashes	finance
cross-correlations	evolution	law	herd behavior	stochastic processes
time	systems	income	prediction	risk
detrended fluctuation analysis	complex systems	wealth	bubbles	
hurst exponent	noise	money	stylized facts	
statistical physics	complexity	complex networks		
stock	chaos	economics		
efficiency	minority game	wealth distribution		
memory	emergence	growth		
statistical properties	self-organized criticality	scaling behavior		
volume	statistics	saving propensity		
multifractality				
long-range dependence				

Source: Computed in VOSviewer by the author

The next cluster, colored blue, has its main keyword “model”, and suggests that models, as a keyword, occur together with the concepts of money, wealth and growth, as well as with tools used in creating them, such as “statistical-mechanics”. Another cluster, colored yellow, contains the stock market and its innate characteristics, such as fluctuations or crashes, and it represents some concepts where econophysics can be applied. The following cluster (colored red) is related to the last one, and it contains prices and notions of statistics and statistical physics that relate to the volatility of mentioned prices, being the main keywords in this cluster. The last and smallest cluster, relates behavior with finances and entropy, showing that in research the behavior in finance can be modelled through entropy or as a stochastic process.

4.2. Citations by country analysis

This type of analysis shows the relationships existing between teams of researchers and the networks that made them possible. This is presented in Figure 3, where the circles represent countries, and the different relationships between researchers from these countries, as well as the strength of these collaborations, judged by the parameter of citations. In this analysis we have considered the minimum number of documents to be 5, which is also the default setting, and out of 70 countries, only 42 countries met this threshold, as evidenced by VOSviewer.

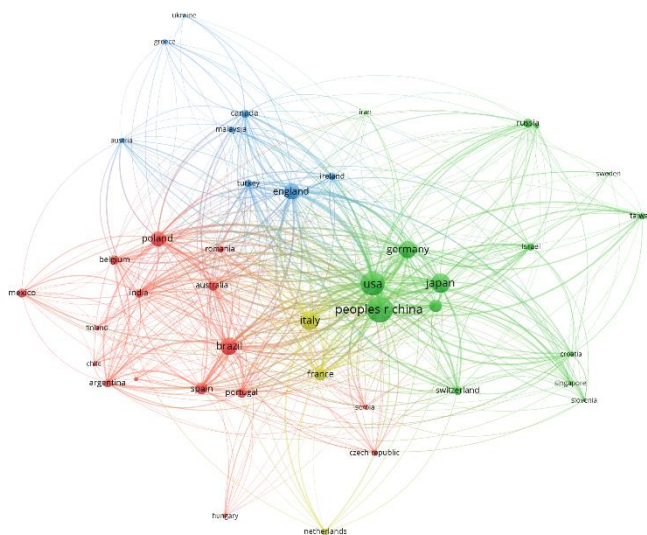


Figure 3. Citations by country visualized
Source: Computed in VOSviewer by the author

It can be observed that the countries with the largest number of documents are People's Republic of China (with 230 documents and 3668 citations) and the United States (with 198 documents and 5778 citations), both belonging to the same cluster and closely connected to each other, showing a close collaboration between researchers from these countries. Other countries with large number of documents and citations evidenced by our analysis are Japan (with 124 documents and 1796 citations), Italy (with 119 documents and 3389 citations), Germany with 105 documents and 2185 citations and Brazil, with 98 documents and 1554 citations.

Most belong to the same cluster, except Italy and Brazil which are part of their own clusters, colored yellow and red respectively. The top countries by documents published also show collaboration between their researchers, as shown in the figure. The countries who published the least documents are Ukraine, Sweden and Slovenia, of which Slovenia has a large number of citations (339) compared to the small number of articles.

The analysis returned four clusters, described in Table 2.

Table 2: Countries by citations clusters

Cluster 1 (red)	Cluster 2 (green)	Cluster 3 (blue)	Cluster 4 (yellow)
Brazil	People's R China	England	Italy
Poland	USA	Canada	France
Spain	Japan	Turkey	Netherlands
Australia	Germany	Ireland	
Portugal	South Korea	Malaysia	
Belgium	Russia	Austria	
Mexico	Switzerland	Greece	
Argentina	Israel	Ukraine	

India	Taiwan		
Romania	Singapore		
Czech Republic	Croatia		
Hungary	Slovakia		
Chile	Iran		
Denmark	Slovenia		
Finland	Sweden		

Source: Computed in VOSviewer by the author

Even delimited in these clusters, most countries are quite close to each other, despite belonging to different clusters. Thus, we have the main cluster (green) with the top contributing countries, closely connected with the yellow cluster that contains the European countries of France, Italy and Netherlands. The other clusters include Mediterranean countries, and countries from the developing world such as Brazil, and the cluster centered on England, containing also Turkey and Canada.

4.3. Citations by authors analysis

This analysis presents the most cited authors on the topic of econophysics, that are indexed in the Web of Science database. Using the threshold settings of minimum 5 documents per author (which were default) and at least 100 citations, VOSviewer evidenced a number of 47 authors that met these conditions, presented in Figure 3. From the analysis it resulted that the most cited authors are Stanley, H. Eugene, with 1996 citations and 27 documents, Zhou, Wei-Xing, with 1833 citations and 59 documents. Other authors who have been positioned at the top, judging by the analysis are Sornette Didier, with 861 citations and 20 documents, Preis Tobias, with 727 citations and 6 documents, and Podobnik Boris with 706 citations and 5 documents.

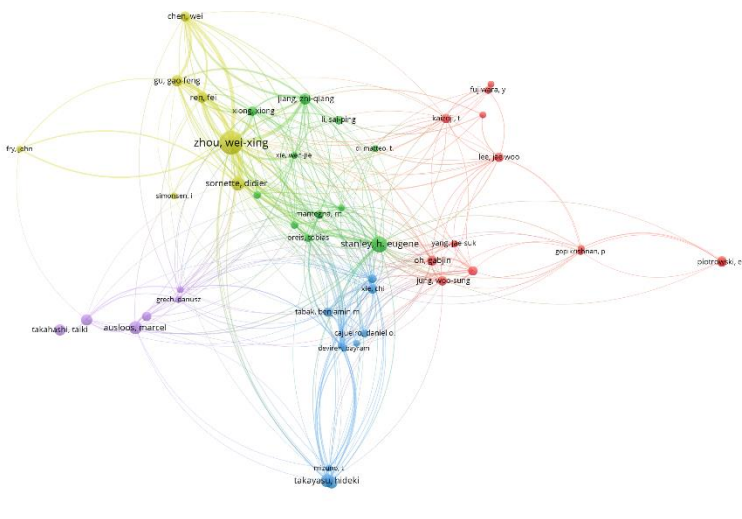


Figure 4. Citations by authors visualized
 Source: Computed in VOSviewer by the author

From Figure 4, we observe there is a strong relationship between Zhou Wei-Xing and Sornette Didier, belonging to the same cluster and having both large numbers of citations,

and in the center there is Stanley H. Eugene, as the larger dot in his corresponding cluster. The other 3 clusters are more dispersed, having a couple of outliers, with fewer connections to others, such as Piotrowski. In Table 3 the top authors by citations are presented, as well as the number of documents published, total number of citations, and the average number of citations. It can be seen that Preis, Podobnik and Fry all have a large number of citations compared to the smaller number of documents, namely five or six, while Zhou has a large number of documents with the smallest average number of citations from this selected group.

Table 3: Top authors by citations

Author	Documents	Citations	Average citations
Stanley, H. Eugene	27	1996	73.92
Zhou, Wei-Xing	59	1833	31.06
Sornette, Didier	20	861	43.05
Preis, Tobias	6	727	121.16
Podobnik, Boris	5	706	141.20
Jiang, Zhi-Qiang	14	540	38.57
Mantegna, Rosario	8	508	63.50
Fry, John	5	488	97.60
Lillo, Fabrizio	6	459	76.50
Fagiolo, Giorgio	5	453	90.60

VOSviewer categorized the size of the dots based on the number of documents published, therefore the largest ones in Figure 3 are not necessarily the authors with most citations, from Table 3. We observe that the authors Ausloos and Takayasu have corresponding larger dots, without having as many citations, also evidenced by not being in the center of the network produced in the software.

5. Conclusions

In this paper the objective was to identify the relationships between the most used keywords in the Web of Science database, on the topic of econophysics, as well as to establish a network of citations by authors and by countries. The results show that the most used keywords are "econophysics", "financial markets", "model", "dynamics" and "stock market", underlining the major applications of econophysics in studying the financial market and its dynamics by using models derived from physics.

The analysis by citations has shown the existence of a tight network between researchers from different countries, with most citations coming from China, USA, Japan, Italy, Germany, countries that are also close in the network analysis provided by VOSviewer. The same analysis when applied to authors revealed the top contributors in the field, with similar results to other recent studies (Sharma & Khurana, 2021), namely the inventor of the term econophysics, H.E. Stanley, and other important authors such as Zhou, Sornette or Mantegna.

The paper can provide a reference for researchers and prospecting authors that wish to publish in the field of econophysics, and for the general audience to understand key concepts regarding econophysics, as shown by the keywords analysis. Being a bibliometric

study on an interdisciplinary field, it can prove useful to both economists as well as physicists interested in applications of their concepts in economy.

The limitations of the paper are that only one database was used in the analysis, namely Web of Science, and that our analysis was based only on keywords and citations. The study can be extended to other databases, or to include co-authorship, by authors and organizations, and also citations by organizations, in order to identify the most relevant ones for the development of the field.

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