

Early warning system in business, finance, and economics: Bibliometric and topic analysis

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Abstract

Different economic crises such as banking, financial, and currency lead to high economic costs and have negative impact to whole society. Development of early warning systems could help in prevention of economic and business crisis, while they present a systematic forecast of unwanted events. Early warning systems are used primary for detecting crises before damage has been made and for reducing false alarms of possible crisis. The aim of our article is to provide bibliometric analysis of early warning system, their development and usage in different environment especially in economic and finance sector. It investigates the role of early warning systems for prediction and recognition of negative events, especially in the area of business, finances, and economy. Moreover, this article contributes to the existing literature by providing systematic analysis of development and usage of early warning systems to predict critical and problematic events for economic and social development.

Keywords

Early warning systems, crisis, banking, insurance, currency, business, finance, economics

Date received: 7 May 2018; accepted: 28 July 2018

Introduction

Early warning systems serve as a key element of preparedness to disasters or other negative events.¹ They can be applied to any area where it has value to obtain indicators of some, typically negative, events that will happen in the future. For instance, in finance field indicators are the value of imports, the value of exports foreign exchange reserves, industrial production, the ratio of domestic credit to nominal gross domestic product (GDP), and so on. Early warning systems refer to technology, policies, and procedures with the main goal to predict negative crisis and can be used in a variety of environments. By its very nature, the early warning systems can use quantitative or qualitative data. It is utmost important that early warning systems are effective and embrace all aspects of the emergency. The components of an effective warning system are risk awareness (prior knowledge), monitoring and warning service for early warning, communication (dissemination of warnings), and response capability (act by all partners of the information chain).^{2,3}

Early research on early warning systems have mostly studied systems usage in the field of disaster management, for example, different authors have examined warning systems in case of tsunamis, tornados, floods, earthquakes, wide land fires, and so on.^{2,4–8} Different risks require different early warning systems. Different models and use of modern technologies are proposed in order to better control warn and safe lives. Most of models are based on regression, multiple logic model, combining prediction model, multiple probability ratio model, and so on.⁸ In management, early warning systems have been mostly studied with the help of qualitative methodology, in areas such as

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strategic and project management using such us techniques that lessen the effects cognitive biases on detecting weak signals. In the fields of economics and finances, the studies start from the end of the 19th centuries. Contemporary companies are using early warning systems to improve organizational change, future development, and to avoid undesirable events. Beside investments in human capital and information and communication technology as the main venue for early warning systems, companies are trying to overcome operational weaknesses focusing on new and advanced systems and structures.⁹ Companies pay more attention to innovative technologies,¹⁰ to integration of knowledge capital and teamwork,¹¹ to creativity and satisfied clients to be able to adapt to fast changes, and to achieve competitive advantage,¹² as well to bridge the digital divide in developing countries.¹³ Moreover, companies are often applying early warning system so they can detect economic crisis and avoid negative events, not only in the areas related to finance but also to different managerial aspects, such as project management¹⁴ and public relations and social media.¹⁵

In the last decade, economic and business crisis had a strong negative impact on society and economy,¹⁶ which incited the development and usage of early warning systems enable to recognize negative events for different environments, especially for financial sector. To the best of our knowledge, there is no structured analysis of the previous research on this topic. Therefore, the goal of this article is to provide the answers to the following research questions: (i) RQ1: What are the bibliometric trends of research in the area of early warning systems in business, finances, and economy? (ii) RQ2: What are typical areas of applications of early warning systems in business, finances, and economy?

This article is structured as follows. This article starts with the theoretical background of early warning systems and the topic of early warning systems in the field of business, economy, and finance, as have been given by different authors. Second section presents the research methodology that is based on bibliometric approach and text mining. In the third section, results and discussion are presented as follows: (i) bibliometric analysis of early warning systems based on distribution by country/territory and institution name, by publication year and language, by source title, and by subject category and (ii) analysis of early warning systems according to type of crisis are described. Discussion section is based mainly on the topic analysis. The main research findings are discussed and presented in the conclusion section of this article, which includes limitations and directions for future researchers.

Methodology

The literature review covers the journal articles from the database of the Science Citation Index (SCI), Social Science Citation Index (SSCI), and Arts and Humanities

Citation Index (A&HCI). Authors trust that Web of Science classification of articles is correct and that the articles indexed in Web of Science database offer a good representation of all research performed in the area of early warning systems. In the first step, search was conducted using the key words “early warning system,” refined by Web of Science following categories: management, economics, public administration, business finance, and business. Only peer-reviewed articles were included in the study. The search was conducted covering the period from January 1970 till December 2016. Only the papers presenting early warning systems were included in the analysis.

This approach retrieved 112 articles, which were examined by three independent researchers (authors of this article). We used methods, Bibliometric or Statistica Data Miner, to conduct research as suggested by Kostoff with colleagues¹⁷ and Macfayden and Dawson.¹⁸ Bibliometric analysis was applied in order to enrich our research by exploring the time(s), place(s), and context(s) in which relevant issue happened. Analyzed parameters included as follows: (i) distribution by country/territory and institution name, (ii) distribution by publication year and language, (iii) distribution by source title, and (iv) distribution by subject category. In the second step, the topic mining was conducted using Statistica Data Miner, which retrieved two main topics: banking and currency crisis. In the third step, the retrieved papers were analyzed according to the type of crisis identified by the topic mining: banking and currency crisis. However, qualitative analysis of the papers identified additional topics, such as macroeconomic and stock exchange crisis, as well as crisis in agriculture, which were briefly discussed.

Early warning systems bibliometric analysis

First, bibliometric analysis on early warning systems in order to examine geographical area (country/territory) of the authors of the papers was conducted. Results regarding geographical area (country/territory) for every article were found and are shown in Table 1. More than half authors of the papers are from Europe, especially from Germany (18), United Kingdom (9), Turkey (6), the Netherlands (6), Italy (5), and France (4). Also, around 30% authors of the papers are from North America. Only one author is from Australia and three of them are from South America. There are 9 authors from Africa and 22 from Asia. There were no papers on early warning system in business, finance, and economics published by authors from different countries/territories.

Second, early warning systems bibliometric analysis was conducted in order to examine institutions of the authors. Table 2 presents the most frequent institutions of the authors of the papers. Most of the authors are enrolled in following institutions: Federal Reserve System USA (six articles), International Monetary Fund (five articles),

Table 1. Geographical area (country/territory) of the authors of the papers.

Countries/territories	Country/number of papers
North America	United States (32), Canada (2)
Europe	Germany (18), United Kingdom (9), Turkey (6), the Netherlands (6), Italy (5), France (4), Romania (3), Ukraine (2), Spain (2), Czech Republic (2), Austria (2), Sweden (1), Poland (1), Macedonia (1), Greece (1), Denmark (1), Scotland (1)
Australia and Oceania	Australia (1)
Asia	China (7), Taiwan (4), South Korea (2), Japan (2), India (2), Singapore (1), Indonesia (1), Philippines (1), Malaysia (1), Kazakhstan (1)
Africa	South Africa (2), Egypt (2), Uruguay (1), Tunisia (1), Sudan (1), Saudi Arabia (1), Iran (1)
South America	Bolivia (1), Paraguay (1), Mexico (1)

Source: Authors' work.

European Central Bank (four articles), University of Texas Austin (three articles), Federal Reserve Bank Cleveland (three articles), and Bucharest Academy of Economics Studies (three articles). In two papers, authors are enrolled in following institutions: University System of Georgia, University of Regensburg, University of Pretoria, University of Orleans, University of Massachusetts System, University of London, University of Groningen, University of California System, Diw Berlin Deutsches, Institut fur Wirtschaftsforschung, Case Western Reserve University, and Cairo University. In 83 papers, authors are enrolled in institutions, which are mentioned only once, and they are categorized as Other.

Table 3 presents the publication year and language of published papers. Most of the papers have been published in the last 3 years: 2014 (17), 2015 (12), and 2016 (15). From 1970 until 1999, only one paper has been published, and not even in every year (1999, 1998, 1997, 1994, 1993, 1987, 1984, 1981, 1980, 1979, 1978, 1976, 1975, 1973, and 1970). Results showed that there have been an increasing number of publications on early warning systems since 2000. Therefore, it can be concluded that there are two periods regarding publications on early warning systems: from 1970 to 1999 and from 2000 to now. Most of the examined papers were written in English language (107 articles), others in Russian (2 articles), Spanish (1 article), German (1 article), and Czech (1 article) language.

Most of the papers regarding early warning systems were published in various journal. Following journals published three and more articles on the early warning systems: *European Journal of Operational Research* (seven articles), *Journal of Banking Finance* (four articles), *Journal of Policy Modeling* (three articles), *Journal of International Money and Finance* (three articles), *International Journal of Forecasting* (three articles), *International Journal of*

Table 2. The most frequent institutions of the authors of the papers.

Organizations enhanced	Number of papers	% of 112
Federal Reserve System USA	6	5.357
International Monetary Fund	5	4.464
European Cent Bank	4	3.571
University of Texas Austin	3	2.679
Federal Reserve Bank Cleveland	3	2.679
Bucharest Academy of Economic Studies	3	2.679
University System of Georgia	2	1.786
University of Regensburg	2	1.786
University of Pretoria	2	1.786
University of Orleans	2	1.786
University of Massachusetts System	2	1.786
University of London	2	1.786
University of Groningen	2	1.786
University of California System	2	1.786
Diw Berlin Deutsches Institut fur Wirtschaftsforschung	2	1.786
Case Western Reserve University	2	1.786
Cairo University	2	1.786
Other	83	74.119

Source: Authors' work.

Finance Economics (three articles), *Futures* (three articles), *Economic Modeling* (three articles), and *Disaster Prevention and Management* (three articles).

Table 4 presents the Web of Science categories of the articles. All of the papers were published in at least one of the four main research areas (economics, business finance, management, and business). Other research areas occur only if one of the main four areas was assigned to the paper. For example, one of the papers has two research areas: economics and environmental studies,¹ while other has three research areas: business finance, operations research management science, and industrial relations labor.¹⁹ Most of the selected articles were grouped into following categories: economics (67 articles), business finance (30 articles), management (27 articles), business (12 articles), planning development (11 articles), and operations research management science (11 articles). In categories of public administration and environmental studies, four papers were published, while in categories of social sciences mathematical methods, public environmental occupational health, and political science, three papers were published. There is only one paper dealing with early warning system in following categories: law, industrial relations labor, geography, engineering multidisciplinary. It can be concluded that early warning systems have been mostly used in the areas where unwanted situations decrease economic and social development on the global level. Predicting situations, which are better to avoid, early warning systems lower the possible damage, which can have unwanted consequences.

Table 3. Publication year and language of paper.

Pub. year	Number of papers	% of 112	Language	Number of papers	% of 112
2014	17	15.179	English	107	95.536
2016	15	13.393	Russian	2	1.786
2015	12	10.714	Spanish	1	0.893
2013	7	6.250	German	1	0.893
2009	7	6.250	Czech	1	0.893
2012	6	5.357			
2011	6	5.357			
2007	6	5.357			
2006	5	4.464			
2003	4	3.571			
2010	3	2.679			
2008	3	2.679			
2005	2	1.786			
2004	2	1.786			
2000	2	1.786			
1999	1	0.893			
1998	1	0.893			
1997	1	0.893			
1994	1	0.893			
1993	1	0.893			
1987	1	0.893			
1984	1	0.893			
1981	1	0.893			
1980	1	0.893			
1979	1	0.893			
1978	1	0.893			
1976	1	0.893			
1975	1	0.893			
1973	1	0.893			
1970	1	0.893			

Source: Authors' work.

Table 4. Web of Science categories of the articles.^a

Web of Science categories	Number of papers	% of 112
Economics	67	59.821
Business finance	30	26.786
Management	27	24.107
Business	12	10.714
Planning development	11	9.821
Operations research management science	11	9.821
Public administration	4	3.571
Environmental studies	4	3.571
Social sciences mathematical methods	3	2.679
Public environmental occupational health	3	2.679
Political science	3	2.679
Mathematics interdisciplinary applications	2	1.786
International relations	2	1.786
Agricultural economics policy	2	1.786
Transportation	1	0.893
Law	1	0.893
Industrial relations labor	1	0.893
Geography	1	0.893
Engineering multidisciplinary	1	0.893

Source: Authors' work.

^aOne paper can have more than one research areas.

Presented findings indicate that research on early warning systems is dispersed among numerous universities and research institutions, published in various journals, further implying the diversity of areas of early warning systems.

Text mining

Text mining was conducted in three phases. First, tag cloud analysis was conducted using the titles of the papers. Second, the most frequent words occurring in the titles of the papers were extracted using Statistica Data Miner. Finally, the topic mining was conducted using singular value decomposition.

Tag cloud analysis

Tag cloud analysis enables better understanding titles of the selected papers. Figure 1 presents tag cloud of the most often used words in paper titles; most frequent 50 words. Tag cloud analysis is valuable tool which simply presents the most occurring words in selected text.¹⁷ In our research, Wordle program was used to create a tag cloud. Figure 1 presents that the words "crisis," "financial," "early," "system," and

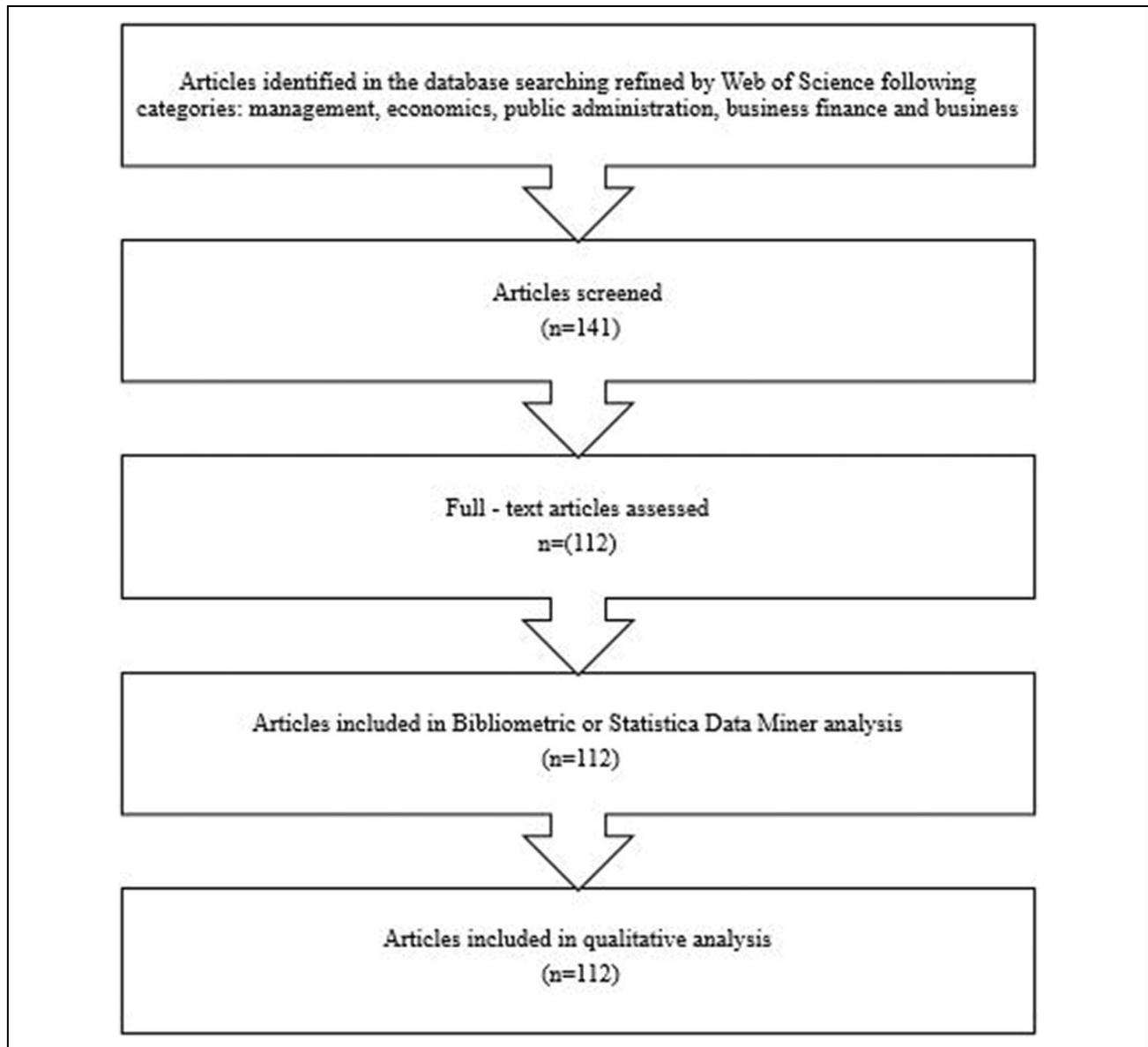


Figure 1. Flow chart of systematic literature review phases.

“warning” are mostly used in the paper titles. In addition, several other words are also frequently used: banking, approach, currency, development, predicting, and signals.

Word frequency analysis

Statistica Data Miner was used to conduct text mining on the titles of papers. Table 5 presents most commonly used words in titles of papers with four occurrences, which were extracted using text mining analysis-stemming approach by Statistica Text Miner program. In all examined papers, the word *system* was used more than once. In more than 10 papers, following words are mostly used: early warning (43), crisis (32), finance (24), currency (17), predict (16), bank (13), and risk (10). Most of the analyzed words are used in titles of three papers: analysis, conditions, differ, dynamic,

economy, emerging, environment, exchange, external, failure, insolvency, insurance, logit, management, monitoring, policy, price, project, rate, sovereign, stress, and value.

Topic mining

In order to extract the topics of the titles of examined papers, singular value decomposition was used. Cattell¹⁸ explained how to plot the eigenvalues, which are connected with each component in order to find a “break” between them. Figure 2 presents scree plot of topics extracted with singular value decomposition. Results showed that only two topics extracted with singular value decomposition are relevant.

Table 6 presents the words that occur the most in the two extracted topics. The first topic consists of following the most occurring 15 words: financi, predict, crise, system,

Table 5. Most commonly used words in titles of papers (≥ 3 occurrences).

Stem/phrase	Number of occurrences in the title	Number of papers	Examples
System	55	50	—
Early warning	43	43	—
Crisis	32	32	Crisis
Financi	24	24	Financial
Currenc	17	17	Currency
Predict	16	16	—
Bank	13	13	—
Risk	10	10	—
Market	9	9	—
Develop	8	7	Developed
Case	7	7	—
Crisi	7	7	Crisis
Signal	7	7	—
Distress	6	6	—
Indic	6	6	Indices
Index	5	4	—
Method	5	5	—
Model	5	5	Models
Network	5	5	—
Countri	4	4	Countries
Crash	4	3	Crashes
Empir	4	4	Empirical
Eval	4	4	evaluate
Event	4	4	—
Hous	4	4	house
Impact	4	4	—
Inform	4	4	Information
Secur	4	3	Security
Statist	4	4	Statistical
Toward	4	4	—
Analsi	3	3	Analysis
Condit	3	3	Conditions
Differ	3	3	Different
Dynam	3	3	Dynamic
Econom	3	3	Economic
Emerg	3	3	Emerging
Environ	3	3	Environment
Exchang	3	3	Exchange
Extern	3	3	External
Failur	3	3	Failure
Insolv	3	3	Insolvency
Insur	3	3	Insurer
Logit	3	3	—
Manag	3	3	Management
Monitor	3	3	Monitoring
Neural	3	3	—
Polici	3	3	Policy
Price	3	3	—
Project	3	3	—
Rate	3	3	—
Sovereign	3	3	—
Stress	3	3	—
Valu	3	3	Value

Source: Authors' work; Statistica Data Miner.

approach, studi, bank, early warning, use, case, currenc, network, market, distress, and statist. The second topic consists on the following the most occurring 15 words: currenc, crise, approach, country, indic, early warning, logit, multinomi, crash, system, new, lead, model, and differ. In order to get more in-depth insight into these papers, we investigated the papers with the highest singular value decomposition scores for two major topics (see Figure 3). Based on the analysis of these papers, it was concluded that the papers extracted in the first topic are mostly related to prediction of banking crisis, while the papers extracted in the second topic are mostly related to currency crisis.

Early warning systems according to type of crisis

Early warning systems of banking crisis. Analyzing selected papers, we have identified 12 papers that are focused on early warning systems in the area of banking crisis. Most of the articles are quite new, written in the last 4 years (2014–2016) and four of them are older (2004–2012).

Canbas and his colleagues¹⁹ recommended a framework for creating early warning systems as a support tool for decision that can be used for banks dealing with unwanted issues. Just few years later Sanchis and other researchers²⁰ tried to investigate other two issues. The first is related with macroeconomic problems and the second one paid more attention to microeconomic topics. First, they wanted to investigate the impact of monetary policy in banking crisis. Second, they aimed to predict insolvency in insurance sector. For further analysis, they developed a bankruptcy prediction model that can be used as early warning system. Dardac and Boitan²¹ combine different techniques (Principal component analysis [PCA], as a factor analysis technique, and binary logistic regression) trying to predict the likelihood of credit portfolio impairment for Romanian banking system. Three years later, Boitan²² made a research about development and usage of early warning system for evaluating the credit portfolio's quality of the Romanian banking system.

In the same year, 2014, two researchers separately made quite similar research. Caggiano²³ presented and defined early warning system to predict banking crisis in a sample of low-income countries in Sub-Saharan Africa, while Qin and Luo,²⁴ created an early warning systems for prediction of banking crisis in the G20 countries. At the same year, Fushing with his colleagues²⁵ created a methodology to present “the joint model of the latent architecture as well as early warning system of an impending crisis.” Authors usually tried to developed and presented early warning systems for predicting banking crisis and to detect potential indicators aimed to find out existence of banking crisis.^{26,27} Results of the research showed that GDP and credit growth and financial liberalization are critical factors for describing existence of banking crises.²⁶ Some of further researches in 2016 are focused on usage of early warning systems for predicting bank failures. The bank-level financial statements were analyzed by Tanaka, Kinkyō, and Hamori,²⁸ aimed to find patterns that

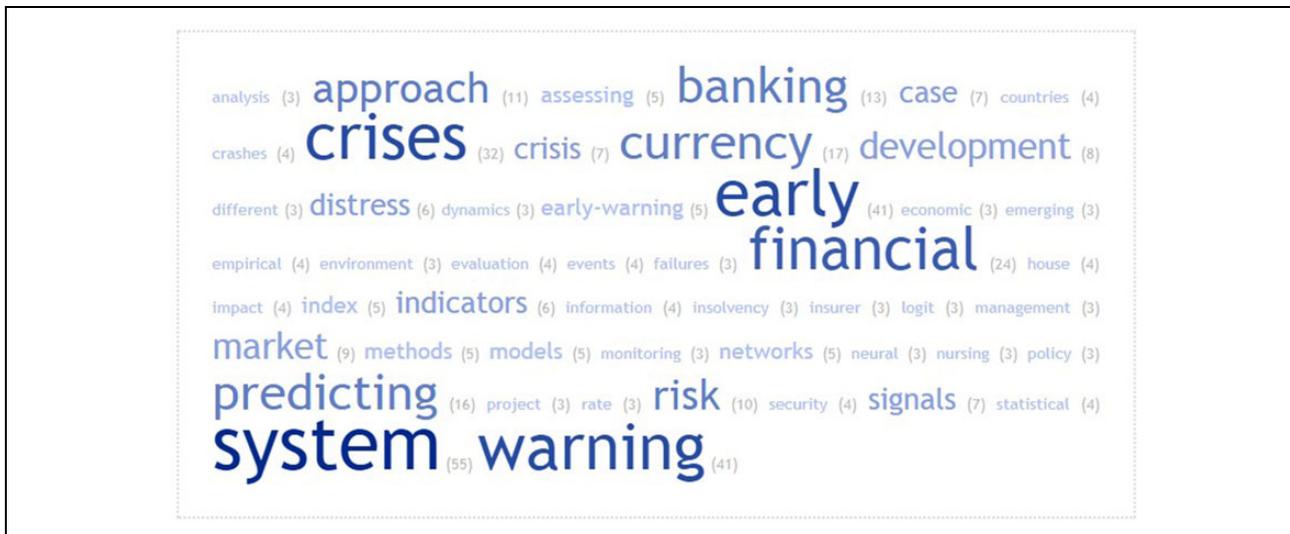


Figure 2. Tag cloud of the most often used words in paper titles; most frequent 50 words. *Source:* Authors’ work, WordItOut.

Table 6. Identification of two major topics with singular value decomposition.

Topic 1: Banking crisis		Topic 2: Currency crisis	
Words	SVD	Words	SVD
Finance	0.016162	Currenc	0.017990
Predict	0.015972	Crise	0.017300
Crise	0.014765	Approach	0.013107
System	0.013421	Countri	0.011582
Approach	0.013196	Indic	0.011444
Studi	0.011724	Early warning	0.011396
Bank	0.011485	Logit	0.010778
Early warning	0.011347	Multinomi	0.009194
Use	0.010983	Crash	0.00895
Case	0.010413	System	0.008647
Currenc	0.010167	New	0.007818
Network	0.009902	Lead	0.007688
Market	0.008346	Model	0.007313
Distress	0.008205	Differ	0.007188
Statist	0.007836	Exchang	0.007004

Source: Authors’ work; Statistica Data Miner.

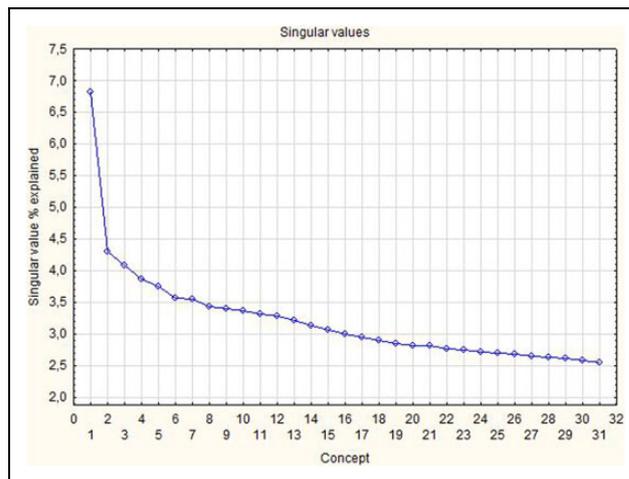


Figure 3. Scree plot of topics extracted with singular value decomposition. *Source:* Authors’ work; Statistica Data Miner.

would help banks to avoid failures. Hamdaoui²⁹ has made a research about early warning system of banking crisis trying to measure exposure of the domestic banking sector to international financial markets. Fendel and Stremmel³⁰ used early warning systems to compare elements of banking sector crisis in a diverse cross-country panel. They analyzed annual data for 152 countries from 1990 to 2011 and results showed systematic differences between country groups.

Most of the papers dealing with early warning systems in the area of banking crises were written after 2010. In other words, after the peak of the economic crises, researchers started to examine and evaluate how early warning systems can help for predicting bank failures. They specifically focused on possible indicators of unwanted situation in the banking sector.

Early warning systems on currency crisis. Analysis of selected papers showed that there are 19 papers that are focused on early warning systems in the area of currency crisis. Most of the articles are quite new, written in the last years (2007–2016) and six of them are older (1998–2005).

Kaminsky and his colleagues³¹ 20 years ago investigated currency crises and suggested early warning system that could help to prevent it. In their research, early warning system was used to observe several critical factors that would indicate unusual events. Factors that were the most significant for predicting currency crisis were deviations of the real exchange rate, exports, output, and equity prices. Two years later Osband and Rijckeghem³² examined set of factors which present environment without currency crisis and they called it “safe or near-safe.” External debt and reserves present significant factors for avoiding currency crisis. In order to avoid currency crisis

that have negative effects to whole economy system, Acevedo and Aguilar³³ developed several early warning systems, which discover unwanted events 9 months in advance. In 2004, Alvarez-Plata and Schrooten³⁴ examined whether the early warning system developed by Kaminsky et al.,³¹ as one of the first early warning system might have predicted the Argentinean currency crisis. Although they used large number of factors, the results showed that early warning system developed by Kaminsky et al.³¹ does not fit for investigation of the recession in Argentina. Berg and his colleagues³⁵ in their study investigated several early warning system models of currency crisis which International Monetary Fund (IMF) has been monitoring since 1999. Jacobs and Kuper³⁶ examined currency crisis indicators which could be used to predict possible financial crisis. They developed early warning system for these indicators and the results showed that money growth national savings and import growth have significant impact to currency crises.

Kamin and his colleagues³⁷ developed early warning system in order to define domestic and external indicators for currency crisis at emerging markets. The results showed that external shocks and imbalances do not have strong impact to currency crisis, while costs of accepting fixed exchange rate regimes have significant impact to currency crisis. Abiad³⁸ in his study developed early warning system that identifies crisis periods endogenously. Chong and his colleagues³⁹ developed early warning system for international currency crisis with the main goal to investigate the possible connection between the dynamics of foreign reserves and currency crises. Model they made enable provide indicators which imply that some actions have to be done to avoid the crisis. Licchetta⁴⁰ examined how external balance sheet variables influence on currency crisis in emerging market and advanced economies. The results showed that there are several significant variables that have strong impact to currency crisis: international capital flow, growth of the real exchange rate above its trend; faster growth in broad money; lower GDP growth; and crisis in neighboring country. El-Shazly⁴¹ examined early warning system and his role in detecting currency crisis. Using early warning system for observation of critical economic factors could help to detect unwanted values of critical indicators. Arduini et al.⁴² used early warning system to estimate the relationship between fundamentals and exchange rates and the possibility of a structural break in the period of 2 years (2007–2009). They extend original data from 1999, include 17 new countries, and had modifications of the original early warning system. Research results showed that early warning systems have not predicted correctly currency crises during the period from 2007 to 2009.

Christensen and Li⁴³ presented an early warning system that can predict the possibility of financial stress events within a certain time frame, focusing on currency

crisis. To achieve the goal of this article, they applied the signal extraction approach proposed in 1998 by Kaminsky et al.³¹ in order to examine economic factors that show unwanted behavior before financial crises occurred. Zhao and other research⁴⁴ in their study analyzed key factors of currency crisis and their role across exchange rate regimes. The results showed that for the fixed exchange rate regimes, external factors have stronger impact, while for the floating exchange rate regimes, monetary policy and credibility variables have more significant impact to predict currency crisis. Candelon and his colleagues⁴⁵ in their research paper broaden previous research on financial crisis early warning systems, which refer mostly on macroeconomic variables. The new, dynamic logit early warning system enables better prediction of currency crisis compared to static, old one early warning system. The main goal of the paper written by Sevim et al.⁴⁶ is to develop early warning system in order to forecast currency crisis. The research results showed that using macroeconomic indicators in early warning system developed by using artificial neural networks, decision tree, and logistic regression models, it is possible to predict currency crisis 1 year earlier with an accuracy rate of approximately 95%. Bucevska⁴⁷ developed an econometric model of early warning system with the goal to forecast currency crisis in the EU candidate countries. Research results showed that real GDP growth rate, contribution in an IMF loan program, current account, and fiscal balance are the most important variables for predicting currency crises in selected countries (Croatia, Macedonia, and Turkey). Chen and Kuo⁴⁸ in their study analyzed early warning system for investigation of exchange rate variability and pressures of the Asian currency unit. The results showed that stable banks business, international trade, and money supplies present the most significant variable to avoid financial crisis related to Asian currency unit. Ari and Cergibozan⁴⁹ in their study define and analyze 10 most significant indicators already used in the literature and created two new crisis indicators.

Analysis of selected papers in the area of currency crises showed that most of the papers have been written after the global economic crises. However, one of the first early warning systems was developed by Kaminsky et al.³¹ and some of other research studies are based exactly on that model. Most of the studies are focused on detecting significant factors that can help to avoid currency crises.

Early warning systems on macroeconomic and stock exchange crisis. Analysis of selected papers showed that there are 34 papers that are focused on early warning systems in the area of macroeconomic and stock exchange crisis. Some of these papers that are presented have been written from 2003 to 2015.

Lo Duca and Peltonen⁵⁰ developed a framework for predicting periods of financial instability. Research results showed that factors of domestic and global macro-financial

vulnerabilities have positive impact in predicting financial crises. Candelon et al.⁴⁵ presented an original tool used to estimate financial crisis early warning systems. Logit model was applied for 12 emerging countries and the results showed that profit is a main factor in predicting financial crises in the area of South Asia. Demyanyk and Hasan⁵¹ analyzed several research paper dealing with financial crises to predict and determine how financial crises could be prevent or avoid. Gray⁵² discussed about global financial crises and its peak of 2 years (2007–2009) and the importance of better and qualitative analysis for prediction of financial crises. Furthermore, he focused on factors important for modeling financial crises and sovereign risk and usage of early warning system, which could help to monitor and prevent possible risks. Fioramanti⁵³ analyzed data about sovereign debt crises which happened in the period of 24 years (1980–2004) in developing countries. Results showed that less developed nonparametric method based on artificial neural networks could help in the better prediction of financial crises. Bussiere and Fratzscher⁵⁴ developed an early warning system based on the multinomial logit model that could be used for precise prediction of a large majority of financial crises in emerging markets. Nocetti⁵⁵ extended the research made by Blejer and Schumacher⁵⁶ who suggested that Central Bank's Value at Risk (VaR) could be used as an early warning indicator of financial crises.⁵⁷ Research results showed that there is strong relationship among different measures focused on value at risk and several univariate leading indicators. Pazour⁵⁸ focused on two standard methods for development of the early warning system: (i) the signal approach and (ii) the regression probit or logit model approach. Results showed that is important for each particular country to construct specific early warning systems. Edison⁵⁹ aimed to develop an operational early warning system, which is able to predict financial crisis. In order to achieve the goal, author investigated and evaluated early warning systems developed by Kaminsky, Lizondo, and Reinhart.³¹ The results are twofold. First of all, early warning system could be used as a useful predicting tool. Second, several weaknesses could be defined.

Geng and his colleagues⁶⁰ studied the issue of financial distress for 107 Chinese companies that were under "special treatment" in the period of 7 years (2001–2008) by the Shanghai Stock Exchange and the Shenzhen Stock Exchange. Data mining techniques were used in order to build financial distress warning models based on 31 financial indicators. Research results showed that financial indicators, such as return on total assets, net profit margin of total assets, earnings per share, and cash flow per share, are significant factors in predicting deterioration in profitability. Gresnigt and his colleagues⁶¹ presented a framework of early warning system which enables predictions on a future market crash. S&P 500 data of the last financial crises were used to test early warning system and the results showed positive Hanssen-Kuiper Skill Scores.

Early warning systems in different areas and industries. Analysis of selected papers showed that there are 49 papers that are focused on different areas and industries where early warning systems can be used to predict possible crises. Some of these papers that are presented have been written in the period of 10 years (2006–2016).

Several papers are focusing to the crisis within companies. Cooper (2006) presented early warning system developed by The 2004 Constitutional Treaty for national parliaments to detect European legislative proposals and their compliance with the principle of subsidiarity. Botterhuis et al.⁶² presented an early warning system, which was developed for the Dutch Ministry of Justice in order to determine scenarios, which could happen and enable its departments to adapt procedures and legislatives to new situations.

Several research models are focusing to environmental and food-shortage crisis. Araujo et al.⁶³ aimed to define warning signs of flooding food crises in African countries (Mali, Burkina Faso, and Niger) through grain price. They define early warning indicators, which were evaluated using panel data qualitative choice models. Results revealed that price at the main markets could be great indicator for predicting future price crises. Abon with colleagues⁴ were the first who intended to involved communities and flood modeling in the implementation of a flood early warning system. The results are used for prediction of flood in different parts of the Philippines. Gül et al.⁶⁴ compared several Turkish farms, which produce different apple products regarding usage of early warning system. Almost 40 years, since 1980, these regions started using early warning systems especially for black spot and codling moth. Research results showed that there is high level of farmers who are using early warning system regarding apple cultivation, that is, 41.6% of the farmers use the pesticide application time from early warning system. Xu et al.⁶⁵ presented how an effective early warning system can enable managers to make efficient decisions in periods of financial crises. Persson et al.⁶⁶ examined development and usage of local early warning systems for floods in Sweden. Results showed that early warning system can help in reducing floods losses, which lead to more investments and further implementation of early warning systems. Aparicio-Effen et al.⁶⁷ presented how climate change and El Niño Southern Oscillation (ENSO) situations influence on human health and on social and economic inequalities in Bolivia, Paraguay, and Uruguay. Usage of early warning systems presents a key factor to overwhelmed extreme and unwanted situations.

These examples indicate early warning systems can be used in different industries and areas. Although they are mostly used to predict economic collapse with the goal to prevent and avoid unwanted situations which lead to economic and social inequality. Analysis showed that early warning systems can be used to detect and prevent food crises, environmental (floods, climate) and agriculture

issues (apple cultivation), and legislative issues (Dutch Ministry of Justice and European parliament).

Conclusion

Early warning systems enable organizations to minimize loss and are of great importance before the emergency occurs.⁶⁸ They should be considered as total systems, relating to the content of risk management, rather than simply forecasting instruments.⁶⁶ In order to conduct the systematic literature review on the early warning systems, this research provided the insight into the bibliometric trends of research in the area of early warning systems in management, economics, public administration, business finance, and business fields. Contribution of our study is that it brings new knowledge and key insights into the subject of early warning systems development and usage in economic and finance sector that is previously not well researched. Early warning systems become new technology, which enables more efficient actions and lowers costs. Therefore, knowledge gathering to detect risk, before it is too late, is essential for the organization to maintain a competitive advantage on the market. Contribution of our study is also the widened understanding of usage of early warning systems in the area of business, finances, and economy. This study provides a road map of a few possible ways for usage of early warning systems. The findings can be useful for managers at all organizational levels, also for the reason that is important, from a risk reduction perspective, to identify added value from early warning systems. With the results of our study, companies might learn about developments in the field of early management systems and learn information that might help with their decision process. The main limitation of this article, which can be, however, addressed in a future research, is that we only looked at articles from the database of the SCI, SSCI, and A&HCI (Web of Science database), so we did not cover journals that might only be available in other databases, such as Scopus. Future bibliometric studies on early warning systems should look at other databases in order to determine which articles were potentially missed by our study. Further researches should be also focused on deeper investigation of this topic and could include case studies of early warning systems with qualitative data.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

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