

## Co-Citation Analysis and Burst Detection on Financial Bubbles with Scientometrics Approach

Wei Zhou, Jin Chen & Yang Huang

To cite this article: Wei Zhou, Jin Chen & Yang Huang (2019) Co-Citation Analysis and Burst Detection on Financial Bubbles with Scientometrics Approach, Economic Research-Ekonomika Istraživanja, 32:1, 2310-2328, DOI: [10.1080/1331677X.2019.1645716](https://doi.org/10.1080/1331677X.2019.1645716)

To link to this article: <https://doi.org/10.1080/1331677X.2019.1645716>



© 2019 The Author(s). Published by Informa UK Limited, trading as Taylor & Francis Group



Published online: 14 Aug 2019.



Submit your article to this journal [↗](#)



Article views: 235



View related articles [↗](#)



View Crossmark data [↗](#)

# Co-Citation Analysis and Burst Detection on Financial Bubbles with Scientometrics Approach

Wei Zhou<sup>a</sup> , Jin Chen<sup>b</sup> and Yang Huang<sup>c</sup>

<sup>a</sup>School of Finance, Yunnan University of Finance and Economics, Kunming, PR China; <sup>b</sup>Business School, Yunnan University of Finance and Economics, Kunming, PR China; <sup>c</sup>Faculty of Management and Economics, Dalian University of Technology, Dalian, PR China

## ABSTRACT

It is found that financial crises generally happen accompanied by the collapse of financial bubbles. Therefore, many scholars have carried out researches on financial bubbles. In this paper, we analyse the current status and explore the development of financial bubbles with scientometric technique. By downloading and analysing 1048 articles from Web of Science, the main findings of this paper are: 1) Three hot topics in the financial bubble research are 'Ledoit-Sornette financial bubble model', 'European Union emission trading scheme' and 'agent-based model'; 2) the current research status of financial bubble is clearly demonstrated by the most productive subject categories, countries, institutions, journals, authors, and cited articles; 3) the investigations that related to 'Chinese stock market' contribute significantly in the financial bubble research; and 4) the burst detection analysis shows that the new trends in recent years are 'asset price bubble', 'herd behaviour', 'crashes', and 'econophysics'. Therefore, this paper provides the knowledge domain, the overall intellectual structure, and the emerging trends of the financial bubble research by analysing the status quo, the co-citations, and the burst detection, which presents more accurate and comprehensive insights into research topics and research development trends over time from various perspectives.

## ARTICLE HISTORY

Received 26 September 2018  
Accepted 11 March 2019

## KEYWORDS

Financial bubble; CiteSpace; scientometric; LPPL model; burst detection

## SUBJECT

### CLASSIFICATION CODES

C10; G10; G24

## 1. Introduction

Financial bubbles are common phenomena in financial and economic development. The formation and collapse of financial bubbles not only cause great losses in financial markets but also lead to great harm to the economy of a country. Moreover, the decrease in citizens' real income and the bankrupting of enterprises after the bubble burst both results in sluggish consumer demand, deflation, and even economic recession. There are many typical cases in history, such as the bubble crisis of the South Sea in 1720, the case of a tulip in 1637 and the subprime mortgage crisis in 2007.

**CONTACT** Yang Huang  [hyang0812@dlut.edu.cn](mailto:hyang0812@dlut.edu.cn)

© 2019 The Author(s). Published by Informa UK Limited, trading as Taylor & Francis Group.

This is an Open Access article distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/4.0/>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Today, financial bubbles still exist from all walks of life, such as the real estate bubbles (Lee & Ong, 2005), the Internet bubble in the U.S.A. (Battalio & Schultz, 2006), the oil prices negative bubble (Fantazzini, 2016) and China's iron ore prices bubble (Su, Wang, Chang, & Dumitrescu-Peculea 2017). In this case, many scholars have carried out researches on measuring financial bubbles. Some quantitative approaches such as the dynamic forecasting model based on the assumption of arbitrage equilibrium (Blanchard & Watson, 1982), the Popular model (Shiller, 1990), the rational general equilibrium model (Demarzo, Kaniel, & Kremer, 2008) and the rational expectation model of bubbles (Andersen & Sornette, 2004) have been developed to simulate the formation of financial bubbles. Many methods which combine financial crashes with bubbles are applied to investigate the explosive financial bubbles, such as the self-consistent model (Lin, Ren, & Sornette, 2014), the bistable model of a financial market (Krawiecki & Hołyst, 2003), the recursive right sided unit root approaches (Creti & Joets, 2017) and the multi-period overlapping-generations model (Chen & Wen, 2017). In terms of bubble measurement, the LPPL (Log-periodic Power Law Singularity) model proposed by Sornette, Johansen, and Bouchaud (1996) has been broadly used. Some vital problems have been solved with the LPPL model, such as the critical point in stock market bubbles (Pele & Mazurencu-Marinescu, 2012), the bubble and anti-bubble identification (Zhang, Sornette, & Balcilar, 2016; Zhou, Huang, & Chen, 2018). Due to the growing importance of financial bubbles, it is important to summarise these studies and highlight their development and trend.

The scientometric technique is suitable for doing this and is introduced in this paper. Scientometry is the quantitative analysis of input, output, and process for scientific activities based on mathematical statistics, computing technology, and other mathematical methods. It aims to elucidate the rules of scientific activities. Some significant achievements are obtained by utilising scientometric techniques, such as the exploration in algae and bio-energy (Konur, 2011), the observation in macrology biomass (Coelho, Barbosa, & Souza, 2014), analysis in microbial fuel cells (Mercuri, Kumata, Amaral, & Vitule, 2016) and the non-point source pollution research (Xiang, Wang, & Liu, 2017). These studies can help researchers to focus on the missing information and determine future research directions. In addition, the popular tool in scientometry is CiteSpace, which was developed by Chen (2004) from Drexel University. Compared with other methods, CiteSpace has many obvious advantages. For instance, one of the significant tools in a CiteSpace package assists identifying betweenness centrality between pivotal points in scientific articles, which indicates the significance of the nodes in a network. Also, research front terms can be provided to clarify the core concepts of co-citation clustering, and then a general knowledge domain and its related network can be available. Finally, the time slice is also a useful tool provided by CiteSpace to show a temporal perspective to publications and present citation bursts (Wei, Grubestic, & Bishop, 2015). Due to the reason that CiteSpace enables scholars to analyse specific research field comprehensively through citations, co-citations, and geographical distribution, it has been broadly utilised in recent years, such as in the field of digital preservation (Hee-Jung, 2005), aerospace engineering (Liang, Yang, & Liu, 2008), heat exchanger network synthesis (HENS) methods (Morar & Agachi, 2010), ecological assets (Lin, Wu, & Hong, 2015), and psychological research

(Pan, Zhao, Li, et al., 2017). Therefore, the arrival of CiteSpace has inspired scholars in various fields, telling them that there are still some new fields to be explored. However, there exists a lack of researches on financial bubbles based on scientometric analysis.

Due to the above and the growing number of publications which investigate financial bubbles, it is significant to learn about the current status and the developmental trends in financial bubble researches. The contributions that this paper made are: 1) the *status quo*, the co-citation analyses, and the burst detection are quantitatively analysed to provide scholars with a more comprehensive insight of financial bubble research; and 2) the overall intellectual structure and the emerging trends of financial bubble research are presented visually, which is helpful for scholars, especially for beginners to learn more about this research field.

To achieve the above aims, the remainder of this paper is organised as follows: [Section 2](#) introduces the data collection and research method, in which the source of data, the corresponding operational process, and relevant techniques are discussed. The Publication number, citation, and hot topic analyses are demonstrated in [Section 3](#). [Section 4](#) is about the current research status of financial bubble research based on the statistics of categories, sources, authors, countries, and institutions in the financial bubble field. [Section 5](#) demonstrates the burst detection in financial bubble research, informing the potential research directions. Finally, [Section 6](#) is the summary, which includes general conclusions and the expectations of this paper.

## 2. Data collection and research method

In order to illustrate how the data are analysed by utilising CiteSpace, the process is introduced on the aspects of data collection and research method. We provide an architecture diagram to briefly summarise the whole analytic process. The explanation of some significant terms and indexes with the corresponding algorithms are shown to present how the techniques work on further analyses in the following sections.

### 2.1. Data collection and architecture diagram

In this study, Web of Science (WoS) is our main data source due to the reason that it is a large platform that enables individuals to know the detailed information of the articles published in approximately 12,000 leading journals worldwide. Besides, the Science Citation Index Expanded (SCI-EXPANDED), the Social Science Citation Index (SSCI) and the Arts & Humanities Citation Index (AHCI) databases are included in WoS (Leeuwen, 2006), making the analytic results more accurate and comprehensive. It should be explained that to eliminate the ‘noise’ that could impact the results’ accuracy, the references published in some databases such as Conference Proceedings Citation Index-Science, Emerging Sources Citation Index and Book Citation Index-Science are not in the scope of consideration in this study. Thus, when searching the research topic ‘financial bubble’, a total of 1048 articles can be shown. The relevant data were downloaded from WoS on 26 October 2017. In order

to make the whole procedure more understandable, an architecture diagram is given in [Figure A1](#) to show the details of the data analysis.

## 2.2. Data analysis and research method

Some important terms and indexes in [Figure A1](#) are explained to clarify how the techniques work, which further supports the reasonability of the analytic results.

- Time slice: The method to divide a period of time into a series of smaller windows.
- Threshold: A selection of criteria which selects items in the modelling and visualizing of the process.
- Top N: The top N frequently cited articles are selected
- Top N%: The articles are selected primarily on the basis of citations, then the top N% of them are finally chosen.
- C, CC, CCV: Citation, co-citation, and cosine coefficient.  $CC(i,j)$  is the co-citation number of reference  $i$  and reference  $j$ .  $C(i)$  and  $C(j)$  are their citation number, respectively. Suppose that in a certain time period, the co-citation number of reference  $i$  and reference  $j$  is 2. Reference  $i$  is cited four times, while reference  $j$  is cited three times, then we have  $CCV = 2/\sqrt{4 \times 3} \approx 0.577$ .
- Density: The ratio of the actual relations to the utmost relations in a network.
- Silhouette: The value that measures the quality of a clustering configuration with the range between  $-1$  and  $1$ . A higher silhouette value indicates a more perfect solution. Basically, the clustering results are efficient and reliable when their silhouette values are bigger than  $0.7$ , and the results can be reasonable when their values are bigger than  $0.5$ .

As mentioned before, some information such as the keywords, journals, and reference that appear or co-cited with high frequency can be found by CiteSpace by choosing different node types. An important index which identifies the above nodes is betweenness centrality. The betweenness centrality is defined in [Eq. \(1\)](#).

$$Centrality(\text{node}_i) = \sum_{i \neq j \neq k} \frac{\delta_{ik}(i)}{\delta_{jk}} \quad (1)$$

In [Eq. \(1\)](#),  $\delta_{jk}$  indicates the number of the shortest paths between node  $j$  and node  $k$ . Also,  $\delta_{ik}(i)$  is the number of abovementioned paths which pass through the node  $i$ . For instance, an article with high betweenness centrality is relatively more significant in a co-citing network (Li, Porter, & Wang, 2017). In this paper, different articles and the relevant clusters with significant influence are illustrated based on the value of betweenness centrality. Furthermore, as analysed in the following sections, the timeline of the most cited references, the articles and the keywords that received strong citation burst are also determined according to this crucial index.

### 3. Publication number, citation, and hot topic analyses

#### 3.1. Publication number and citation analyses

The financial bubble stems from Tulipmania in Holland in 1637 (Garber, 1989). However, the tulip bulbs were unusually appealing at that time, triggering a scramble for them. After that, the price of tulip soared rapidly. After the bubble bursts in 1637, the tulip was worth only 1% of the price in a bubble, leaving all major Dutch cities in chaos. Same cases never come to an end, the South Sea Company suffers a financial bubble in 1720 (Carswell & Goodison, 1960) and the world falls into the great depression from 1920 to 1933 (Lucore, 1991). In the late twentieth century, the global economy burst out another financial bubble that consisted of a real estate bubble in Japan (Kim & Suh, 1993). The advent of financial bubbles usually brings serious crises to countries and regions. As a kind of systematic financial risk, it encourages scholars to research on avoiding and dealing with financial bubbles from different industry risks and different levels of regulatory measures.

In order to present the current status and the emerging trends in financial bubble research, the paper sorts out the publications and citations primarily in this field. It can be learned from [Figure A1](#) that the topic of financial bubbles has obtained growing attention. The quantity of publications about financial bubbles is increasing every year. Specifically, the number of the 1048 articles' citations per year from 1994 to 2017 is shown in [Figure A2](#). According to the statistics in [Figure A2](#), the citations of financial bubbles are also increasing every year. In other respects, the 1048 articles are cited 12,499 times apart from the self-citations by October 26 2017, and 13.27 times for an average article. It should be noted that there are two months left in 2017, hence the articles published in these two months cannot be obtained due to retrieval delay. However, the number of articles published in 2017 is predicted to increase because there are about 100 publications each year from 2011 to 2016 in the field of financial bubbles. On the other hand, the growth of publications has slowed down in the past five years because the related research methods are still limited, and many fields have been investigated repeatedly. However, the bursts still exist, which is the new direction of financial bubble researches. More information is given below.

#### 3.2. Hot topic analysis

This subsection illustrates the research focus and hot topic of financial bubbles through cluster analysis. The position of clusters and the association among clusters in co-citation networks displays the intellectual structure in science mapping. It is easy to take a clear view of the whole picture in financial bubble researches. [Figure A3](#) shows the cluster network in the financial bubble field. The clusters are labelled by index terms from their own citers. Meanwhile, the fields that are coloured differently indicate the time when co-citation links in those fields appear for the first time, and the fields in yellow are earlier than the ones in red. Moreover, the summary of the largest 10 clusters in financial researches is shown in [Table A1](#).

The size in [Table A1](#) demonstrates the number of publications in the cluster. For more details, please see [Figure A4](#). For instance, the cluster (#0) has 66 members,

which is one of the largest clusters in the financial bubble field. The second cluster (#1) and the third cluster both have 65 members. On the other hand, Silhouette is an index to measure the homogeneity of a cluster, the greater the value of this index the better the homogeneity. LLR (log-likelihood ratio) is a kind of algorithm according to the probability density function to determine the maximum likelihood and find the most likely words. The index of Mean (Year) in [Table A1](#) represents the average published articles per year of the nominated cluster. It can be learned that the cluster 0, cluster 1, cluster 4, and cluster 8 are the main clusters in the research field of financial bubbles, which are ‘Ledoit-Sornette financial bubble model’, ‘European Union emission trading scheme’, ‘Asset market’, and ‘Macro risk’, respectively. Obviously, two of the three largest clusters investigate the significant models in the financial research area, namely the Ledoit-Sornette model which is also the Johansen-Ledoit-Sornette (JLS) model and the agent-based model. By applying these two models, some scholars have made great contributions in terms of theoretical improvement and empirical investigation.

Specifically, the JLS model is proved to own the predictive power to diagnose the times of major marker rebounds (Yan, Woodard, & Sornette, 2012). Moreover, Sornette, Woodard, Yan, and Zhou (2013) reviewed the general problems of the JLS model and summarised the status quo of it and existing best practice. There are also some improvement methods proposed to further optimise the application of the JLS model. For instance, Filimonov and Sornette (2013) proposed a simple transformation of the calculating process in this model to decrease the complexity and improved efficiency. In consideration of the agent-based model (ABM), it is also a useful tool for researchers to observe, investigate, and simulate the diversity, dynamics, and interdependence in financial markets. Samanidou, Zschischang, Stauffer, and Lux (2007) reviewed some microscopic (agent-based) models utilised in financial markets. Based on the ABM, some phenomena have been studied in financial markets, e.g., Alfi, Cristelli, Pietronero, and Zaccaria (2009) proposed a minimal agent-based model to learn the nature and self-organisation of the stylised facts in capital markets. Also, Lengnick and Wohltmann (2013) integrated the theory of ABM and a New Keynesian macroeconomic model, then gave some suggestions based on the corresponding simulation.

In general, the results of the clusters are satisfactory according to the value of silhouette in [Table A1](#) and the classification of colours in [Figure A3](#). It is desirable to define the specialties in science mapping in terms of co-citation clusters. Moreover, the topic of ‘Ledoit-Sornette financial bubble model’ has more potential for further researches due to the high cluster.

#### **4. Current research status of the financial bubble**

In order to clarify the current state of financial bubble researches, this section sorts out the significant subject categories and productive sources, authors, countries, and institutions in financial bubble research to give a detailed illustration.

[Table A2](#) illustrates the top 10 subject categories in financial bubble research. It can be found that ‘Business Economics’ is the most popular subject category with 681 publications which account for 64.734% of the total publications. The second is

'Physics' and the third is 'Mathematics', which indicates that the researches on financial bubbles mainly utilise physical and mathematical methods. The following categories are 'Government Law', 'Mathematical Methods in Social Sciences', 'Environmental Sciences Ecology', 'Geography', 'Social Sciences other topics', 'Urban Studies', and 'Computer Science'.

Table A3 and Figure A5 show that *Physica A: Statistical Mechanics & Its Applications* is the most productive source with 65 publications which account for 6.179% of the total publications. According to the categories published from *Physica A: Statistical Mechanics & Its Applications*, it can be found that this journal mainly introduces statistical mechanics (to explain the behaviour of macroscopic systems by studying the statistical properties of their microscopic constituents) and widespread applications of the techniques of statistical mechanics, such as physical systems, economic and sociological systems. According to Table A2, there is no doubt that *Physica A: Statistical Mechanics & Its Applications* is the most productive source in the financial bubble field.

There are hundreds of scholars worldwide to carry out researches on financial bubbles. Table A4 illustrates the top 10 most productive authors in this field. Sornette, who contributes theoretical models, empirical tests of the detection and operational implementation of financial bubble forecasts, is the most productive author. The LPPLS (Log-periodic Power Law Singularity) model was first proposed by Sornette et al. in 1995 as a theoretical formulation of the acceleration moment release to predict earthquakes (Sornette & Sammis, 1995). Then, the LPPLS model was applied to analyse financial bubbles and their burst by Sornette (Sornette et al., 1996). Based on Table A1, it is obvious that Sornette is leading a new way to carry out researches on financial bubbles today.

The development of the researches on financial bubbles differs from country to country. Table A5 shows the top 10 most productive countries in this research. The U.S.A. is the most productive country in financial bubble research followed by England, Germany, People R China, France, Italy, Japan, Spain, Switzerland, and Canada.

Since the establishment of the financial markets in western countries is early historically, the economic development in those countries is more normative and more mature than in any other countries. Table A6 shows that the University of Geneva from Switzerland contributes the most publications in financial bubble research with 24 publications. The second is the Swiss Federal Institute of Technology Zurich from Switzerland and the third is the University of California-Los Angeles from the U.S.A. Among the top 10 institutions in Table A6, five of them are from the U.S.A. Switzerland and England both have two and one is from Germany. However, China, France, Italy, Japan, Spain, and Canada are the most productive countries in terms of financial bubble researches, but there is no productive research institution in these countries.

Figure A6 shows the timeline of the top 20 cited articles in each year. It provides an intuitive and accurate way to understand the evolution path of each sub-field. It can be learned that there are many significant achievements from 1997 to 2016 in financial bubble research. The researches mainly investigate the 'agent-based model'



and the ‘Log-periodic precursor’ from 1997 to 2000. Moreover, scholars focus more on ‘Asset bubble’, ‘Chinese stock market’, and ‘Modern rheology’ from 2000 to 2010. The ‘Bubble indicator’ and ‘European Union emission trading scheme’ have become the current research subjects from 2010 to 2016. Additionally, there are many types of research about ‘bubble indicator’ and ‘European Union emission trading scheme’ based on the researches of the ‘Chinese stock market’. Compared with the research directive of financial bubbles, more articles are published and cited in the ‘Asset bubble’ Class.

Today, many types of research on financial bubbles are inspired by China’s stock market. Both China and Chinese scholars are ranked in the top 10 in [Tables A4](#) and [A5](#), but the most productive institutions are from the U.S.A., Switzerland, England and Germany. This implies that more should be done to develop financial bubble institutions in China. Setting up the special departments to carry out researches on financial bubbles is of great necessity.

## 5. Burst detection in financial bubble research

Burst detection will make it possible to find the articles that receive particular attention from the related scientific communities in a certain period of time. It should be noted that a research cluster containing a certain quantity of articles with citation burst can be considered as a new research field. In order to reveal the potential research directions, this paper selects the references with citation bursts and keywords with bursts to explain the focus of financial bubble researches in a different time.

[Table A7](#) illustrates the top 20 references with strongest citation bursts. In the last columns, the length of the line represents the period from 1945 to 2017, in which the red line means the time period of citation bursts. It is clear that more bursts arise in the second half of the whole time period. The first one ranked in [Table A7](#) is Allan (1988) with a burst strength of 6.8111, followed by Delong, Shleifer, Summers, and Waldmann (1990) with a burst strength of 5.3726.

[Table A8](#) lists the top 10 keywords with bursts, which are the fast-growing topics in financial bubble research. Different keywords with bursts represent the corresponding characteristics in each time period. ‘Herd behaviour’ is first proposed in stock investment. Banerjee (1992) pointed out that the herd behaviour is a ‘behaviour that people do what other people are doing even though their own private information suggests that the behaviour should not be taken’, which is to say an individual takes the same action as any other person takes despite private information. Shiller (1995) defines herding as a way of thinking and behaving such that people in an interacting community tend to behave similarly.

Some financial crisis bursts from 1992 to 2007, such as the financial crisis in Mexico from 1994 to 1995, the financial crisis in Southeast of Asia in 1997 and the financial crisis triggered by the subprime mortgage crisis in 2007. The researches on ‘herd behaviour’ imply that the phenomenon is more serious than at any other time, leading to the financial bubble bursts. Moreover, ‘Econophysics’ was first proposed by Stanley from Boston University in 1995, which has been developed as an emerging subject. ‘Econophysic’ bursts arose almost at the same time period with ‘Herd

behaviour', 'Crashes', and 'Fluctuation'. It is popular to use statistical physics, complex systems theory, applied mathematics, and other methods to observe the formation and collapse of the bubble quantitatively in a financial crisis. The burst detection of keywords is to find the high-frequency words or phrases in the literature at different time intervals. In 2013, some big events took place such as the U.S. withdrawing from quantitative easing and the European Central Bank cutting interest rates twice during the year to promote the economy. Furthermore, Bitcoin prices have gone from \$20 at the beginning of the year to \$1,200. These international events have caused the discussion on 'asset price bubbles'. Hence, the keyword 'asset price bubbles' bursts from 2013 to 2015, which means it has been mentioned more times than any other terminologies in a short time period.

Generally, 'Bubbles, fads, and stock price volatility tests: a partial evaluation' by West in 1998 is an important article which indicates the long-term trend with high bursts. Today, 'asset price bubble' is popular in financial bubble researches. In both industrialised and developing countries, the sharp fluctuations in asset prices have become a prominent phenomenon in the macroeconomy. Therefore, it is essential to find an efficient and appropriate level of supervision measure to investigate the price change and to avoid the financial bubbles.

## 6. Conclusions

This paper provides a scientometric review of financial bubble studies by CiteSpace based on 1048 articles from Web of Science. According to the analyses above, some conclusions are derived as follows: 1) 'Business Economics', 'Physics', and 'Mathematics' are the most popular subject categories in financial bubble research. 2) *Physica A: Statistical Mechanics & Its Applications* has published the highest number of articles in this field. 3) Sornette is the most productive author of financial bubble researches. 4) The U.S.A., England, and Germany are the three most productive countries. The University of Geneva, Swiss Federal Institute of Technology Zurich and the University of California-Los Angeles are the most productive institutions in financial bubble research. 5) 'Ledoit-Sornette financial bubble model', 'European Union emission trading scheme', 'Agent-based model', 'Critical market crashes', 'Asset market', 'Predatory-prey decision', 'Switching processes', 'Japanese economy', 'Macro risk', and 'Stock market' are the most popular research directions in financial bubble research.

According to the visualization analysis and review of the articles about financial bubbles, it is easy for readers to obtain a better understanding of the trends in financial bubble research. From different perspectives of bibliometric analysis, we provide an overview about the current status and the emerging trends of financial bubble research, which helps researchers who are interested in knowing the general picture of this knowledge domain understand the dynamics of hot spots in the last few decades. According to the current research status in different countries, some of them with little achievements in financial bubble research should focus more attention on it. On the other hand, this paper offers a picture of the directions in the financial bubble researches, which helps the researches step into

a mature stage. Financial bubble risk as a kind of systematic financial risk is a result of a dynamic game between financial institutions and supervision departments. How to balance the relationship between supervision and innovation is still a problem.

In China, the report of the 19th National Congress specifically stated that it is necessary to improve the financial supervision system and maintain the bottom line of systemic financial risks. In the reconstruction of the financial regulatory framework reform, although the Financial Stability Development Committee was established in 2017, and new regulations such as assets were introduced, many institutional challenges were still faced. How to create an effective financial supervision system that encourages financial innovation and balances stability, efficiency and fairness has become a top priority for the Chinese government.

## Acknowledgments

This work was supported by the Natural Science Foundation of China under Grants [71561026 and 71840001]; Social Science Youth foundation of Ministry of Education of China under Grant [18YJC790118], and Applied Basic Research Programs of Science and Technology Commission of Yunnan Province under Grant [2017FB102].

## Disclosure statement

The author reports no conflicts of interest.

## ORCID

Wei Zhou  <http://orcid.org/0000-0002-0849-1524>

## References

- Alfi, V., Cristelli, M., Pietronero, L., & Zaccaria, A. (2009). Minimal agent-based model for financial markets I. *The European Physical Journal B*, 67(3), 385–397. doi:10.1140/epjb/e2009-00028-4
- Allan, W. K. (1988). Bubbles, fads and stock price volatility tests: A partial evaluation discussion. *Journal of Finance*, 43(3), 639–656.
- Andersen, J. V., & Sornette, D. (2004). Fearless versus fearful speculative financial bubbles. *Physica A: Statistical Mechanics and Its Applications*, 337(3-4), 565–585. doi:10.1016/j.physa.2004.01.054
- Bak, P., Paczuski, M., & Shubik, M. (1997). Price variations in a stock market with many agents. *Physica A: Statistical Mechanics and Its Applications*, 246(3-4), 430–453. doi:10.1016/S0378-4371(97)00401-9
- Banerjee, A. V. (1992). A simple model of herd behavior. *The Quarterly Journal of Economics*, 107(3), 797–817. doi:10.2307/2118364
- Battalio, R., & Schultz, P. (2006). Options and the bubble. *The Journal of Finance*, 61(5), 2071–2102. doi:10.1111/j.1540-6261.2006.01051.x
- Blanchard, O. J., & Watson, M. W. (1982). *Bubbles, rational expectations and financial markets*. (NBER Working Papers).

- Bornholdt, S. (2001). Expectation bubbles in a spin model of markets: Intermittency from frustration across scales. *International Journal of Modern Physics C*, 12(05), 667–674. doi:10.1142/S0129183101001845
- Carswell, J., & Goodison, N. (1960). The south sea bubble. *Journal of Modern History*, 34(2), 198–199.
- Chen, C. M. (2004). Searching for intellectual turning points: Progressive knowledge domain visualization. *Proceedings of the National Academy of Sciences of Sciences*, 101(Supplement 1), 5303–5310. doi:10.1073/pnas.0307513100
- Chen, K. J., & Wen, Y. (2017). The great housing boom of China. *American Economic Journal: Macroeconomics*, 9(2), 73–114. doi:10.1257/mac.20140234
- Coelho, M. S., Barbosa, F. G., & Souza, M. D R. A. Z. D. (2014). The scientometric research on macroalgal biomass as a source of biofuel feedstock. *Algal Research*, 6, 132–138. doi:10.1016/j.algal.2014.11.001
- Cont, R., & Bouchaud, J. P. (2000). Herd behavior and aggregate fluctuations in financial markets. *Macroeconomic Dynamics*, 4(2), 170–196. doi:10.1017/S1365100500015029
- Creti, A., & Joets, M. (2017). Multiple bubbles in the European union emission trading scheme. *Energy Policy*, 107, 119–130.
- Demarzo, P. M., Kaniel, R., & Kremer, I. (2008). Relative wealth concerns and financial bubbles. *Review of Financial Studies*, 21(1), 19–50. doi:10.1093/rfs/hhm032
- DeLong, J. B., Shleifer, A., Summers, L. H., & Waldmann, R. J. (1990). Noise trader risk in financial markets. *Journal of Political Economy*, 98(4), 703–738. doi:10.1086/261703
- Fantazzini, D. (2016). The oil price crash in 2014/15: Was there a (negative) financial bubble. *Energy Policy*, 96, 383–396. doi:10.1016/j.enpol.2016.06.020
- Filimonov, V., & Sornette, D. (2013). A stable and robust calibration scheme of the log-periodic power law model. *Physica A: Statistical Mechanics and Its Applications*, 392(17), 3698–3707. doi:10.1016/j.physa.2013.04.012
- Garber, P. (1989). Tulipmania. *Journal of Political Economy*, 97(3), 535–560. doi:10.1086/261615
- Hee-Jung, K. (2005). A study on visualization of digital preservation knowledge domain using CiteSpace. *Transplantation Proceedings*, 39(4), 891–892.
- Johansen, A., & Sornette, D. (1999). Financial ‘anti-bubbles’: Log-periodicity in gold and Nikkei collapses. *International Journal of Modern Physics C*, 10(04), 563–575. doi:10.1142/S0129183199000437
- Johansen, A., & Sornette, D. (1999b). Log-periodic power law bubbles in Latin-American and Asian markets and correlated anti-bubbles in western stock markets: An empirical study. *International Journal of Theoretical and Applied Finance*, 4(6), 853–920. doi:10.1142/S0219024901001218
- Johansen, A., & Sornette, D. (2000). The Nasdaq crash of April 2000: Yet another example of log-periodicity in a speculative bubble ending in a crash. *The European Physical Journal B*, 17(2), 319–328. doi:10.1007/s100510070147
- Johansen, A., & Sornette, D. (2001). Large stock market price drawdowns are outliers. *The Journal of Risk*, 4(2), 69–110. doi:10.21314/JOR.2002.058
- Kaizoji, T. (2000). Speculative bubbles and crashes in stock markets: An interacting-agent model of speculative activity. *Physica A: Statistical Mechanics and Its Applications*, 287(3–4), 493–506. doi:10.1016/S0378-4371(00)00388-5
- Kim, K. H., & Suh, S. H. (1993). Speculation and price bubbles in the Korean and Japanese real estate markets. *The Journal of Real Estate Finance and Economics*, 6(1), 73–87. doi:10.1007/BF01098429
- Konur, O. (2011). The scientometric evaluation of the research on the algae and bio-energy. *Applied Energy*, 88(10), 3532–3540. doi:10.1016/j.apenergy.2010.12.059
- Krawiecki, A., & Hołyst, J. A. (2003). Stochastic resonance as a model for financial market crashes and bubbles. *Physica A: Statistical Mechanics and Its Applications*, 317(3–4), 597–608. doi:10.1016/S0378-4371(02)01375-4
- Lee, N. J., & Ong, S. E. (2005). Upward mobility, house price volatility and housing equity. *Journal of Housing Economics*, 14(2), 127–146. doi:10.1016/j.jhe.2005.06.004

- Leeuwen, T. V. (2006). The application of bibliometric analyses in the evaluation of social science research. *Who Benefits from It, and Why It Is Still Feasible. Scientometrics*, 66(1), 133–154.
- Lengnick, M., & Wohltmann, H. W. (2013). Agent-based financial markets and new Keynesian macroeconomics: A synthesis. *Journal of Economic Interaction and Coordination*, 8(1), 1–32. doi:10.1007/s11403-012-0100-y
- Li, M., Porter, A. L., & Wang, Z. L. (2017). Evolutionary trend analysis of nanogenerator research based on a novel perspective of phased bibliographic coupling. *Nano Energy*, 34, 93–102. doi:10.1016/j.nanoen.2017.02.020
- Liang, Y. X., Yang, Z. K., & Liu, Z. Y. (2008). Fronts of aerospace engineering domains based on CiteSpace II. *Studies in Science of Science*, 26(S2), 303–312.
- Lin, L., Ren, R., & Sornette, D. (2014). The volatility-confined LPPL model: A consistent model of ‘explosive’ financial bubbles with mean-reverting residuals. *International Review of Financial Analysis*, 33, 210–225. doi:10.1016/j.irfa.2014.02.012
- Lin, Z., Wu, C., & Hong, W. (2015). Visualization analysis of ecological assets/values research by knowledge mapping. *Acta Ecologica Sinica*, 35(5), 142–154. doi:10.1016/j.chnaes.2015.07.005
- Long, J. B. D., Shleifer, A., Summers, L. H., & Waldmann, R. J. (1990). Noise trader risk in financial markets. *Journal of Political Economy*, 98(4), 703–738. doi:10.1086/261703
- Lucore, R. E. (1991). Lessons from the great depression. *Journal of Interdisciplinary History*, 13(4), 417–432.
- Lux, T. (1995). Herd behavior, bubbles and crashes. *The Economic Journal*, 105(431), 881–896. doi:10.2307/2235156
- Lux, T., & Marchesi, M. (1999). Scaling and criticality in a stochastic multi-agent model of a financial market. *Nature*, 397(6719), 498–475. doi:10.1038/17290
- Lux, T., & Sornette, D. (2002). On rational bubbles and fat tails. *Journal of Money, Credit and Banking*, 34(3a), 589–610. doi:10.1353/mcb.2002.0004
- Mercuri, E. G. F., Kumata, A. Y. J., Amaral, E. B., & Vitule, J. R. S. (2016). Energy by microbial fuel cells: Scientometric global synthesis and challenges. *Renewable and Sustainable Energy Reviews*, 65, 832–840. doi:10.1016/j.rser.2016.06.050
- Morar, M., & Agachi, P. S. (2010). Review: Important contributions in development and improvement of the heat integration techniques. *Computers & Chemical Engineering*, 34(8), 1171–1179. doi:10.1016/j.compchemeng.2010.02.038
- Pan, X.-J., Zhao, H.-N., Li, M.-M., Hou, L.-H., Guo, Y.-Q., Zheng, X., ... Zhang, C.-C. (2017). Information visualization on advances in psychological science: 1983-2014. *Chinese Nursing Research*, 4(3), 124–129. doi:10.25164/SEP.2017040204
- Pele, D. T., & Mazurencu-Marinescu, M. (2012). Modelling stock market crashes: The case of Bucharest stock exchange. *Procedia - Social and Behavioral Sciences*, 58(7), 533–542. doi:10.1016/j.sbspro.2012.09.1030
- Samanidou, E., Zschischang, E., Stauffer, D., & Lux, T. (2007). Agent-based models of financial markets. *Reports on Progress in Physics*, 70(3), 409–450. doi:10.1088/0034-4885/70/3/R03
- Santos, M. S., & Woodford, M. (1997). Rational asset pricing bubbles. *Econometrica*, 65(1), 19–57. doi:10.2307/2171812
- Shiller, R. J. (1990). Speculative prices and popular models. *Journal of Economic Perspectives*, 4(2), 55–65. doi:10.1257/jep.4.2.55
- Shiller, R. J. (1995). Conversation, information, and herd behavior. *American Economic Review*, 85(2), 181–185.
- Shiller, R. J. (2000). *Irrational exuberance*. Princeton: Princeton University Press.
- Sornette, D., & Andersen, J. V. (2002). A nonlinear super-exponential rational model of speculative financial bubbles. *International Journal of Modern Physics C*, 13(02), 171–188. doi:10.1142/S0129183102003085
- Sornette, D., & Johansen, A. (2001). Significance of log-periodic precursors to financial crashes. *Quantitative Finance*, 1(4), 452–471. doi:10.1088/1469-7688/1/4/305

- Sornette, D., Johansen, A., & Bouchaud, J. P. (1996). Stock market crashes, precursors and replicas. *Journal de Physique I*, 6(1), 167–175. doi:10.1051/jp1:1996135
- Sornette, D., & Sammis, C. G. (1995). Complex critical exponents from renormalization group theory of earthquakes: Implications for earthquake prediction. *Journal de Physique I*, 5, (5), 607–619. doi:10.1051/jp1:1995154
- Sornette, D., Woodard, R., Yan, W., & Zhou, W. X. (2013). Clarifications to questions and criticisms on the Johansen-Ledoit-Sornette bubble model. *Physica A: Statistical Mechanics and Its Applications*, 392(19), 4417–4428. doi:10.1016/j.physa.2013.05.011
- Su, C.-W., Wang, K.-H., Chang, H.-L., & Dumitrescu-Peculea, A. (2017). Do iron ore price bubble occur. *Resources Policy*, 53, 340–346. doi:10.1016/j.resourpol.2017.08.003
- Vandewalle, N., Ausloos, M., Boveroux, P., & Minguet, A. (1998). How the financial crash of October 1997 could have been predicted. *The European Physical Journal B*, 4(2), 139–141. doi:10.1007/s100510050361
- Vandewalle, N., Boveroux, P., Minguet, A., & Ausloos, M. (1998). The crash of October 1987 seen as a phase transition: Amplitude and universality. *Physica A: Statistical Mechanics and Its Applications*, 255(1-2), 201–210. doi:10.1016/S0378-4371(98)00115-0
- Wei, F. W., Grubestic, T. H., & Bishop, B. W. (2015). Exploring the GIS knowledge domain using CiteSpace. *The Professional Geographer*, 67(3), 374–384. doi:10.1080/00330124.2014.983588
- Xiang, C., Wang, Y., & Liu, H. (2017). A scientometric review on nonpoint source pollution research. *Ecological Engineering*, 99, 400–408. doi:10.1016/j.ecoleng.2016.11.028
- Yan, W. F., Woodard, R., & Sornette, D. (2012). Diagnosis and prediction of market rebounds in financial markets. *Physica A: Statistical Mechanics and Its Applications*, 391(4), 1361–1380. doi:10.1016/j.physa.2011.09.019
- Zhang, Q., Sornette, D., & Balcilar, M. (2016). LPPLS bubble indicators over two centuries of the S&P 500 index. *Physica A: Statistical Mechanics and Its Applications*, 458, 126–139.
- Zhou, W., Huang, Y., & Chen, J. (2018). The bubble and anti-bubble risk resistance analysis on the metal futures in China. *Physica A: Statistical Mechanics and Its Applications*, 503, 947–957. doi:10.1016/j.physa.2018.08.120

Appendices

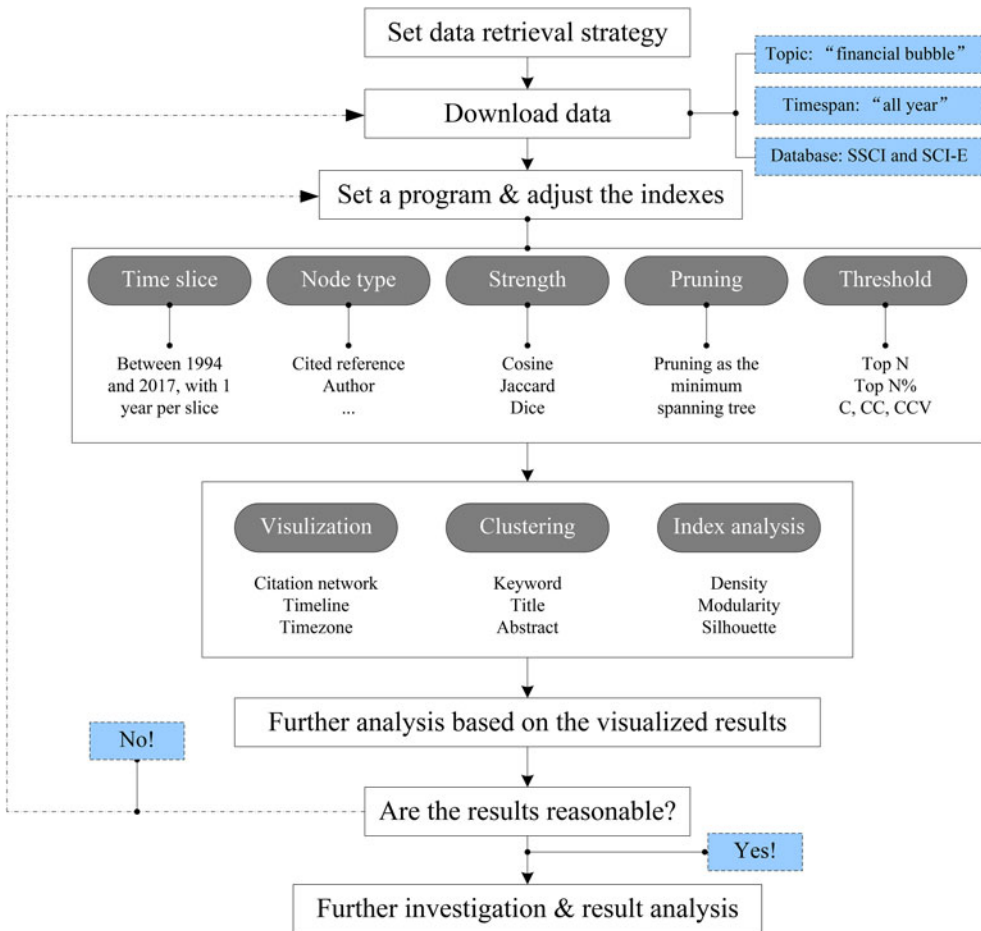


Figure A1. Architecture diagram of data analysis.

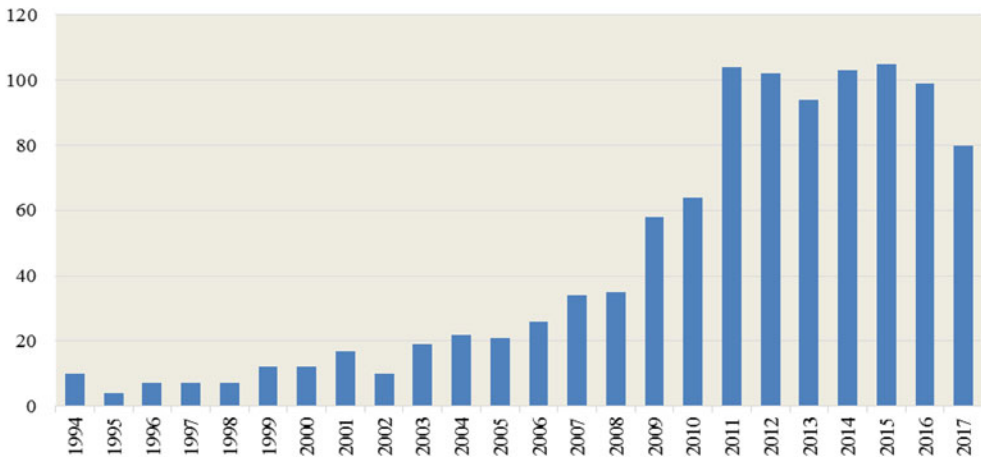
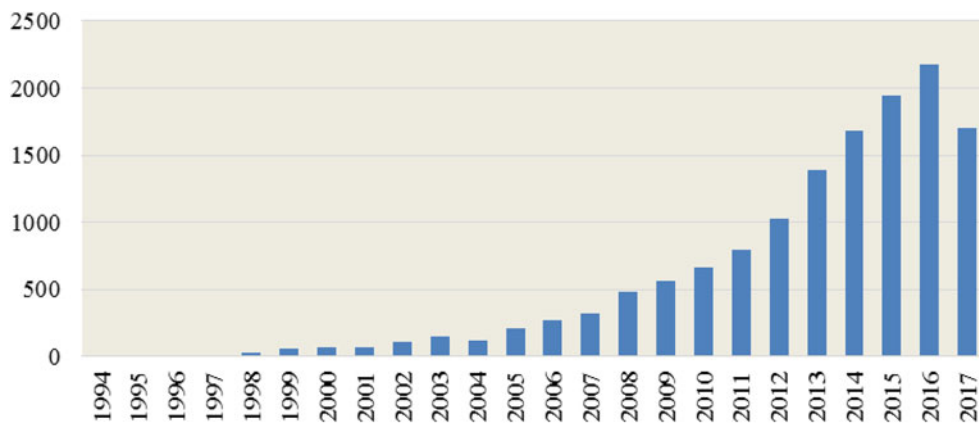
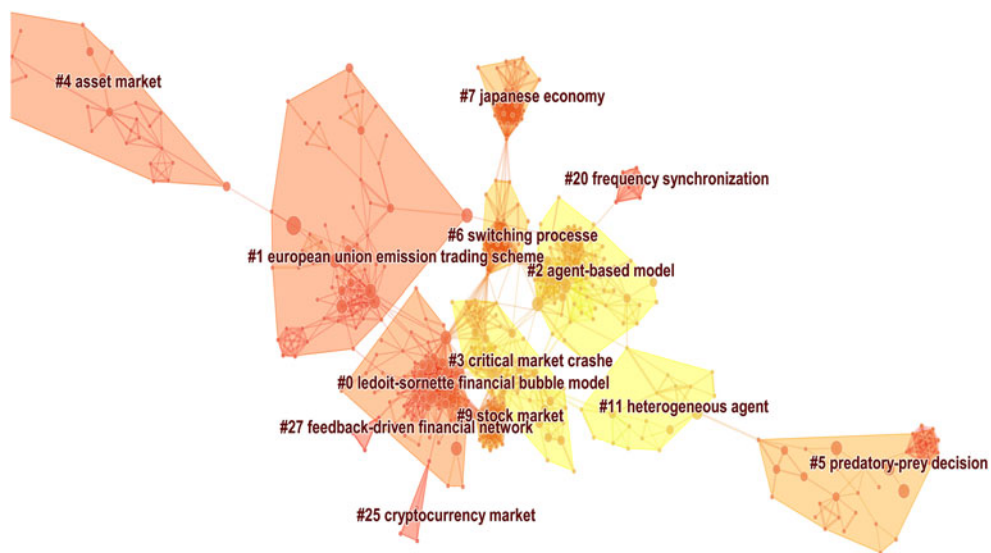


Figure A2. Number of publications in financial bubble research from 1994 to 2017.



**Figure A3.** Number of citations per year in financial bubble research from 1994 to 2017.



**Figure A4.** Cluster network in financial bubble research.





Figure A5. Main journals in financial bubble research.

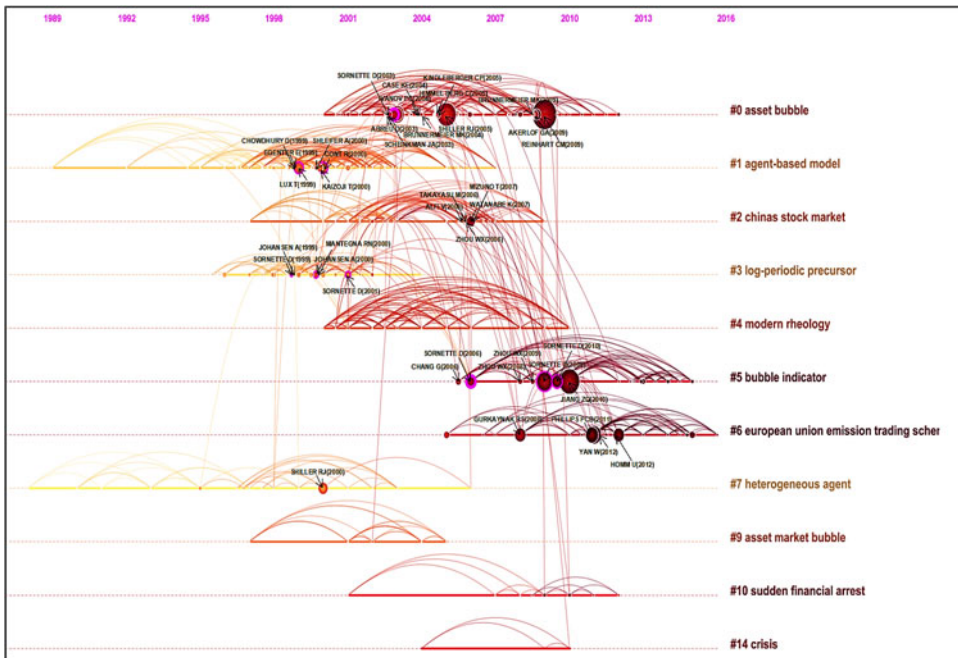


Figure A6. Timeline of top 20 cited articles each year.

**Table A1.** Summary of the largest 10 clusters in financial bubble research.

ClusterID	Size	Silhouette	Label (LLR)	Mean (Year)
0	66	0.849	Ledoit-Sornette financial bubble model	2009
1	65	0.959	European union emission trading scheme	2009
2	65	0.916	Agent-based model	2000
3	47	0.815	Critical market crashes	2001
4	34	0.97	Asset market	2009
5	34	0.98	Predatory-prey decision	2007
6	27	0.948	Switching processes	2005
7	25	0.992	Japanese economy	2005
8	22	0.982	Macro risk	2009
9	20	0.965	Stock market	2003

**Table A2.** Top 10 subject categories in financial bubble research.

Subject categories	Publication Number	The percentage of total
Business Economics	681	64.734%
Physics	122	11.597%
Mathematics	79	7.510%
Government Law	58	5.513%
Mathematical Methods in Social Sciences	53	5.038%
Environmental Sciences Ecology	34	3.232%
Geography	34	3.232%
Social Sciences other topics	30	2.852%
Urban Studies	28	2.662%
Computer Science	27	2.567%

**Table A3.** Top 10 most productive sources in financial bubble research.

Sources	Number	The percentage of total
<i>Physica A: Statistical Mechanics &amp; Its Applications</i>	65	6.179%
<i>Journal of Economic Dynamics Control</i>	22	2.091%
<i>Quantitative Finance</i>	18	1.711%
<i>Journal of Economic Behavior Organization</i>	15	1.426%
<i>Journal of Financial Economics</i>	15	1.426%
<i>Economic Modeling</i>	13	1.236%
<i>European Physical Journal B</i>	12	1.141%
<i>International Review of Financial Analysis</i>	12	1.141%
<i>Journal of Banking Finance</i>	12	1.141%
<i>Journal of Behavior Finance</i>	12	1.141%

**Table A4.** Top 10 most productive authors in financial bubble research.

Authors	Publication Number	The percentage of total
Sornette D	44	4.183%
Zhou WX	13	1.236%
Lux T	9	0.856%
Allen F	8	0.760%
Protter P	8	0.760%
Woodard R	8	0.760%
Glark GL	7	0.665%
Kaizoji T	6	0.570%
Rosser JB	6	0.570%
Andersen JV	5	0.475%

**Table A5.** Top 10 most productive countries in financial bubble research.

Countries	Number	The percentage of total
USA	359	34.125%
England	141	13.403%
Germany	95	9.030%
People R China	89	8.460%
France	87	8.270%
Italy	57	5.418%
Japan	50	4.753%
Spain	48	4.563%
Switzerland	46	4.373%
Canada	43	4.087%

**Table A6.** Top 10 most productive institutions in financial bubble research.

Institutions	Number	The percentage of total
University of Geneva (Swiss)	24	2.281%
Swiss Federal Institute of Technology Zurich (Swiss)	22	2.091%
University of California-Los Angeles (USA)	19	1.806%
University of Pennsylvania (USA)	16	1.521%
Columbia University (USA)	14	1.331%
University of Cambridge (England)	14	1.331%
University of Oxford (England)	14	1.331%
Cornell University (USA)	13	1.236%
National Bureau of Economic Research (USA)	13	1.236%
University of Kiel (Germany)	13	1.236%

**Table A7.** Top 20 references with the strongest citation bursts.

References	Year	Strength	Begin	End	1945–2017
Allan	1988	6.8111	1988	2009	-----
DeLong, Shleifer, Summers and Waldmann,	1990	5.3726	1995	1999	-----
Lux	1995	4.4206	1997	2005	-----
Lux & Marchesi,	1999	11.7501	1999	2009	-----
Bak, Paczuski, & Shubik,	1997	4.6174	1999	2007	-----
Santos & Woodford,	1997	5.6047	2000	2006	-----
Johansen & Sornette,	1999a	5.042	2000	2006	-----
Lux & Sornette,	2002	4.5735	2002	2005	-----
Kaizoji,	2000	8.89	2002	2009	-----
Johansen & Sornette,	1999b	7.6007	2002	2004	-----
Cont & Bouchaud,	2000	9.4525	2002	2010	-----
Bornholdt,	2001	7.0339	2002	2008	-----
Sornette & Johansen,	2001	6.3567	2003	2010	-----
Johansen & Sornette,	2000	6.7834	2003	2010	-----
Shiller,	2000	10.2107	2003	2010	-----
Vandewalle, Ausloos, Boveroux, & Minguet,	1998	5.4474	2003	2007	-----
Vandewalle, Boveroux, Minguet & Ausloos,	1998	5.9947	2003	2007	-----
Sornette & Andersen,	2002	4.8025	2003	2009	-----
Johansen & Sornette,	2001	6.7418	2003	2004	-----
Sornette & Sammis,	1995	6.7418	2003	2004	-----

**Table A8.** Top 10 keywords with bursts.

Keywords	Strength	Begin	End	1945–2017
Volatility	8.1876	1945	2007	-----
Financial market	6.2942	1995	2005	-----
Stock market	7.6797	1997	2006	-----
Herd behavior	6.3426	2002	2010	-----
Crashes	10.1809	2002	2010	-----
Fluctuation	5.649	2002	2009	-----
Econophysics	5.8504	2002	2009	-----
Dynamics	4.6228	2007	2008	-----
Performance	4.5612	2007	2008	-----
Asset price bubble	5.3723	2013	2015	-----