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Mapping the oil price-stock market nexus researches: A scientometric review

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ABSTRACT

The interaction between oil and stock markets has become one of the most critical financial academic areas. Thus, this study applied a scientometric analysis of 1342 academic publications in this area so as to present intellectual map about its evolution. The results revealed that this area experienced two development phases with 2007 as the boundary meanwhile many subdivisions and high-yield scholars have emerged. Additionally, through the co-citation analysis, we effectively clustered popular topics and assisted establishing guidance to future research directions. This study therefore provides an extensive understanding of the research status and trends of oil price-stock market nexus.

1. Introduction

Oil is the blood of a modern industry and has a close relationship with macroeconomy. For instance oil resource has obvious characteristics of non-renewability and imbalance of distribution around the world, its price will not only be affected by basic supply and demand but also sensitive to geopolitics, military or other external shocks. Especially since the 1970s, as the crude oil futures and other petroleum derivatives evolve, crude oil began to have the financial attributes, which also further intensified the volatility of oil price (Alquist & Gervais, 2013; Ma, Ji, & Pan, 2019; Zhang et al., 2015; Zhang & Wang, 2015). Thus, the link between the oil price and other financial markets has been gradually strengthening, and two-way effects between them have been detected by investors and researchers. The stock market is an important projection of the economic development of a country or region. As a part of the financial market, its volatility exhibits characteristics similar to oil price, influenced by many external factors and always be intense (Batten, Ciner, & Lucey, 2017; Ji, Liu, Zhao, & Fan, 2018). Therefore, it is meaningful to study the linkages between oil price and stock market, which can help us to further understand the characteristics of stock market volatility and hedge price risk (Białkowski & Ronn, 2019; Lin & Chen, 2019; Ma, Zhang, Wahab, & Lai, 2019). Hence, the oil price-stock market nexus has always been highly valued by economists, and the number of related works of literature is growing rapidly.

Against this background, this area has received extensive attention and has produced a wealth of existing achievements. With the continuous deepening of relevant researches, various subdivisions have been presented, including the spillover effect of oil price and stock market (Du & He, 2015; Ji, Liu, Zhao, & Fan, 2018; Wen, Wang, Ma, & Wang, 2019); the linkages between oil price and stocks from the industry level or national level (Badeeb & Lean, 2018; Pal & Mitra, 2019); the structural oil shocks affect stock markets (Apergis & Miller, 2009; Bastianin, 2016; Kang, Ratti, & Yoon, 2015) and etc. Meanwhile, there are also few investigators who have summarized the existing studies to clarify the progress in this domain and the research trends into the future. For instance, Degiannakis and Arora

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(2018) reviews research on the oil price and stock market relationship and find that most of them study the impacts of oil price on stock markets while little focused on the reverse direction. Liu, Ding, Lv, Wu, and Qiang (2019) also concentrated on this issue, after a detailed review of the literature in this area, they proposed some future research directions, such as the application of behavioral finance theory and implied volatility index. However, these reviews only applied qualitative and descriptive statistical analysis, which cannot effectively grasp the overall structure of an intellectual landscape and easily overlook the intrinsic link between some key literature.

Scientometric study is a useful way to find an internal connection between the literature from the level of the author, journal, reference and etc. It is always based on the knowledge domain visualization, and effectively realizes the mapping, mining, analyzing, sorting and displaying the macro structure of a knowledge domain. In recent years, this method has drawn a great deal of attention in different research fields, such as social commerce investigation (Cui, Mou, & Liu, 2018); ecological models in the field of water eutrophication (Hu et al., 2019); identifying emerging trends of CCS technology (Qiu & Liu, 2018) and showing the intellectual landscape of industrial biowastes treatment using membrane bioreactors (Zandi et al., 2019). These papers demonstrate the advantages of scientometric method in the field of detecting the emerging topics and finding vital trends and pivotal points in a knowledge structure. Compared with the traditional qualitative method, this visualized way can provide more detailed and rational analysis results, as well as reducing users' cognitive burden. Some recent examples for related areas also reverifed the worth to visulaze literatures. For instance, (Corbet et al., 2019)clear the broad field of research on the financial economics of precious metals and thus obtained some details about this field. That is, this fractured research area still needs to better ballance the split between the industrial/ecological area and the financial economics area. (Ozdagoglu et al., 2020) applied similar scientimetric way to shed light on the holistic view of blockchain literature, which provided a effective support for related researchers and practitioners. Therefore, scientimetric mapping method is indeed fitting for exploring academic development, hot contents and cutting-edge issues in a certain field.Despite the popularity of scientometric methods, to our knowledge, few published studies have employed it to analyze the rapidly expanding literature in the area of oil price-stock market nexus, and even no attempt has been made to visualize its knowledge structure and detect the research frontiers. Because of this, we want to fill in this gap. The main objectives of this study are classified into four points: (1) to summarize the literature and identify the overall research status from the perspective of duration, country, authors and keywords in the field of the links between oil price and stock market; (2) based on the visualization of literature in research topic, to understand the characteristics of research collaboration; (3) to present integrated knowledge gaps about the documents co-citation, author co-citation and keyword co-occurrence so that detect emerging topics for this domain.

The remainder of this paper is organized as follows; Section 2 "Methodology and data" describes the tools we applied, research process and data collection. section 3 "Results" makes a comprehensive introduction for the literature in the field and presents our main analysis based on visualization, including the analysis of countries' network, authors network, published journals, high-frequency keywords, co-citation clusters (e.g. references, authors and journals) and frontiers analysis. Finally, section 4 which is "Summary and Discussion", contains a comprehensive summary of the key results from scientometric analysis thus made some corresponding discussion.

2. Methodology and data

2.1. Methodology

To examine the basic research outputs, hot topics and frontiers for a research area, the detailed records and citation links of academic articles should be collected and analyzed under a scientometric framework. The scientometric method is one of the most popular methods to get an in-depth understanding of the structure of a research area, which can examine the research development and performance of journals, academics, authors, countries in an identified research field (Hood & Wilson, 2001; Konur, 2011). In addition, with the function of building diagrams and maps, scientometric method can visualize the clusters, research trending topics to bring an intuitive structure display to the research field (Paltrinieri, Hassan, Bahoo, & Khan, 2019). This method is a fully quantitative approach to summarize the circumstances and citations at subjects, journals and authors, the main indicators are related to research impact, such as total citations, number of achievements, citations per paper and etc. In this study, several scientometric techniques are adopted, (1) Countries analysis: This includes the published situation of different countries in the research field and co-occurrences of countries; (2) Authors analysis: This shows contributions of different authors and maps their collaboration history; (3) Keywords analysis: From this way, occurring keywords will be identified, and which represent the main focus for this domain; (4) Co-citation analysis: This analysis is the integration of multiple contents, including co-cited authors, co-cited journals and co-cited documents (references), through this means, it is possible to fully clarify the mutual citations and identify key results; (5) Cluster analysis: This analysis needs to be based on the results of the previous technique, from the theme linkages and cited situation, it constructs the clusters to illustrate the hot topics of this area. Meanwhile, by narrowing the time interval, we can further analyze the recent frontier issues in this field.

2.2. Software tool

In this study, the CiteSpace (version 5.3.R4) was used as the main scientometric software tool to capture the basic situation and hotspot frontier in the research field. This software is a kind of visualization tool for scientometric study, created by Chen (2006), which is available for all the scientometric techniques we mentioned above. Specifically, CiteSpace can be used to vasulize intellectual basis, landmarks, hotspots, emerging trends, and pivotal points of various papers in a research field by quantitative analysis the citations of the articles. Gephi is another popular software for vasulizing the results of scientometric analysis(Corbet et al., 2019; Ozdagoglu, Damar, & Ozdagoglu, 2020). For example, Andreas and Georgios (2018) explored publication patterns for Journal of Corporate Finance. However,

itself does not have the function of analyzing literature relationships and can only vasulize the social network. Compared with it, in addition to visualizing the social network relationships of the literature, the clustering function of Citespace can further gather recent research frontiers so that make an in-depth exploration of the knowledge structure of the field. Thus, this software is more available for multiple visualization graph options, using these different graph options, the emergence time of research hotspots and the closeness of cooperation between authors can be well discovered. Each automatically generated nodes or links in graphs always show different colors and sizes, such can effectively demonstrate differences in time, influence and published time of the articles. It should be noted that Histcite is also utilized in this study to summarized published years and countries, from which some precise statistic information about research achievements in this domain was obtained.

2.3. Data

There are two main steps in collecting data for CiteSpace. At first, a reputable and comprehensive bibliographic database should be selected to give wide-ranging access to journal articles. There are several primary databases that can be adopted in the process of scientometric analysis, like Scopus, ISI Web of Science (WoS) and Google Scholar. (Olawumi and Chan, 2018)have provided a comparative assessment of these databases, pointing out that WoS covers various core journals' publishing houses and most relevant journals in its record. In this background, we selected WoS as the data source. The second step is to use appropriate keywords to select suitable articles from database. According to our target research field, the data were searched by using the search string- "oil price or petroleum price and stock market or stock or stock price or stock return" and in order to study the time period as long as possible, we

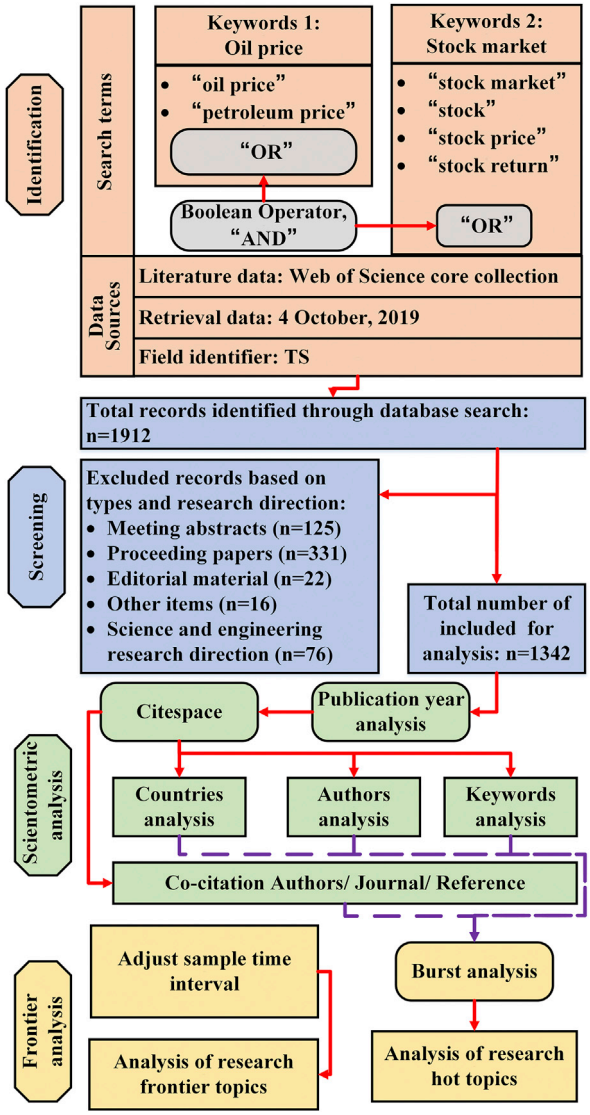

Fig. 1. Framework of this study.

didn't control time-span ranges of dataset (The whole available duration for WoS is about 40 years, 1980–2019). The total number of article records obtained through database search process is 1912, but it should be underlined that limited search string might lead some "noise". To overcome this weakness, we further filtered out some records in dataset based on types and research direction, and the final records for our dataset was reduced to 1342. The complete research framework utilized in this study is represented in Fig. 1.

3. Results

The total number of 1342 English bibliographic records was obtained using search WoS database, which is adopted as the main data source to detect the specific circumstances in the field. According to the research design of Fig. 1, descriptive analysis for their publication year is first performed and then employed in the program of CiteSpace to enhance the encyclopaedical understanding of the area about oil price-stock market nexus.

3.1. Time distribution of research outputs

By employing the Histecite software, we can gain a detailed statistical result about the time distribution of research outputs in the specific field. The progression of papers published related to oil prices and the stock market from 1980 to 2019 has been shown in Fig. 2. As can be observed from this figure that the first paper in this area was published in 1985 and then there is an overall clear upward trend for the number of articles over time, which illustrated that scientific attention in oil price and stock market has been growing. Further, according to the curve in this figure, two main stages can be distinguished:

(1) *Budding phase (1985–2007)*: At this stage, there are still a small number of annual publications in the whole field, remaining below 25, and even in some years (like 1987 and 1989), 0 publications were recorded. This shows that this period did not receive sufficient attention from the academic community. Meanwhile, from Fig. 2, it can also be found that this stage presents a relatively stable development trend, indicating that breakthrough literature have not yet appeared, and most articles only performed shallow analysis for oil price-stock market nexus.
(2) *Development phase (2007–2019)*: By this stage, many foundational theories and research methods on links between oil prices and the stock market had been put forward. As a result, the literature in this area has risen rapidly, especially since 2011, the annual volume of this field has shown a trend of spurt growth. In the past two years, the number of annual publications has reached more than 200, which reveals that this domain has gradually gained more and more academic attention. Since our data interval is only up to the retrieval day, the full publication volume of 2019 should be larger than the current one. According to this situation, we conclude that the growth of publications will continue and this field will become a more mature research hotspot.

Combining the actual situation of the international crude oil market and the stock market, we can further speculate on the possible reasons for the formation of the boundary in 2007. First, in that year, the US subprime mortgage crisis and the subsequent international financial crisis occurred, which made the macroeconomy and stock market more complex and unstable. Therefore, the related fields received more extensive attention, and the actual economic situation could broaden the research ideas for scholars, which eventually caused increased the number of academic publications. Second, the oil prices in 2007 were also more volatile than before (Lin & Xu, 2019), which was not only caused by financial crisis, but also influenced by several historical events for oil market, such as the US winter blizzard, the political and military conflicts in Nigeria and etc. The surge in oil prices away from the basic supply and demand had led scholars to realize that financial properties of crude oil were strengthening, thus it became more and more popular to in-depth explore the oil price-stock market nexus from a financial perspective.

3.2. Contributions among the countries

With the collated data and CiteSpace software, papers published in this field can be classified and summarized by country (region), as shown in Fig. 3. In accordance with the outcomes gained from WoS, all top 30 countries published more than 20 papers in the area of oil price-stock market nexus. And among these countries, China conducts the highest contribution in terms of the number of published

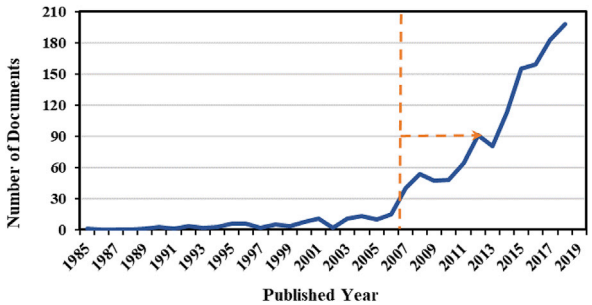

Fig. 2. Time distribution analysis.

articles, accompanied by 302 papers and 22.50%. USA with 263 articles and 19.60% emerge the second most remarkable performance in this field. It is easily observed from Fig. 3 that China and the United States are at the first echelon of scientific research in this area, followed by UK, France, and Australia with more than 100 papers. In addition, other countries have also produced a few amounts of papers in this field, but which are all bellow 100.

In order to obtain a more comprehensive analysis of countries (regions) distribution and cooperation in this field, we further constructed a "National Cooperation Network Knowledge Map" as shown in Fig. 4. In the figure, each circular node represents a country or region, each connecting line represents a cooperative relationship, and countries with more than 40 publications show their names. The above-detailed information is also demonstrated in Table 1, but it only covered the ten countries (regions) with the highest centrality.

Both the above figure and table illustrated that China and USA made the major portion of contributions, but from the perspective of citations, the latter is obviously more influential. Meanwhile, centrality is a metric of a node, also representing the cooperative influence of a node in the specific domain. As shown in Table 1, USA severed the largest centrality (0.25) while China is a long way behind (only 0.12). these suggest that even though there exists a large number of works in the area of oil price-stock market nexus, China should further pay more attention to the quality of papers to improve their international academic influence and strengthen cooperation with other countries. In addition, also from Table 1, we find that European countries play a crucial role in this area too, they have not only done some pioneering work (e.g. British entered the field in 1991), but also gained big average citations and have promoted international cooperation around this field.

3.3. Contributions and cooperation among authors

Table 2 lists the top 10 most productive authors in this field, thus from which, American professor Hammoudeh S achieved the highest contributions with 38 works. However, from another point, Nguyen DK (24 articles) though published less papers than Hammoudeh S, obtains a higher TLCS (517), which interprets that Nguyen DK is the most influential author in the area of oil price-stock market nexus. Similarly, Narayan PK published 19 documents, ranking third, but has a 325 TLCS, also reflecting a huge influence of his works. Further, knowledge of the existing collaborations in a research area can enhance the approach to promote productivity (Hosseini et al., 2018), therefore, we draw an author collaboration network (as shown in Fig. 5) by CiteSpace to in-depth detect their partnerships. According to Fig. 5, the network contains nodes and links, which stand for authors and the patterns of cooperation among them, respectively. Specifically, the size of nodes and links demonstrates the basic situations for the number of publications of authors and strength of partnerships between them. That is, the more articles, the bigger the author's node and the closer the cooperation, the thicker the links. Note that only the names of authors with more than 10 publications are shown in Fig. 5, but from which the main partnerships in this field can still be discovered. For instance, the node of Hammoudeh S is located in the center of figure that reflects his key role in collaborative activities with others, and the node of Narayan PK in the lower-left corner of the image tells that he has no partnership with most authors in this field, similarly with Zhang DY, Zhang YJ, Sadorskey P and Ratti RA.

3.4. Major oil price-stock market nexus research areas

Most contents for research articles can be reflected in their keywords, in other words, the keywords are always consistent with the research theme of the articles (Su & Lee, 2010; Van and Waltman, 2014). Thus, frequency analysis of keywords can effectively extract research domains for a given subject. CiteSpace provides an efficient co-occurrence analysis for keywords in various documents, with which the primary topics of oil-stock nexus can be identified. Based on this approach, we try to combine multiple research keywords to create a detailed exploration of the major oil price-stock market nexus research areas.

Fig. 6 reveals the network of keyword co-occurrence including 642 nodes that highlights the keywords occurring more than 60 times, the size of keywords and their cross are proportional to their frequency of occurrence. From this figure, the keywords "stock market" and "oil price" have the highest frequency (366 times and 325 times), which together refer to the core research content of oil price-stock

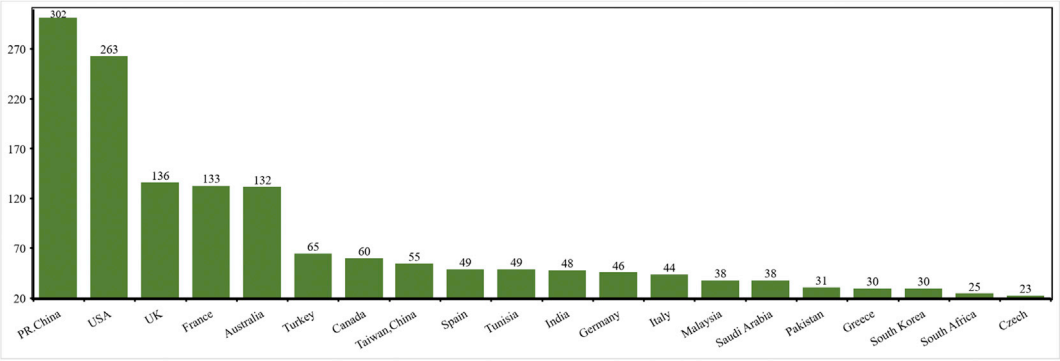

Fig. 3. Paper contributions among the countries.

Fig. 4. National cooperation network knowledge map.

Table 1
Top 10 countries based on centrality.

Country	Centrality	Counts	Number of Citations	Average citations	Earliest published year
USA	0.25	263	7342	28	1985
UK	0.23	136	2497	18	1991
FRANCE	0.2	133	2458	18	2001
AUSTRALIA	0.19	132	2710	21	2004
PRC	0.12	302	4177	14	2004
GERMANY	0.11	46	580	13	2005
MALAYSIA	0.09	38	334	9	2009
SPAIN	0.09	49	1025	21	2009
HUNGARY	0.08	11	51	5	2010
ITALY	0.07	44	860	20	2005

Table 2
Author contributions in the area of oil price-stock market nexus.

Author	Country	Counts	TLCS
Hammoudeh S	USA	38	319
Nguyen DK	France	24	517
Narayan PK	Australia	19	325
Wang YD	PR China	19	210
An HZ	PR China	18	53
Gupta R	Canada	18	129
Shahbaz M	Pakistan	18	61
Mensi W	Oman	17	144
Bouri E	Lebanon	16	146
Shahzad SJH	France	16	66
Tiwari AK	India	16	47

Note: Total local citation scores (TLCS): the number of times an article has been cited by the other articles in the specific document records. In this paper, this indicator reflects the cited times of one paper by other literatures in oil price-stock market nexus literature.

market nexus. Apart from them, “volatility”, “return” and “shock” attract high attention in this area, with 290, 281 and 227 times respectively. These keywords outline the basic research domains in the area of oil price-stock market nexus. “volatility” and “return” indicate the volatile relations and financial returns relations are the most two important links for oil price-stock market nexus, while “shock” reflects the impact of financial shocks from the supply or demand changes of oil or from other markets, which is crucial influencing factor to detect the relationships between oil and stock. To better reveal the main contents of the area about oil price-stock market nexus, the twenty keywords showed the highest frequency are summarized in Table 3. It should be noted that the column “Year” shows the time when the keyword first appeared in the selected documents of this study, and it can declare the evolution of the main contents in this research area. Combine with this column, around 2008, many new keywords appeared, such as exchange rate, United States (US), financial markets and etc. The reason for this phenomenon may be due to the important influence of the global financial crisis, in other words, the real financial situation has broadened the research ideas. This finding furtherly proved the previous conclusion about the time distribution of the outputs in this field.

Fig. 5. Author collaboration network.

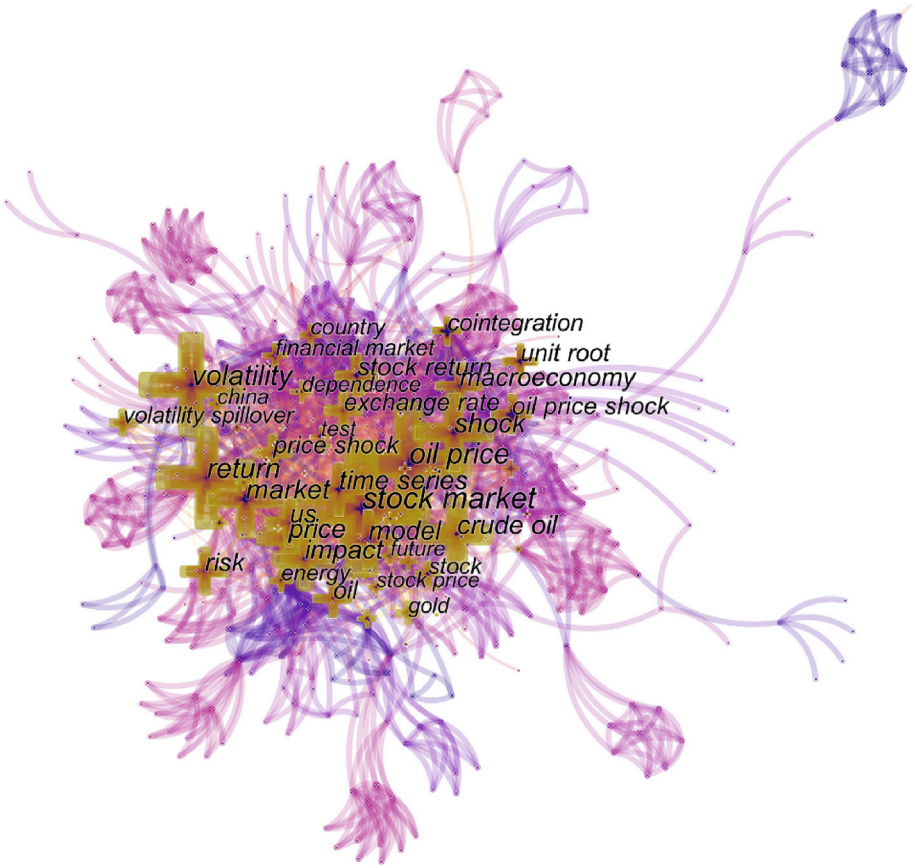

Fig. 6. Keywords co-occurring networks for oil price-stock market nexus.

3.5. Analysis of co-citation and research hot topics

In this part, we applied the co-citation analysis as the main scientometric technique to detect the research hot topics in the field of oil price-stock market nexus. More specifically, there are three kinds of Co-citation analysis that are co-cited authors, co-cited journals and co-cited documents (Zandi et al., 2019). Based on these analyses, the co-citation relationships between the literature can be obtained from the perspectives of authors, journals, and articles, further after employing the clustering method on these results, the research hotspots are obtained from these different perspectives.

Table 3
The twenty highest frequency keywords.

Year	Count	Keywords
1993	366	stock market
1985	325	oil price
2001	290	Volatility
2002	281	Return
2001	227	Shock
2002	184	model
2001	173	time series
2002	171	impact
2008	150	US
2005	148	Risk
2001	144	macroeconomy
2001	115	unit root
2008	114	exchange rate
2001	94	cointegration
2002	84	Stock
2008	83	financial market
2001	82	Energy
2013	78	volatility spillover
2008	76	country
2002	69	dependence

3.5.1. *Cited authors*

Fig. 7 indicates the authors with a higher number of citations for publications on the oil price-stock market nexus and the clusters based on the main keywords in their literature. In this figure, the larger the author's name, the more articles he writes are cited, and thus he deserves more recognition in this area. According to the results, Sadorskey P is the most influential author in this area, followed by Hamilton JD and Kilian L, it reflects their outstanding contributions for investigating the oil price-stock market nexus. What's more, authors are be categorized in clusters to reflect their main research focus. The Log-Likelihood ratio (LLR) algorithm is a useful way to generate clusters with high intra-class similarity and low inter-class similarity, thus the process of clustering is completed by this algorithm (Olawumi & Chan, 2018). From Fig. 7, there are 15 main clusters from the perspective of authors focus, which can construct an impression about this area. For instance, "long memory" is the cluster #0 and located in the center of this figure, it does not only reflects the most authors' attention was paid on this domain but also demonstrates the influential status of this cluster that other clusters almost gradually form based on the achievements of this cluster. Combining the clusters and author's name we can find the authors with greater influence are more likely to develop new research concerns, such as Reboredo JC in cluster #30, attracting scholars to study the oil

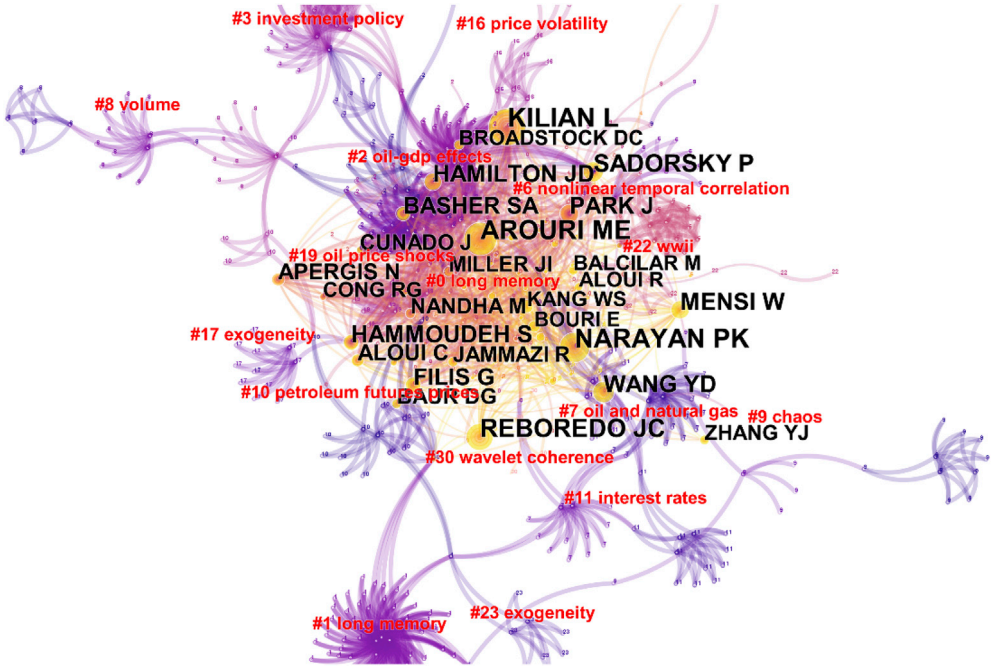

Fig. 7. Cited authors network and clusters.

price-stock market nexus with wavelet coherence.

3.5.2. Cited journal

When analyzing "cited journal" in the area of oil price-stock market nexus, citation frequency is also used as the main indicator to reveal the most influential journals. The scientometric technique and the process of analysis are similar to the "cited author" previously. Also after an automatic big data calculation, CiteSpace can draw the co-citation status for journals, just as shown in Fig. 8, the size of nodes reflect the citation frequency of journals and only those cited more than 300 times are listed. Table 4 displays the highest cited journals in this area more in detailed. Both from Fig. 7 and Table 4, Energy Economics is the most influential journal in the field of oil price-stock market nexus, with a citation frequency of 965, and Journal of Finance and Journal of Econometrics are the journals that follow Energy Economics based on their citation frequencies. After an analysis of high-impact journals in the field, it can be found that the vast majority of these journals are in economics or finance, and also in terms of segmentation, they mainly include those related to futures finance, econometrics or combined with the energy field. The above situation reveals that the oil price-stock market nexus is a specific academic domain in the field of economics, and it is closely related to futures finance and has high requirements for econometric methods. Furthermore, this domain can also be treated as an interdisciplinary field between energy and finance.

In order to get knowledge of the main focuses of these cited journals, we also utilized the clustering method to classify them on their important keywords appeared in the published literature. Fig. 9 shows the clusters based on the cited journals network, some of which are clusters related to econometric methods, while others are related to research contents. This result illustrates that there are two main directions in the area of oil price-stock market nexus from the perspective of the cited journal that are to update the econometric models to explore the complex relationships between variables and in-depth analyzing the various characteristics of markets or combing with other financial markets. For instance, cluster #5 "random walk" is a typical econometric concept, indicating the irregular fluctuations for returns of financial products, while cluster #8 "financial market integration" is a newly emerging concept in the financial sector in recent years, the definition of this cluster describes the increasingly close relationship between international financial activities.

3.5.3. Cited documents (references)

Through the same procedure, that is the two analyses above, CiteSpace can also provide us the cited situation from the perspective of the documents, and Table 5 shows the ten documents with the highest rate of citation or centrality. Note that centrality presents the mediating role of literature in the development of scientific research, in other words, centrality is the importance of a document in a particular research area.

From the left side of Table 5, The impact of oil price shocks on the US stock market authored by Kilian L in 2009 has the highest rates of citations, which proposed a new perspective to decompose the oil price into demand and supply shocks and gained some expressive results (Kilian & Park, 2009). Followed this document, Oil price shocks and stock markets in the US and 13 European countries worked by Park and Ratti (2008) and Kilian's another article Not all oil price shocks are alike: Disentangling demand and supply shocks in the crude oil market (Kilian, 2009) also gained higher rates of citations.

From the right side of Table 5, further evidence on breaking trend functions in macroeconomic variables is the document with the largest centrality. This paper mainly introduces that most macroeconomic time series are best construed as stationary fluctuations around a deterministic trend function, which is not based on the field of connectedness between oil and stock (Perron, 1997). Thus, the literature with high centrality do not necessarily need to be based on a particular field, but it must play a strong intermediary role in the subsequent development of the field. Another example is, causal relations among stock returns, interest rates, real activity, and inflation has got a centrality about 0.05, the research domain of this paper is only related to stock market, but proposed a new research paradigm using VAR model to analyze the links between different financial markets (Lee, 1992), which inspired the follow-up research in the oil price-stock market nexus area, thus creating an important intermediary impact.

Fig. 10 clusters the cited documents in the area of oil price-stock market nexus and shows the references cited more than 100 times. From this figure, there are 18 visible research hot topics can be summarized from the perspective of reference, further combining with

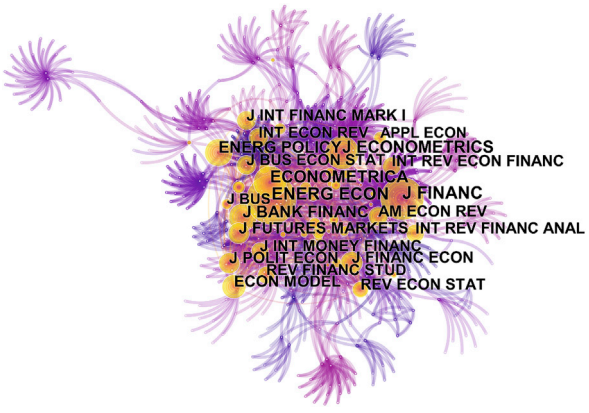

Fig. 8. Cited journals network.

Table 4
The twenty highest frequency cited journals.

Ranking	Citation Counts	Journal
1	965	Energy Economics
2	840	Journal of Finance
3	691	Journal of Econometrics
4	677	Econometrica
5	603	Journal of Banking & Finance
6	566	Energy Policy
7	490	Journal of Financial Economics
8	483	Economic Modelling
9	472	Journal of Futures Markets
10	449	Journal of Political Economy
11	442	American Economic Review
12	430	Journal of Business & Economic Statistics
13	422	International Economic Review
14	415	Journal of International Money and Finance
15	410	Review of Financial Studies
16	397	International Review of Economics & Finance
17	388	Review of Economics and Statistics
18	386	International Review of Financial Analysis
19	384	Journal of International Financial Markets Institutions
20	309	Applied Economics

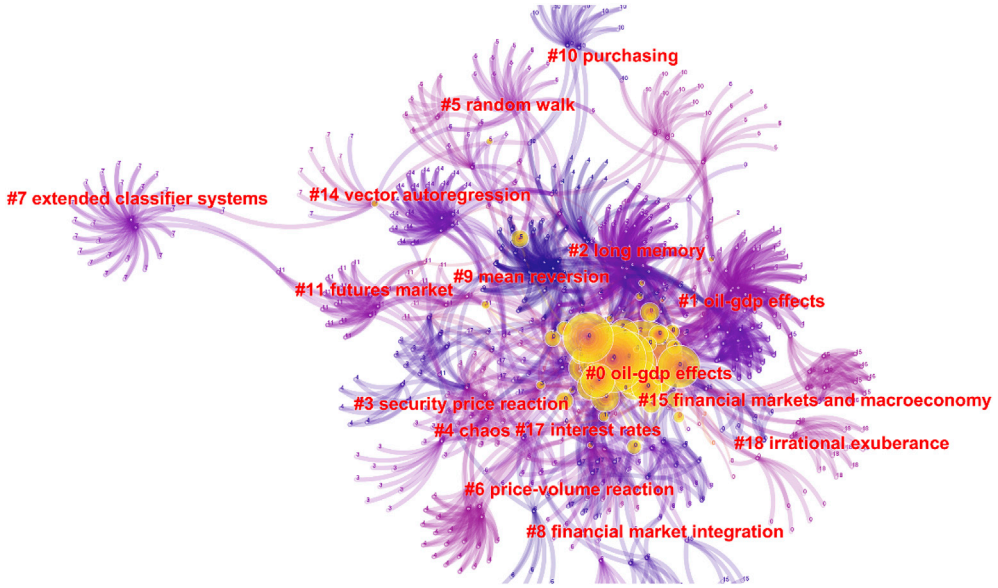

Fig. 9. The clusters based on the cited journals network.

Table 5
The ten documents with the highest rates of citations or centrality.

Citations	Documents	Centrality	Documents
174	Kilian, 2009, INT ECON REV, 50, 1267	0.09	Perron, 1997, J ECONOMETRICS, 80, 355
156	Park & Ratti, 2008, ENERG ECON, 30, 2587	0.08	Aleisa E, 2003, INT REV ECON FINANC, 15, 1
135	Kilian & Park, 2009, AM ECON REV, 99, 1053	0.06	Sadorsky P, 2001, ENERG ECON, 23, 17
112	Apergis & Miller, 2009, ENERG ECON, 31, 569	0.06	Adelman MA, 1993, EC PETROLEUM SUPPLY, 0, 0
101	Filis G, 2011, INT REV FINANC ANAL, 20, 152	0.05	Lee BS, 1992, J FINANC, 47, 1591
97	Miller JI, 2009, ENERG ECON, 31, 559	0.04	Papapetrou E, 2001, ENERG ECON, 23, 511
90	Nandha M, 2008, ENERG ECON, 30, 986	0.04	Hamilton JD, 1994, TIME SERIES ANAL, 0, 0
88	Narayan PK, 2011, J BANK FINANC, 35, 3253	0.04	Baig T, 1999, INT MONET FUND S PAP, 46, 167
87	Cong RG, 2008, ENERG POLICY, 36, 3544	0.03	Nandha M, 2008, ENERG ECON, 30, 986
83	Arouri MEH, 2010, ENERG POLICY, 38, 4528	0.03	Narayan PK, 2011, J BANK FINANC, 35, 3253

the literature in different clusters, these research hotspots can be divided into three domains: (1) basic relationships analysis, It mainly discusses how oil price affects stock market changes and what is the relationship between oil prices and stock markets, Cluster #0, #3, #4, #17 and #19 are included in this domain, mainly related to basic concept and various links in oil price-stock market nexus; (2) Analysis based on updated econometric methods, this domain covers clusters #5, #14, #27, #60 and #70, the relative literature pay a lot of attention on the utilization and evaluation of different models and is committed to proposing more appropriate methods to detect the relations between oil and stock; (3) Expanded analysis combining other financial sectors and market characteristics, remaining clusters can be classified into this domain. It is mainly based on the hotspots (1) and expands those researches by considering the natures of financial markets or combing with other relative fields, for instance, cluster #1 concerns the long memory of stock returns and cluster #10 focus on the analysis of the relations between oil and stock from an in-depth perspective about intraday trading activity.

3.6. Analysis of research frontiers

The above analyses are based on the full available duration for WoS, from 1980 to 2019, covering the all related literature in the field of oil price-stock market nexus, thus the scientometric process can detect the whole situation of this field and summarize the research hot topics from different perspectives with the utilization of cluster analysis. However, the hot topics obtained from this procedure have little capacity to reflect the research trends for an academic area, since they don't consider the timeliness of different literature exerting influence. To overcome this weakness, we further adjust the sample time interval of the document records to analyze the references of literature in the past two years (about 369 records). And for the reason that the clusters from the perspective of cited documents reflect the focuses of different articles, while those from author or journal perspectives involve the preferences and pursuits of authors or journals, we eventually carried out cluster analysis from the literature perspective to obtain the frontiers of this field.

Fig. 11 is a visualization network of the cited-documents analysis, from which there are 9 articles cited more than 30 times in the past two years. These articles with higher rates of citations are mainly published around the year 2012, it demonstrates that most of the current frontier problems in the oil price-stock market nexus field are beginning to occur during this period. Further, applying Log Likelihood Ratio (LLR) as the principle of classification statistics like previous studies (Fang, Yin, & Wu, 2018; Li, Xu, Xie, & Wang, 2018; Si, Shi, Wu, Chen, & Zhao, 2018) and categorizing the literatures based on their references, we obtain the clusters network as shown in Fig. 12.

Fig. 12 reveals the six research trends for the oil price-stock market nexus and their relative importance rank through the LLR test and based on the keywords of literature records, from this figure, some parts between different clusters may overlap. In addition, their detailed information has been listed in Table 6, which benefits from the visualization of the grouping structure. Thus, according to the results shown in the figure and table, Cluster #0 is the largest cluster whereas the minimum cluster is #5, and all clusters have good capability to catch the similarity and homogeneity of literature (Costa, Carvalho, & Moreira, 2019; Tang, Liao, Wan, Herrera-Viedma, & Rosen, 2018; Zhang, Zhong, & Geng, 2019).

Among all clusters, cluster #0 is stock returns that is the most basic variable of this field, representing that exploring the complex relationship between oil and stock is always a frontier and fundamental issue. This speculation can also be supported by its alternative labels include oil prices, oil markets, and so on, they are also the most basic and direct concepts in the field.

Cluster #1 (gold) and its alternative labels mainly concern with the concepts about financial hedging and precious metals. It reflects another frontier of oil price-stock market nexus research, namely how to hedge the risks that oil shocks bring to the stock market, especially safe haven roles or co-movements of precious metals. In this direction, Junttila (2018), Mensi (2018) and Elie (2019) have made some contributions.

Cluster #2 and #4 are similar for their alternative labels, which both cover keywords related to volatility, such as OVX, realized volatility, oil volatility and etc. These two clusters demonstrate that there is an apparent trend in the area of oil price-stock market nexus that considering the volatility of markets and inspecting their co-spillover or co-movements, meanwhile it is found that time-varying methods are the most popular econometric models to solve related problems. However, this frontier still has some intrinsic heterogeneities so that automatically filtered into two clusters, that is, Cluster #2 pays more attention to the integrity of the global oil market while Cluster #4 focuses on changes in volatility itself. In detail, Cluster #2 emphasis on the application of systemic approaches to detect the effect of oil price volatility, for example, Zhang, 2017employed a systemic method to construct a net directional connectedness matrix for oil and stock markets thereby clarifying the relationship between market volatility. On the other hand, Cluster #4 is more willing to proceed from the characteristics of market volatility itself, such as signed jump, time-varying relationship, or volatility forecasting, so it brings more emphasis on using high-frequency data and corresponding models (like HAR-RV models) to capture volatility characteristics in empirical researches. A typical example is the study by Kumar (2017), who examined the realized volatility transmission from crude oil to various equity sectors with the utilization of HAR-DL model, it did not only capture the volatility characteristics of the oil and stock markets but also it supports the structural instability and breaks in the transmission of volatility.

The label of Cluster #3 is green bonds, defined as bonds specifically earmarked to be used for climate and environmental projects (Zerbib, 2019), moreover, clean energy stock price returns and new energy stock are two alternative label keywords that both related to pollution reduction. Therefore, it can be concluded that the literature in cluster #3 is generally combined with the field of environmental finance for research. Also, in accordance with other alternative labels, the studies in this frontier are committed to detecting the price spillovers, co-movements or dependence linkages for oil and stock markets under the framework of environmental finance. Reboredo (2018) made a significant and fundamental contribution to this frontier, where he examined co-movements between the green bond and financial markets and eventually found that the green bond market weakly co-moves with stock and energy commodity markets. Subsequently, based on this study, Reboredo & Ugolini, 2019 examined the price connectedness between the green bonds and financial markets, this empirical research by applying SVAR model also supported that green bonds market is weakly tied to the stock, energy and

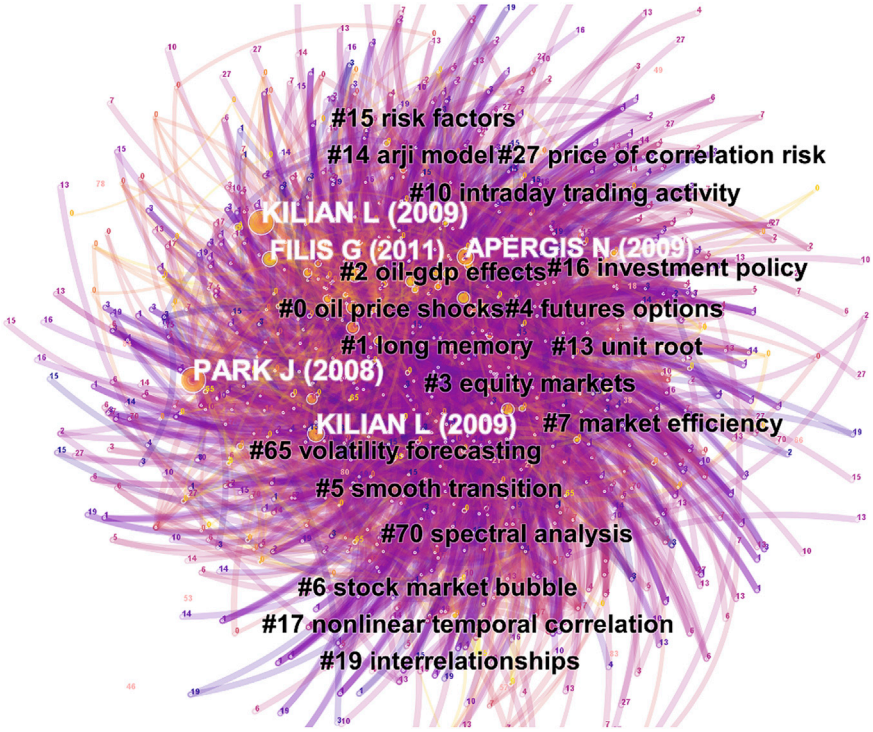

Fig. 10. The clusters based on the cited documents (references).

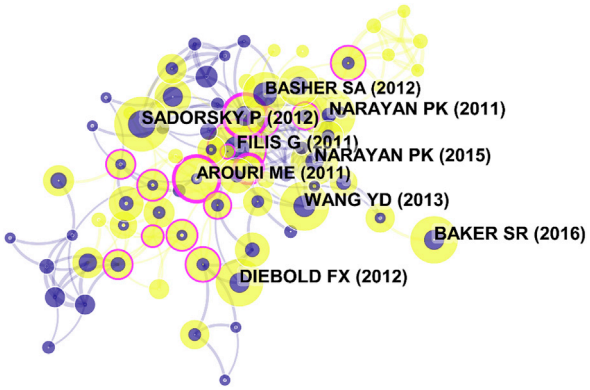

Fig. 11. The cited documents network (after duration adjustment).

high-yield corporate bond markets.

Cluster #5 is the minimal cluster reflecting it is a frontier gained less attention than others. The main label of this cluster is the Chinese stock market, meanwhile, sectoral indices, oil-importing, and oil-exporting countries are its alternative labels, thus this frontier represents a kind of oil price-stock market nexus study that decomposes the stock market from on national or sectoral level to investigate these intrinsic heterogeneities. For a typical instance, Ferreira, Pereira, da Silva, and Pereira (2019) revisited the relationship between oil prices and stock markets after 2008 crisis from the national level, and its obtained detrended correlation coefficients revealed that stock markets are more exposed to oil price fluctuation than before the 2008 crisis.

All in all, these clusters above are research frontiers for the field of oil price-stock market nexus, and also reflects some developing trends to some extent. To better understand the evolution of these frontiers, we draw an evolution view of clusters as shown in Fig. 13. From this figure, cluster #0 and cluster #1 both have the earliest birth time and similar duration of related references, which indicates that they are hot research topics all along and play a huge impact continuously in this field. Meanwhile, many nodes in cluster #2 and cluster 5 show a large size, illustrating that good research accumulation has been formed in these frontiers. In contrast, cluster #3 and cluster #4 only contain few works of literature with high rates of citation, especially for cluster #4, it shows that breakthrough progress has not yet emerged and there are still some apparent knowledge gaps in these frontier areas.

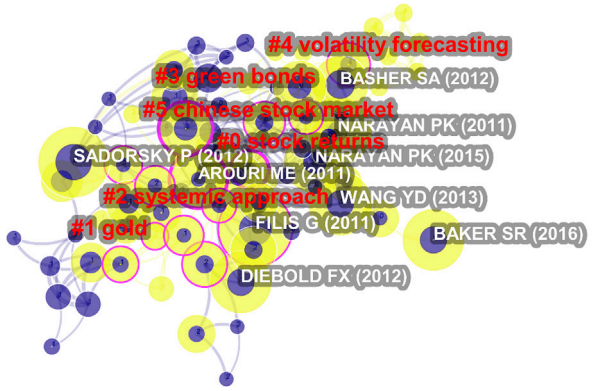

Fig. 12. The clusters based on the cited documents (after duration adjustment).

Table 6
The six frontier hot topics in the oil price-stock market nexus field.

Cluster ID	Label (LLR)	Size	Sihouette	Alternative labels
0	stock returns	21	0.699	oil prices, investor utility, predictor, oil price volatility, oil market, interconnectedness, oil-importers, oil-exporters, economic policy uncertainty
1	gold	21	0.743	safe haven, hedge, co-movements, commodities, precious metals, hedge ratios
2	systemic approach	13	0.806	OVX, implied volatility, Asian premium, VIX, time varying jumps, oil volatility shocks
3	green bonds	10	0.801	price spillovers, co-movements, dependence, clean energy stock price returns, new energy stock
4	volatility forecasting	7	0.957	realized volatility, oil volatility, HAR-RV model, time varying parameter, signed jump
5	Chinese stock market	7	0.743	correlation coefficient, sectoral indices, detrended cross-correlation analysis, oil-importing and oil-exporting countries

Note: silhouette shows the similarity and homogeneity of members in the same cluster, if this value is larger than 0.5, the corresponding cluster has a good characterization effect.

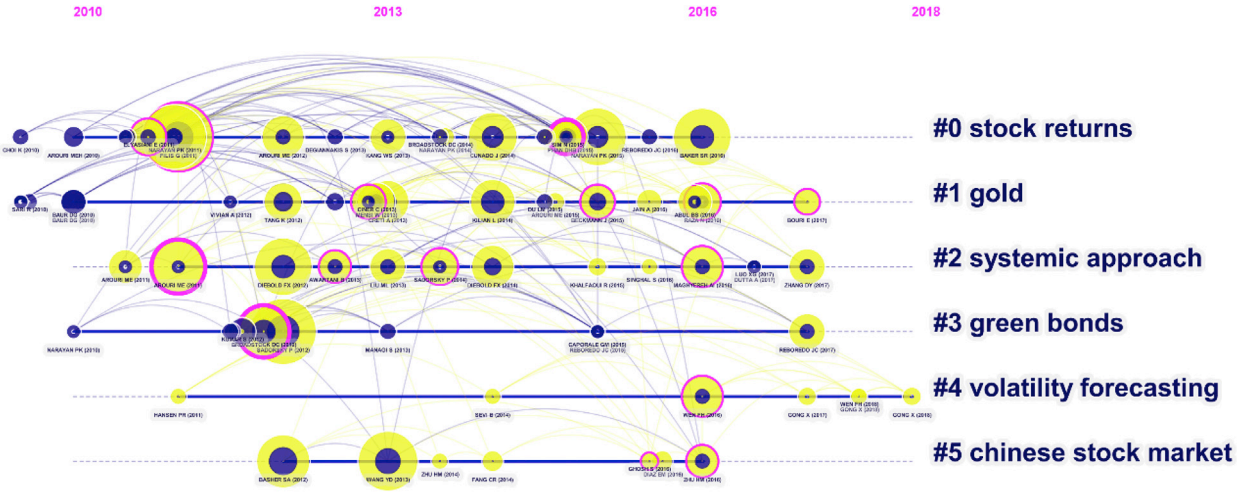

Fig. 13. The evolution view of clusters (after duration adjustment).

4. Discussion

This study aimed to perform a scientometric study on the oil price-stock market nexus with the utilization of CiteSpace and 1342 document records to obtain some knowledge about current status of this field and detect its hot topics and research trends. First, it can be concluded by publication year analysis that the amount of publications within the field is roughly divided into two stages (Budding phase and Development phase) and the boundary between them is the year 2007. Second, based on the national (regional) level analysis

we find that China is the most productive country in this area, while the USA and some European countries complete the pioneering work and have a larger academic research influence (high citation rats and centrality). Third, the most influential authors are almost consistent with the most productive authors, from the publication and citation statistics, Nguyen DK published the second most papers while deserving the highest co-citation rates and maximum influence. Since frequency analysis of keywords can effectively extract research domains for a given subject, we also construct a keyword co-occurrence network, roughly outlining the research domains about oil price-stock market nexus.

Then, with three kinds of co-citation analysis, we detect the hot focuses and their intrinsic relations from the perspective of the author, journal, and documents. Especially from the analysis of co-cited documents, we divide its research hotspots into three segmentation, they are basic relationships analysis, analysis based on updated econometric methods and expanded analysis combining other financial sectors and market characteristics. To clarify the research frontiers and trends, the sample time interval of the document records was shortened to nearly two years and employed into the cited documents analysis, eventually the six frontier hot topics and their specific characteristics were obtained.

Author statement

We declare no interest conflict.

Declaration of competing interest

None.

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