Adv. Math. Fin. App., 2022, **7(**1), P.1-36

Advances in Mathematical Finance & Applications
www.amfa.iau-arak.ac.ir
Print ISSN: 2538-5569
Online ISSN: 2645-4610
Doi: 10.22034/AMFA.2021.1942092.1639

Review Paper

DEA Approaches for Financial Evaluation - A Literature Review

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ARTICLE INFO

Article history:
Received 17 May 2021
Accepted 16 September 2021

Keywords:
Data Envelopment Analysis (DEA),
Financial evaluation,
Efficiency,
Literature review

ABSTRACT

Today, marketing researchers are constantly trying to carefully examine consumer behavior and accordingly, provide appropriate solutions for better and more effective sales, which in turn will lead to an increase in their market share. In this regard, the purpose of this study is to investigate the role of customer clustering in the design of a targeted marketing model. The research method is applied and exploratory. The statistical population studied in the qualitative section was sales and marketing managers of companies providing Internet of Things technology services, and 15 people were selected for interviews by non-random and available methods. In the quantitative section, all the customers of the studied companies were included, and due to the unlimited nature of the society with Morgan's table, 384 people were selected as the sample size. The data collection tools in this study were interviews and questionnaires, which used the opinions of marketing experts and reliability of Cronbach's alpha to examine the validity of the questionnaire. In order to analyze the data, first decision methods such as entropy and VIKOR were used and then to analyze the results, structural equations obtained with PLS2 software were used. The results showed that the dimensions of the model in question fall into four main clusters, communicational factors, behavioral factors, individual factors and economical factors that customers are classified according to the characteristics of using the services provided, are classified in these clusters.

1 Introduction

Data Envelopment Analysis (DEA) is a data-driven and non-parametric mathematical programming approach which is originated by [34]. The DEA utilizes multiple inputs and multiple outputs for evaluating the relative efficiency of homogeneous and comparable Decision-Making Units (DMUs) [172]. Because of the uniqueness of DEA, it has been widely developed and used to measure performance in different domains since 1978 [89]. A growing body of literature has investigated its application in various fields, such as performance evaluation([178], [149]), supplier selection ([170], [90]), energy efficiency ([8], [100]) and in many industries such as auto parts ([156], [171]), stock exchange ([113], [133]), insurance companies ([192], [95]), banks ([2], [83]). Financial evaluation of a project is analysis

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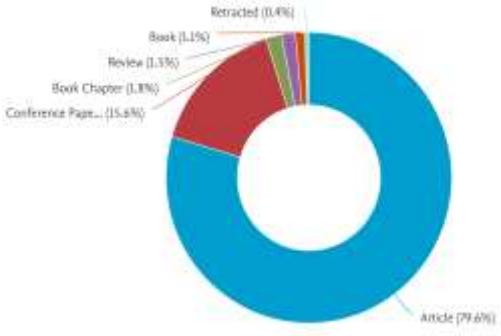
of a project for checking whether project is profitable or not before taking project in hand ([120]). We also review the project by investigating its cost, risk and return. If we have lots of alternatives projects, then we select best project on the basis of financial evaluation ([48]). Data Envelopment Analysis Models as efficient mathematical models, are also a practical tool for financial evaluation of industries and organizations. Ozcan and McCue [139] presented a method of measuring and assessing financial performance for hospitals using data envelopment analysis. Ray and Mukherjee [150] utilizing the input and output data for the years 1984-1990, developed a mixed integer programming DEA model for evaluating the 201 large banks. Resti [152] applied a DEA based cost function method to generate the data of six samples of firms producing three outputs by means of two factors. Grosskopf and Moutray [71] applied the DEA methodology to analysis the changes in performance for Chicago high schools between 1989 and 1994, and to assess whether this decentralization improved performance or not. Chen [37] applied both chance-constrained data envelopment analysis and stochastic frontier analysis to measure the technical efficiency of 39 banks in Taiwan. For the purpose of measuring the performance of ethical mutual funds, Basso and Funari [19] employed the data envelopment analysis approach to propose a performance indicator that considers the expected return, the investment risk, the ethical component and the subscription and redemption costs together. Bowlin ([26]) evaluated the financial stability of Civil Reserve Air Fleet participants using data envelopment analysis complemented by ratio analysis. Ouellettea and Vierstraete [138] applied Data Envelopment Analysis model to measure the efficiency of Quebec's school boards during a period of severe cutbacks in their finance. Yang ([192]) developed a two-stage data envelopment analysis to provide valuable managerial insights when assessing the dual impacts of operating and business strategies for the Canadian life and health insurance industry. Liu ([115]) employed the data envelopment analysis models to evaluate the relative efficiencies of the credit departments of farmers' associations in Taiwan. Tseng et al. ([173]) used an integrated data analysis scheme based on Analytical Hierarchical Process and Data Envelopment Analysis to assess the performance and to rank importance of inputs/outputs for Taiwan's retailing industry. In order to develop a meaningful set of financial benchmarks that will dictate best practices and shape up a successful hotel business model, Min et al. ([127]) applied a data envelopment analysis model to help the hotel management enhance its financial efficiency and price leverage in the increasingly competitive hotel industry. Guan and Chen ([73]) developed a methodological framework based on a non-radial data envelopment analysis model and a non-radial Malmquist index for effectively measuring the production frontier performance of macro-scale R&D activities. Gregoriou et al. ([69]) presented a data envelopment analysis model to measure the "congestion amount" that can offer a more precise picture of identifying Commodity Trading Advisors suffering from congestion. Elyasiani and Wang [53] applied the Data Envelopment Analysis to calculate the Malmquist index of productivity, and the total factor productivity change for a sample of Bank Holding Companies over the period 1997–2007. Varabyova and Schreyögg [177] employed the nonparametric data envelopment analysis model and parametric stochastic frontier analysis to provide a comparison of the technical efficiency of the hospital sector using unbalanced panel data from OECD countries over the period 2000–2009. Basso and Funari ([20]) presented some DEA models to evaluate the performance of Swedish socially responsible investing mutual funds in the period June 2006 to June 2009.

Yang et al. ([191]) applied some various statistical techniques such as data envelopment analysis, structural equation modeling and factor explanatory financial model, to develop a conceptual framework which links various assets, capabilities and firm value.

Sexton ([160]) employed the data envelopment analysis models to assess the relative performance of New York State school districts in the 2011–2012 academic year and provided detailed alternative improvement pathways for each district. Hoe ([84]) proposed a financial ratio based Data Envelopment Analysis model to evaluate and compare the efficiency of listed technology companies in Malaysia for the period of 2011–2015. Moreno and Lozano ([134]) proposed a two-stage network data envelopment analysis structure, to identify inefficiencies in the management of public finance, such as overspending, unreasonable debt, and excessive taxes, while maintaining the same level of social welfare. Xiong [189] developed a distance friction minimization model model based on multi-objective, quadratic and non-linear programming model to analyse China's transportation sectors. Li et al. ([108]) used a min/max slacks-based measure data envelopment analysis to explore the operational efficiency of 37 banks in Taiwan from 2012 to 2016. Dutta ([52]) presented a data envelopment analysis model to analysis the performance of non-banking finance companies in the Indian context.

Mohsin et al. ([132]) used a DEA like composite indicator to develop a low carbon finance index that may help out to entice foreign direct and private investment in low-carbon energy sector. Chien ([40]) applied a data envelopment analysis method to analysis the relationship between energy, financial, and environmental sustainability and the regions' social performance. Mugambi ([135]) used the Data Envelopment Analysis model to determine whether the Spanish regions maintain homogeneous efficiency levels by using resources to improve the levels of environmental quality related to renewable energies. Kedžo et al. ([63]) employed the data envelopment analysis model to evaluate the small food and drink producers from selected countries in the European Union and estimates their financial efficiency using raw financial variables instead of financial ratios. Petridis et al. ([143]) proposed a two-stage approach for prioritizing volatility models, where in the first stage they developed a new slack-based data envelopment analysis to rank volatility models. In the second-stage analysis, it is investigated whether the efficiency scores depend on model characteristics. For this evaluation, research activities in which data envelopment analysis method is used in financial issues and published in the period 1994 to 2021 are considered. The search string format used was: TITLE-ABS-KEY ("Data Envelopment Analysis" OR "DEA") AND TITLE-ABS-KEY ("Finance" OR "Financial") AND PUBYEAR > 1990). Based on this, selected works have been selected and published in the Scopus citation database[1], and therefore 455 research activities including journal articles, conference papers, book series, and books are listed in Table 1.

Table 1: Used Sources

Source	**Number of Docs**	**Illustration (%)**
Journal	371	
Conference_Proceeding	59	
Book_Series	14	
Book	11	
Total	455	

[1] www.Scopus.com

We can see that, the major share of the found resources (i.e., 81.5%), belongs to journal papers. Moreover, the last column of Table 1 illustrates the share of each sources.

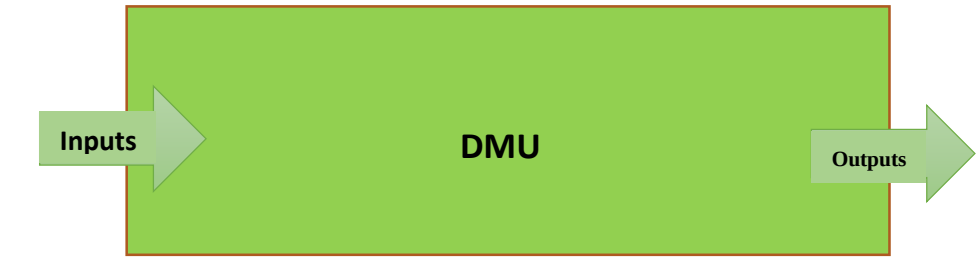
2 DEA History and Models Development

In this section, we review the main models of data envelopment analysis from a mathematical perspective and then we check their applications to the financial evaluation of organizations.

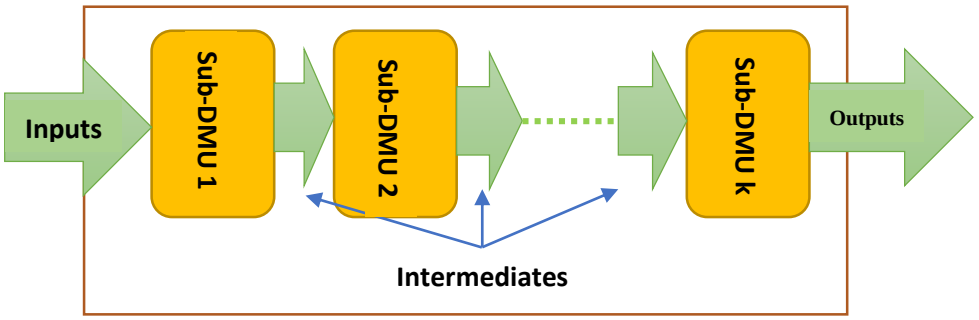
2.1 Data Envelopment Analysis Models

Data envelopment analysis was first introduced by Charnes et al. ([35]) by presenting the CCR model and then used in various applications of industries and organizations ([91], [99]). The CCR model, which uses fixed-scale efficiency technology to evaluate decision-making units, is presented in the form of Model (1).

$$
\begin{aligned}
&\theta_o^{CCR} = \min\ \theta \\
&\text{s.t.} \\
&\sum_{j\in J} \lambda_j x_{ij} \le \theta x_{io} \quad \forall i \\
&\sum_{j\in J} \lambda_j y_{rj} \ge y_{ro} \quad \forall r \\
&\lambda_j \ge 0 \quad \forall j
\end{aligned}
\tag{1}
$$



a: a black-box DMU



b: a DMU with Network Structure

Fig. 1: Black-box vs. Network DEA approaches

The BCC model ([15]) is also one of the basic models of data envelopment analysis based on variable scale efficiency technology ([47]). CCR and BCC models are considered as radial models. Due to the drawbacks of radial models, non-radial models such as the SBM model were developed ([172], [167]). The conventional DEA models make no assumptions regarding the internal operations of a DMU and consider each DMU as a 'black-box' ([96]). This structure reveals no insight related to the sources of inefficiency and cannot provide process-specific guidance to DMUs' managers to improve the DMU's efficiency ([107]). On the other hand, many real-world problems, have a network structure such that the production process (DMU) is divided into multiple stages (sub-DMUs) so that an intermediate product plays the role of an output for one stage meanwhile it plays the role of an input for another stage ([128], [106]). In the black-box approach the efficiency score of a DMU is a function of its inputs and outputs, meanwhile in the network DEA approach opens the black-box of efficiency and evaluates the performance a DMU with taking its inputs, outputs, and intermediate factors into consideration. Fig. 1 illustrates the difference between the traditional and network DEA approaches.

2.2 DEA Methodologies Employed

The majority of the reviewed papers focus on analytical models, and a variety of DEA methods have been applied in developing these models. The evaluation of the methodologies used in the articles under review shows that, the researchers in the financial evaluation of organizations have mainly used seven approaches: Cross Efficiency (0.78%), Dynamic Efficiency (1.30%), Extending DEA Models (22.54%), Malmquist Model (12.69%), Multi-Objective DEA (3.63%), Network DEA (6.48%), and Traditional DEA (52.59) %). It can be seen that the approach of using traditional models such as CCR and BCC has been most used in this study. Fig. 2 depicts the distribution of using different DEA methods in financial evaluations.

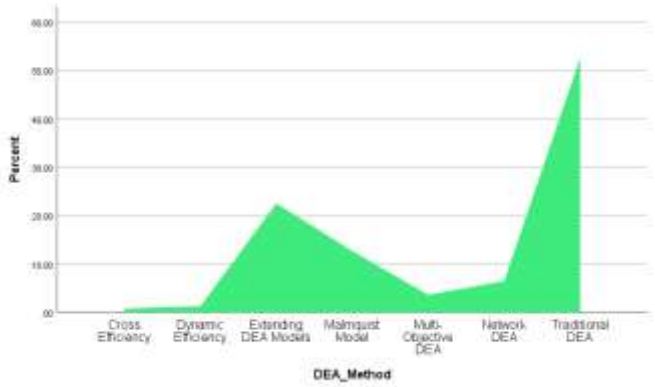


Fig. 2: Distribution of using different DEA methods

As Fig. 2 shows, the most frequently used DEA methods in financial assessment study are Traditional DEA models (e.g., CCR and BCC models). Recently, more and more advanced DEA models (the other six Categories) have been developed and applied in financial research in response to the growing demand for analysis accuracy and data complexity. Additionally, Fig. 3 illustrates the distribution of applying different DEA methods based on various years. We can see that the biggest share is assigned to the "Traditional DEA" for the year 2020.

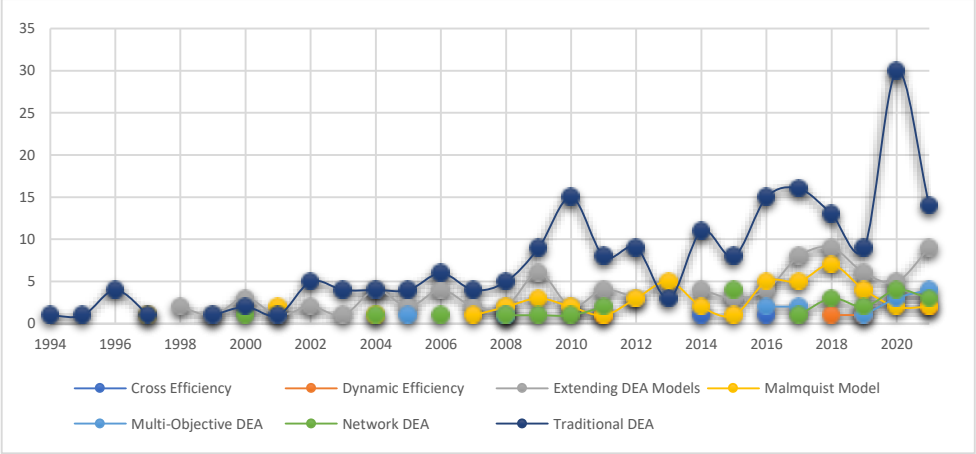


Fig. 3: Distribution of applying different DEA methods based on various years

On the other hand, data envelopment analysis models evaluate decision-making units both radially and non-radially. Typically, traditional DEA models use the radial measure and calculate efficiency based on the input excesses and output shortfalls. However, non-radial DEA models are also frequently applied for measuring the financial performances. The study shows that in 89% of the recorded studies, radial models and in 11% of non-radial models have been used (Fig. 4).

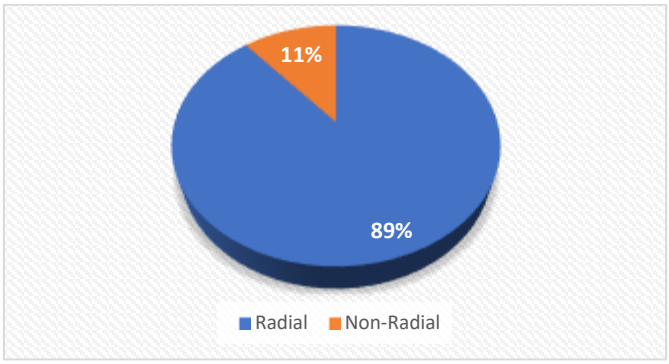


Fig. 4: Radial and Non-Radial Distribution

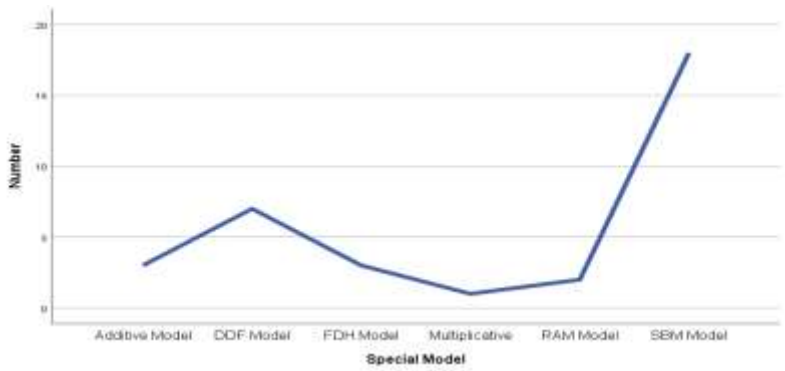


Fig. 5: Distribution of using different DEA models

Table 2: Most important scientific published works

No	Documents Title	Year	Reference	Source	Publisher	Second Method	Application	Citations
1	The efficiency of Australian universities: a data envelopment analysis	2003	[1]	EER[2]	Elsevier	-	University	385
2	Multi-factor performance measure model with an application to Fortune 500 companies	2000	[202]	EJOR[3]	Elsevier	Network DEA	Business Sector	299
3	Efficiency of mutual funds and portfolio performance measurement: A non-parametric approach	1997	[136]	EJOR	Elsevier	Statistics	Portfolio	205
4	The Application of Data Envelopment Analysis in Conjunction with Financial Ratios for Bank Performance Evaluation	1996	[194]	JORS[4]	Taylor and Francis	Statistics	Bank	179
5	Social efficiency in microfinance institutions	2009	[74]	JORS	Taylor and Francis	Statistics	Bank	155
6	Cost efficiency measurement with price uncertainty: a DEA application to bank branch assessments	2005	[30]	EJOR	Elsevier	-	Bank	152
7	A Data Envelopment Analysis Approach to Measure the Mutual Fund Performance	2001	[18]	EJOR	Elsevier	Statistics	Portfolio	138
8	A Comparison of Data Envelopment Analysis and Artificial Neural Networks as Tools for Assessing the Efficiency of Decision Making Units	1996	[10]	JORS	Taylor and Francis	Neural Network	Bank	131
9	A hybrid approach of DEA, rough set and support vector machines for business failure prediction	2010	[193]	ESWA[5]	Elsevier	Rough Set	Business Sector	120
10	Use of DEA cross-efficiency evaluation in portfolio selection: An application to Korean stock market	2014	[203]	EJOR	Elsevier	Statistics	Stock Exchange	116
11	Measuring DEA efficiency in Internet companies	2005	[159]	DSS[6]	Elsevier	-	Industry	115
12	Ownership, organization, and private firms' efficient use of resources	2003	[51]	SMJ[7]	John Wiley	-	Industry	111
13	Impact of Ownership and Competition on the Productivity of Chinese Enterprises	2001	[198]	JCE[8]	AP	Malmquis t index	Business Sector	111
14	International comparisons of the technical efficiency of the hospital sector: panel data analysis of OECD countries	2013	[177]	HP[9]	Elsevier	SFA	Hospital	106
15	Operational efficiency versus financial mobility in the global airline industry: a data envelopment and Tobit analysis	2004	[158]	TRP A[10]	Elsevier	Regression	Airport	104
16	DEA as a tool for bankruptcy assessment: A comparative study with logistic regression technique	2009	[145]	EJOR	Elsevier	Regression	Simulation	102
17	A balanced scorecard analysis of performance metrics	2004	[14]	EJOR	Elsevier	Balanced Scorecard	Industry	101

Total citations to selected research papers during the years 2017 to 2021 is depicted in Fig. 6. The upward trend in citations indicates the growing importance of financial issues in real applications.

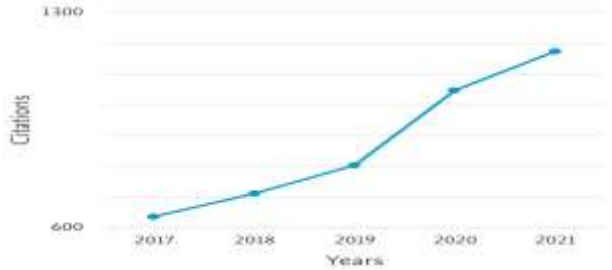


Fig. 6: Total citations during the years 2017 to 2021

[2] EER: Economics of Education Review
[3] EJOR: European Journal of Operational Research
[4] JORS: Journal of the Operational Research Society
[5] ESWA: Expert Systems with Application
[6] DSS: Decision Support Systems
[7] SMJ: Strategic Management Journal
[8] JCE: Journal of Comparative Economics
[9] HP: Health Policy
[10] TRP A: Transportation Research Part A

The analysis of the recorded scientific works as well as the number of citations to them during the study period shows that the h-index for the scientific works under study is equal to 49. That is, 49 documents out of all documents have been cited at least 49 times. The related *h*-graph, which is one way of displaying and comparing the productivity and impact of published work of scholars, is depicted in Fig. 7.

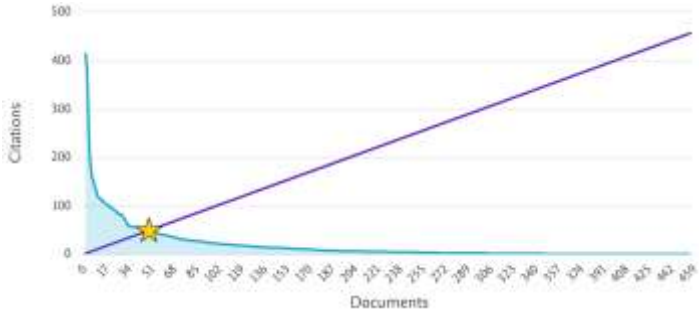
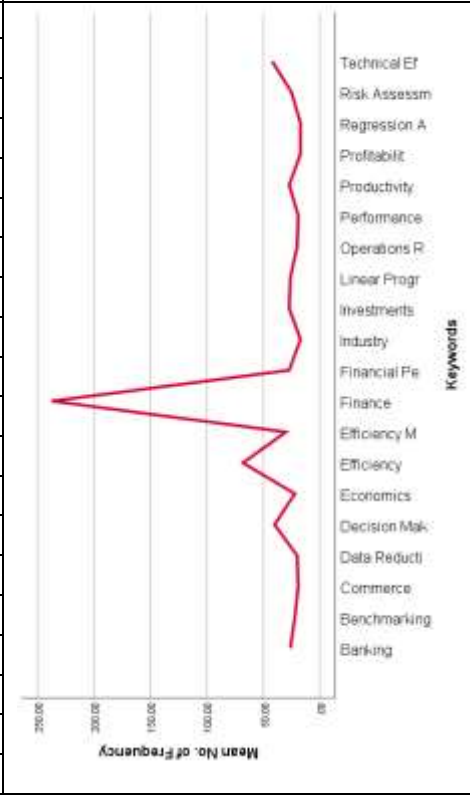


Fig. 7: H index of the selected papers

The most important keywords used in the research under review (except for data envelopment analysis, of course) are summarized in the Table 3. These keywords reflect the methods and methodologies that, along with data envelopment analysis methods, work on the financial evaluation of organizations.

Table 3: Most important keywords used in the research under review

No.	Keywords	No. of Frequency	Illustration
1	Finance	237	
2	Efficiency	68	
3	Technical Efficiency	42	
4	Decision Making	40	
5	Efficiency Measurement	30	
6	Financial Performance	27	
7	Investments	27	
8	Productivity	27	
9	Banking	26	
10	Linear Programming	26	
11	Risk Assessment	25	
12	Benchmarking	22	
13	Economics	22	
14	Data Reduction	20	
15	Operations Research	20	
16	Commerce	19	
17	Performance	19	
18	Industry	17	
19	Profitability	17	
20	Regression Analysis	17	

3.2 Publications over time

Fig. 8 demonstrates the number of publications per year from 1994 to 2021. It can be seen that the chart generally has an increasing trend. This indicates the growing importance of evaluating different industries and organizations from a financial perspective with the help of data envelopment analysis approach. It can be said that the first paper in this field was presented in 1994 by [120] to evaluate the financial performance of hospitals using the data envelopment analysis approach. Since then, many researchers have drawn attention to the use of DEA method for financial evaluation of organizations, and the number of researches in this field has increased year by year.

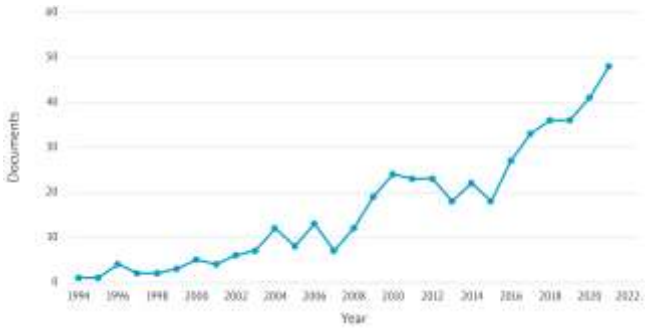


Fig. 8: Publication based on each year

It can be seen that in 2021, a significant share of writings in this field (i.e., 10.5% of the total works) has been recorded. Therefore, the field of application of optimization problems and especially data envelopment analysis in financial issues is always welcomed by scientists. This growing trend is directly related to the promotion and prosperity of industry in societies.

3.3 Publication outlets and scholarly community

Approximately half (22%) of the reviewed articles were published in 10 journals (see Table 4) and these journals present a wide range of research scope from specialized journals in financial and economic journals to general operational management journals. Among the 10 journals, three journals published at least 10 articles, including Energy Econ European Journal of Operational Research, Journal Of The Operational Research Society, Expert Systems With Applications. The considered works have been published in 160 sources, with the largest share belonging to the European Journal of Operational Research (29 docs out of 160; 18.13%). Table 4 reports the ten sources that have the largest share in the explore of publications in the field of application of data envelopment analysis in financial issues during the period 1994-2021.

Table 4: Top ten sources

No.	Source/Journal	Publisher	No. of Documents	Percent	Rank
1	European Journal Of Operational Research	Elsevier	29	18.13%	1
2	Journal Of The Operational Research Society	Taylor and Francis	21	13.13%	2
3	Expert Systems With Applications	Elsevier	13	8.13%	3

Table 4: Continue

No.	Source/Journal	Publisher	No. of Documents	Percent	Rank
4	Sustainability Switzerland	Springer	7	4.38%	4
5	Applied Economics	Taylor and Francis	6	3.75%	5
6	Energy Policy	Elsevier	5	3.13%	6
7	Environmental Science And Pollution Research	Springer	5	3.13%	6
8	Industrial Management And Data Systems	Emerald	5	3.13%	6
9	International Transactions In Operational Research	Blackwell	5	3.13%	6
10	Journal Of Physics Conference Series	IOP	4	2.50%	10

The process of publishing financial writings works during the period under evaluation by the top five sources is depicted in Fig. 9.

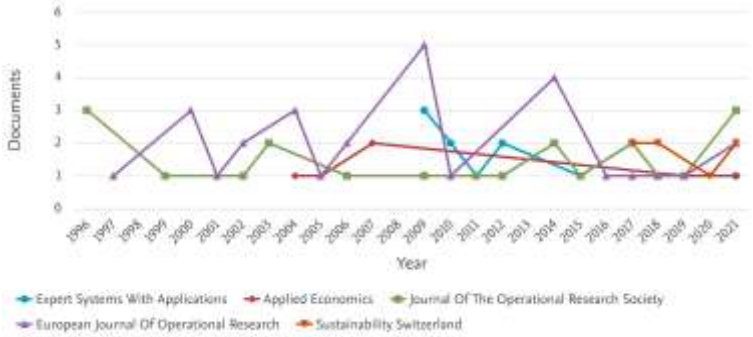


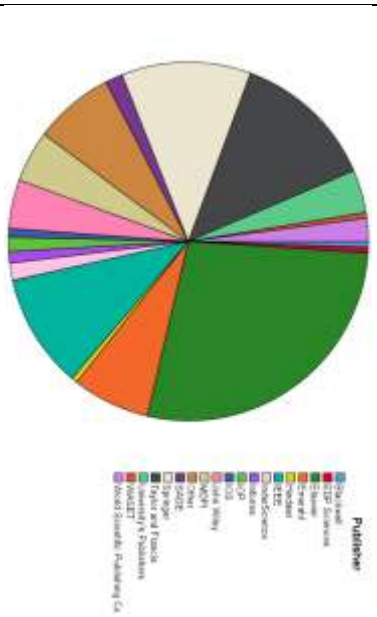
Fig. 9: Trends of top five sources

Table 4 illustrates the publishers of the top ten sources for publishing works. We can see that, the publishers Elsevier, Taylor and Francis, and Springer have published the most frequency scientific works. These publishers are the most important publishers in the field of operations research. The table below shows the number and percentage of scientific publications published in the top publishers in this field. Elsevier Publications has the largest share, publishing 107 scientific papers (27.6%) out of 455 papers during the period. Also, the contribution of each publisher in the publication of related scientific works throughout the period is depicted in the last column of Table 5.

Table 5: Scientific publications' share published in the top publishers

Publisher	Number	Percent	Rank	Illustration
Blackwell	2	0.5	16	
EDP Sciences	2	0.5	16	
Elsevier	107	27.6	1	
Emerald	27	7.0	6	
Hindawi	2	0.5	16	
IEEE	40	10.3	4	
InderScience	6	1.6	11	
INFORMS	4	1.0	14	
IOP	5	1.3	13	

Table 5: Continue

Publisher	Number	Percent	Rank	Illustration
John Wiley	17	4.4	8	
MDPI	18	4.7	7	
Other	28	7.2	5	
SAGE	6	1.6	11	
Springer	45	11.6	3	
Taylor and Francis	50	12.9	2	
University's publishers	15	3.9	9	
WASET	2	0.5	16	
World Scientific Publishing Co.	8	2.1	10	

In addition, the process of publishing scientific works related to the application of data envelopment analysis in financial fields during the period under review for each publication is illustrated in Fig. 10. It should be noted that publishers with the publication of at least two articles are mentioned in this evaluation.

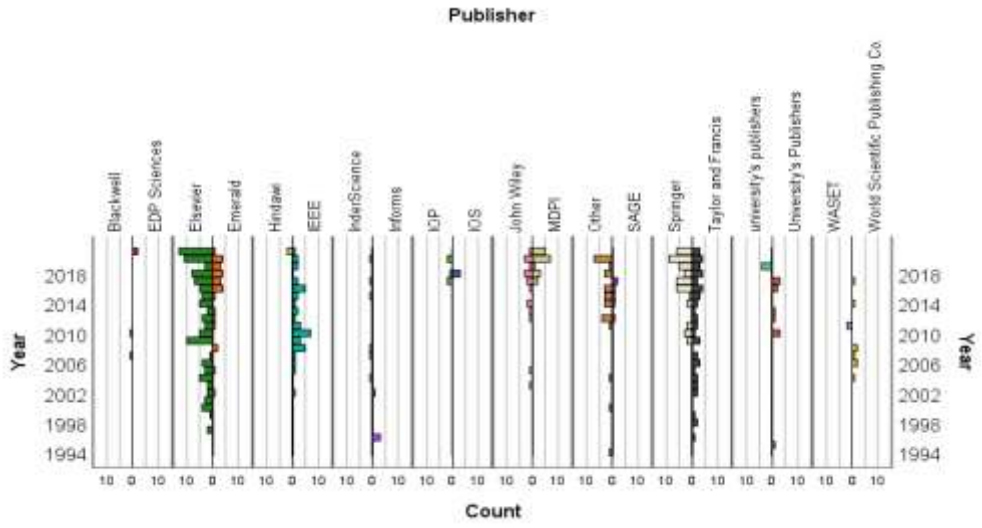


Fig. 10: Number of documents published in various publishers each year

Fig. 11 shows that the largest share of scientific publications in the whole period is related to the year 2021, in which Elsevier Publications has succeeded in publishing 13 scientific works in the field of application of data envelopment analysis method in financial issues. Various authors have participated in the publication of scientific works related to the application of data envelopment analysis method in finance. The most participation in this area are recorded by Sueyoshi T. (1.98%), Goto M. (1.54%),

Basso A. (1.32%), Funari S. (1.10%), Tzeremes N.G. (1.10%), Fernandes E. (0.88%), and Lu W.M. (0.88%), respectively. The contribution of the authors with the most recorded scientific work is depicted in Fig. 11.

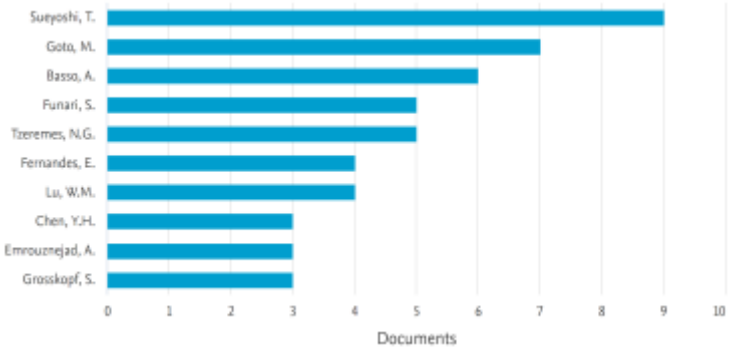


Fig. 11: Contribution of the authors with the most recorded scientific

In addition, the research institutes that have the largest share in the publication of scientific works are depicted in the figure below (Fig. 12). It can be seen that the largest share of participation in scientific work belongs to Ca 'Foscari University of Venice (1.76%), National Cheng Kung University (1.76%), and New Mexico Institute of Mining and Technology (1.76%), respectively.

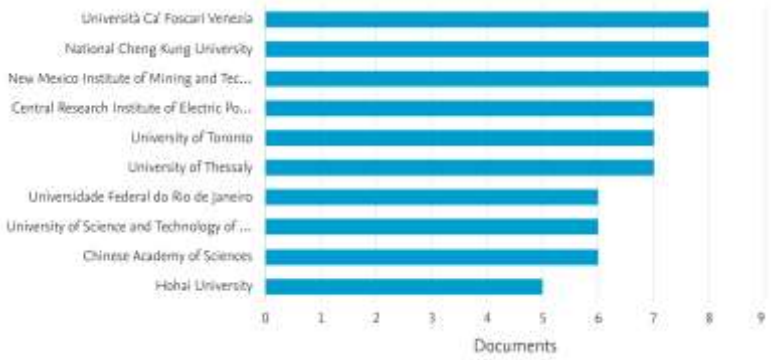


Fig. 12: Research institutes with most publications

In addition, a list of the top 20 countries that have contributed to the publication of scientific papers in the field of finance using data envelopment analysis is summarized in the table below. It can be seen that China had the most participation with 106 scientific works (17.64%). In addition, Iran, with the publication of 13 scientific works (2.16%) in this regard, is ranked 15th.

Table 6: Top 20 countries that have contributed to the publication of scientific papers

No.	country/territory Number	No. of Documents	Percent	Rank
1	China	106	17.64	1
2	United States	72	11.98	2
3	Taiwan	52	8.65	3
4	United Kingdom	31	5.16	4
5	Australia	21	3.49	5
6	Japan	18	3.00	6
7	Spain	18	3.00	6

Table 6: Continue

No.	country/territory Number	No. of Documents	Percent	Rank
8	Canada	17	2.83	8
9	India	17	2.83	8
10	Malaysia	16	2.66	10
11	Greece	14	2.33	11
12	Brazil	13	2.16	12
13	Czech Republic	13	2.16	12
14	France	13	2.16	12
15	Iran	13	2.16	12
16	South Korea	13	2.16	12
17	Italy	11	1.83	17
18	Turkey	10	1.66	18
19	Slovakia	8	1.33	19
20	Indonesia	7	1.16	20

Fig. 13 depicts the participation of countries in the publication of scientific works using the data envelopment analysis method in financial matters.

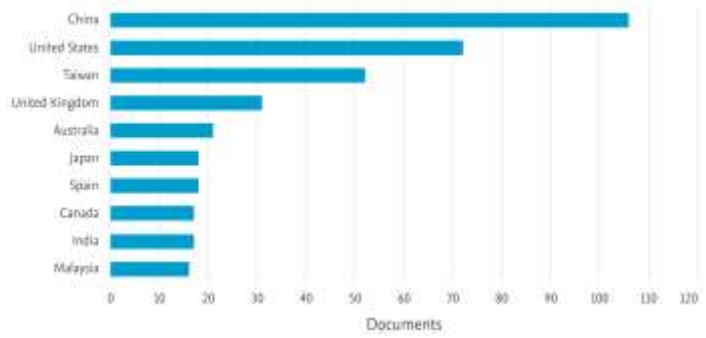


Fig. 13: Participation of countries in the publication of scientific works

4 Distribution of data envelopment analysis application

The following discussion is structured into four sections that are related to the different applications of data envelopment analysis method in financial evaluations. To this end, we first survey the research analysis unit and application area along with the distribution of various data in financial evaluation and the distribution of assistant methods in financial assessment. The we analysis the various categories of functions into real problems.

4.1 Research analysis unit and application area

The study of published publications shows that data envelopment analysis has been used in the financial evaluation of various practical and real issues, the most important of which are summarized in the table below. Accordingly, sixteen categories of the applications in real-world problems have been detected throughout the selected papers. The summary of information about the distribution of various financial applications are given in Table 7.

Table 7: Distribution of various financial applications

Application	Selected References	No. of Documents	Percent	Rank
Agriculture	[101], [105], [43], [109], [180], [62], [191], [188], [81], [3], [119], [164], [129], [195]	23	5.82	6
Airport	[140], [26], [31], [158], [55], [125], [12]	8	2.03	11
Bank	[10], [194], [152], [114], [68], [56], [11], [112], [116], [78], [53], [154], [46], [58], [130], [183], [179], [41]	91	23.04	1
Business Sector	[201], [148], [17], [44], [38], [137], [73], [32], [131], [162], [24], [182], [144], [143]	69	17.47	2
Energy sector	[75], [70], [77], [85], [155]	17	4.30	7
Hospital	[120], [16], [177], [61], [60], [22]	17	4.30	7
Industry	[136], [202], [59], [192], [27], [176], [92], [64], [196], [199], [168]	68	17.22	3
Marketing	[123], [147], [66], [204]	6	1.52	13
Portfolio	[136], [18], [94], [184], [21], [28], [57], [63]	25	6.33	5
School	[71], [138], [5], [175], [80]	9	2.28	10
Simulation	[163], [25], [103]	6	1.52	13
Stock Exchange	[181], [174], [6], [7], [141], [117], [132], [200]	30	7.59	4
Supply chain	[151], [110], [13], [157]	7	1.77	12
Transport	[54], [122], [36], [50], [166]	11	2.78	9
University	[169], [1], [88]	5	1.27	15
Other	[127], [126], [118]	3	0.76	16

A closer look shows that the most common applications of data envelopment analysis in financial matters are related to Bank (23.04%), Business Sector (17.47%), and Industry (17.22%). Of course, given the importance of financial issues in banks, the business sector, and industry, it can be said that such an expectation already existed. Fig. 14 also illustrates the contribution of different applications of data envelopment analysis to real-world problems.

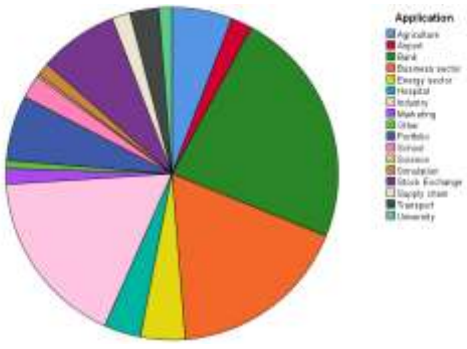


Fig. 14: Various Applications

In the above evaluation, the Business Sector includes applications such as the following, which account for a significant share of applications.

- Information System
- Chinese Enterprises
- Credit union merger
- Finance/securities companies
- Small Firm Accounting
- Private Firms
- High-tech Business
- Financial Holding Companies
- Resource Companies
- Non-OECD Economies
- Credit Department of Farmers
- South Korea Distribution System
- Local Government Finance in Japan
- Venture Capital Firm Efficiency
- Financial Holding Companies in Taiwan
- Financial Holding and Non-Financial Holding System from Taiwan
- Housing Provident Fund in China,
- Socio-economic development,
- Efficiency in the provision of public services,
- Finance industry in China
- Local government sector,
- Credit Evaluation
- European ports
- Financial environment,
- Chinese province-level R&D,
- Business failure prediction,
- Taiwan financial holding companies
- Economic Development Efficiency in Shandong Province
- Local Public Finance Performance in China,
- State-Owned Enterprises,
- E-Governance of Crime Data
- Microfinance Institutions,
- Risk Estimation,
- Financing Efficiency of Enterprises
- Local municipalities in South Africa,
- Economic efficiency of the provincial museums located in 31 provinces in China
- Commodity Trading Advisors

Also, the Industry sector has a significant share and includes the following:

- Electricity Board
- Fortune companies
- Oil and gas industry
- Italian factoring industry

- Productivity Research
- Telecommunications industry
- Internet companies
- Electronic data interchange
- Life and health insurance companies
- Taiwan’s PC Industry
- Electronics industry in Taiwan
- Risk management in insurance industry
- Japanese machinery industry
- Financial Service Industry in China
- Japanese construction industry
- Telecommunications industry
- China's Auto Enterprises
- Japanese manufacturing firms
- Steel sale enterprises
- China`s Hi-tech Companies
- Regional Financial Ecosystem Efficiency in China
- Telecom Company
- Firms in 16 industries in South Korea
- Communication technology industry
- China’s wind power industry
- Assess the Financial Strength of Construction Companies
- Evaluating multi-level structure
- Portuguese public management
- Internet Finance Companies
- Welfare Offices
- Technology Companies in Malaysia
- Chinese wind power industry
- Corporate financial performance
- Low-Carbon Economy Efficiency
- China's coal mine
- Corporate material flow management in Thailand
- Financial Efficiency Profiles in Exporting Companies

And, also “Other” consists of Shipping service, Hotel, and Military. A study of the recorded scientific works in the period in question shows that there are thematically the following types of categories, which indicates the breadth of topics related to the financial field.

- Business Management and Accounting
- Computer Science
- Decision Sciences
- Economics Econometrics and Finance
- Engineering
- Social Sciences

- Mathematics
- Environmental Science
- Energy
- Agricultural and Biological Sciences
- Medicine
- Earth and Planetary Sciences
- Arts and Humanities
- Physics and Astronomy
- Psychology
- Materials Science
- Chemical Engineering
- Multidisciplinary
- Nursing
- Biochemistry Genetics and Molecular Biology
- Chemistry
- Health Professions
- Neuroscience

The variety of subject categories reflects the fact that financial assessment is not just about economic issues, but about a wide range of real issues. Statistical analysis shows that the topics Business Management and Accounting, Computer Science, and Decision Sciences are most of the topics considered by researchers in this field. Fig. 15 shows the contribution of each topic to the published work during the course. It can be seen that Business Management and Accounting accounted for 15.6% of the works in this period.

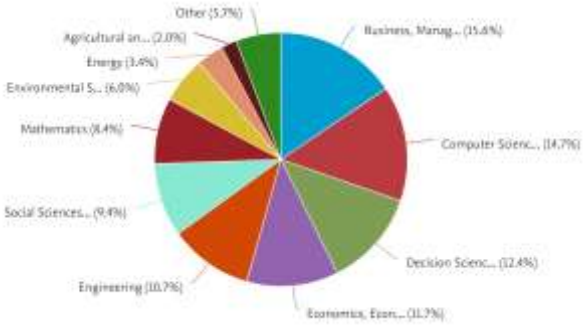


Fig. 15: Subject area

In addition, the distribution of different applications of data envelopment analysis method in financial issues for different years is illustrated in Fig. 16. Due to the importance of scientific works published in important fields Bank, Business Sector, and Industry, we examine their publishing process in different years. According to Fig. 16, it can be seen that the most application of data envelopment analysis in banks' financial issues occurred in 2020 (16.48% of cases). After that, the highest cases are observed in 2018 (14.29% of cases), 2016 (7.69% of cases), and 2009 (7.69% of cases). Therefore, recently, researchers have paid considerable attention to the application of data envelopment analysis in financial issues related to banks (see Table 8). This indicates the importance of strengthening the structure of banks in the promotion and sustainable development of countries.

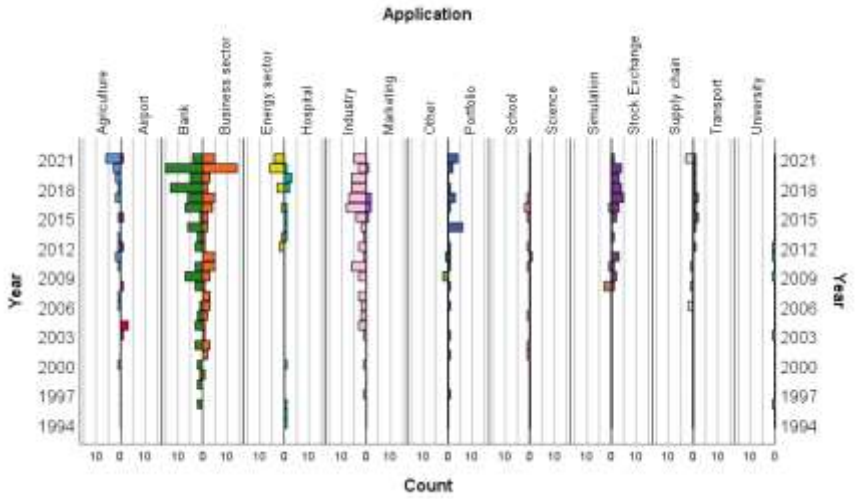


Fig. 16: Distribution of applications based on years

Table 8: Publishing process of Bank, Business Sector, and Industry in different years

Bank			**Business Sector**			**Industry**		
Year	No.	Percent	Year	No.	Percent	Year	No.	Percent
2009	7	7.69	2010	5	7.25	2010	6	8.82
2016	7	7.69	2011	5	7.25	2016	8	11.76
2018	13	14.29	2017	5	7.25	2017	7	10.29
2020	15	16.48	2020	14	20.29	2018	6	8.82
			2021	5	7.25	2019	6	8.82
Total =91			Total =69			Total=68		

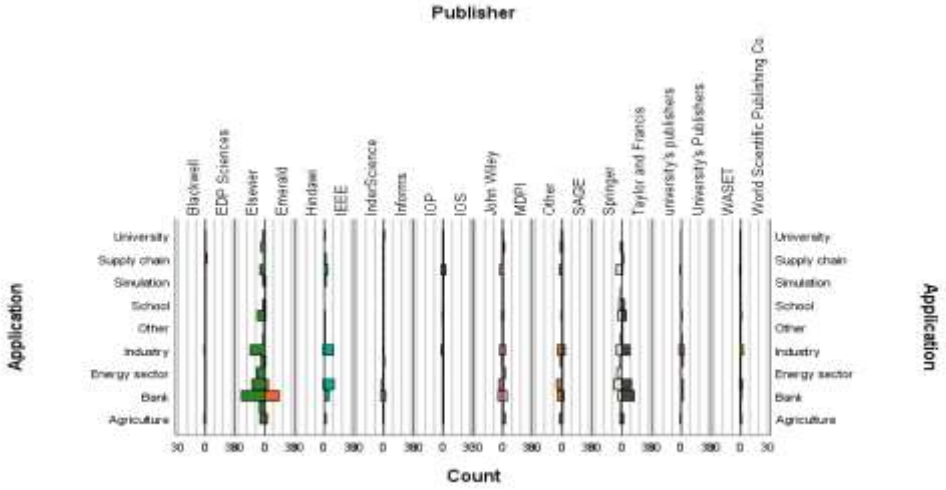


Fig. 17: Contribution of each publisher in various applications

On the other hand, it is observed that the most application of data envelopment analysis in business finance issues occurred in 2020 (20.29% of cases). Then the most cases are observed in 2010, 2011, 2017, and 2021 (7.25% of cases). It can also be seen that the most application of data envelopment

analysis in industrial sector financial issues occurred in 2016 (11.76% of cases). After that, the highest cases are observed in 2017 (10.29% of cases), 2010, 2018, and 2019 (8.82% of cases). Studies show that the share of application of data envelopment analysis method in the financial issues of the industrial sector has been almost uniform over the years. In the Fig. 17, the contribution of each publisher in using the data envelopment analysis method to financially evaluate the types of organizations and applications is specified. It can be seen that the data envelopment analysis method can be used in various applications. Also, the Elsevier Publishing has the largest share in publishing scientific works in the field of financial issues of banks.

4.1.1 Distribution of Various Data in Financial Evaluation

On the other hand, a review of published works shows that in real problems, in addition to exact and definite data, we may encounter various other types of data such as uncertain, random, fuzzy, interval data. In 94% of cases, researchers have used certain data, which indicates the major contribution of this data to the financial evaluation of organizations. Another reason may be that it is easier to use definitive data in modeling. About 27 cases (6%) of the recorded research used uncertain data. Most of them were related to stochastic and fuzzy data, respectively. Fig. 18 depicts the contribution of data types in various applications of data envelopment analysis in finance. Accordingly, the largest share of uncertain data has been recorded the works related to stochastic data (5 cases) in problems Portfolio, Bank, And then stochastic data (3 items) in the energy section, and fuzzy data (3 items) in the Stock Exchange sector.

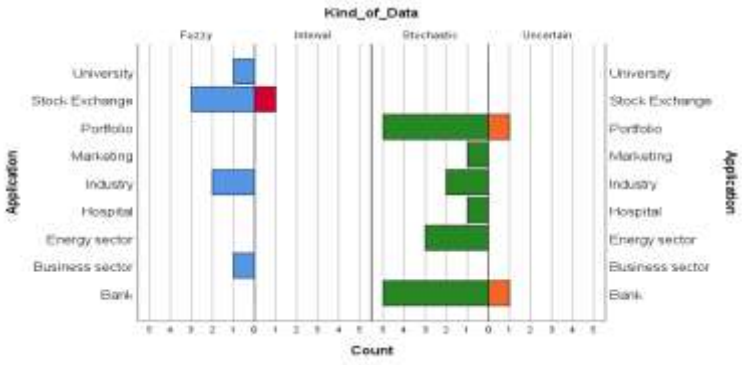


Fig. 18: Contribution of data types in various applications

In general, the highest share of uncertain data was related to stochastic data, which accounted for 62.96% of all uncertain cases. Fig. 19 depicts the participation of uncertain types of data in financial evaluation.

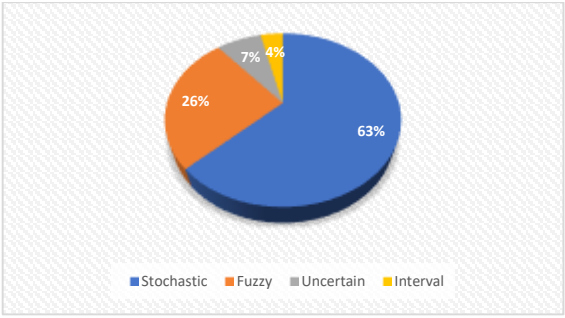


Fig. 19: Participation of uncertain types of data

4.1.2 Distribution of Assistant Methods in Financial Assessment

For more accurate analysis, research has usually included methods and methods as the Second Method. The second method provides meticulous analysis and contributes to the financial productivity of companies and organizations. Table 9 Shows the types of second methods and their contribution to the financial evaluation of organizations. Surveys show that about 28% of research works have used only data envelopment analysis models or their development in evaluation. The information of Table 9, indicates the methods Regression (16.33%), Statistics (15.82%), and Malmquist index (14.29%), have had the most participation in data evaluation methods with data envelopment analysis methods, respectively.

Table 9: Distribution of Assistant Methods in Financial Assessment

Method	Selected References	No. of Docs	Percent	Rank
Balanced scorecard	[14], [118], [92], [9], [12]	7	1.79	8
Bootstrap	[5], [76], [22]	6	1.53	10
Cost efficiency	[146], [30], [98]	3	0.77	13
Data mining	[82], [39]	2	0.51	16
DEA/AR	[169], [190]	2	0.51	16
DEA/DA	[165], [67]	4	1.02	12
Game theory	[92], [161]	3	0.77	13
Malmquist index	[197], [87], [53], [160], [111], [121], [144], [168]	56	14.29	3
MCDM	[48], [72], [45], [200]	13	3.32	5
MOLP	[189], [85], [157]	3	0.77	13
Monte Carlo	[77], [104]	2	0.51	16
Network DEA	[202], [124], [42], [93], [63]	23	5.87	4
Neural Network	[10], [141], [3], [187]	8	2.04	7
Regression	[120], [27], [6], [186], [52], [204], [143], [168]	64	16.33	1
Resource allocation	[71], [102]	2	0.51	16
SFA	[153], [65], [4]	9	2.30	6
Statistics	[136], [142], [185], [23], [79], [166]	62	15.82	2
Stochastic DEA	[152], [184], [97], [33]	7	1.79	8
Other	[29], [151], [49], [86]	6	1.53	10

Moreover, ‘Other’ consists of some methods like PCA, LCA, Target setting, Rough sets, and Score model. The second methods along with the data envelopment analysis method have played a significant role in a variety of applications in the financial field. Fig. 20 illustrates the distribution of different applications for the second method. As can be seen from the figure, the latter methods have played a large role in the evaluation of the bank, business sector, industry, and portfolio, respectively.

In addition, the contribution of each publication in using the second method along with the data envelopment analysis method for financial evaluation of organizations has been specified in the Fig. 21. It can be seen that the scientific works presented in publishers Elsevier, IEEE, Taylor and Francis, and Springer, have the largest share of the application of the second method along with the data envelopment analysis method in the financial evaluation of organizations.

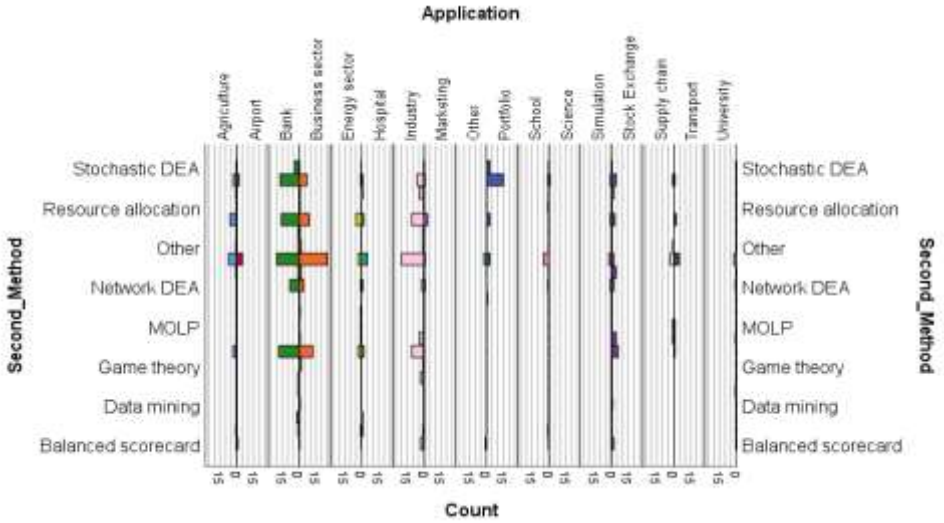


Fig. 20: Distribution of different applications for the second method

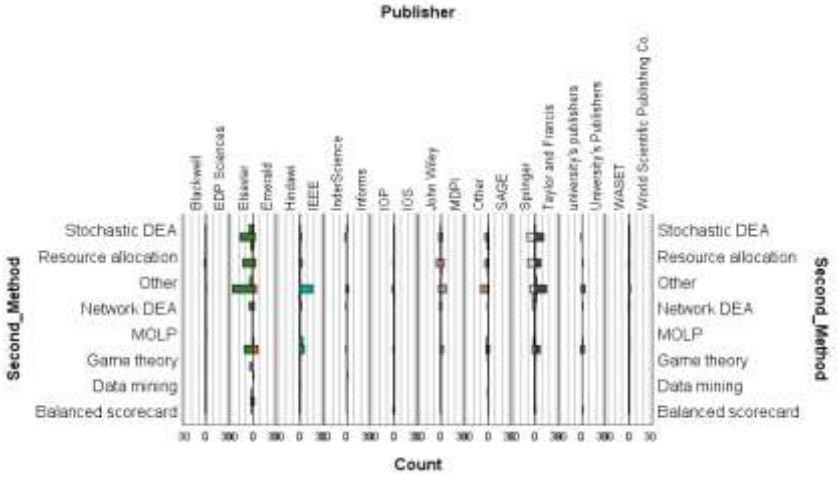


Fig. 21: Contribution of each publisher in using the second method

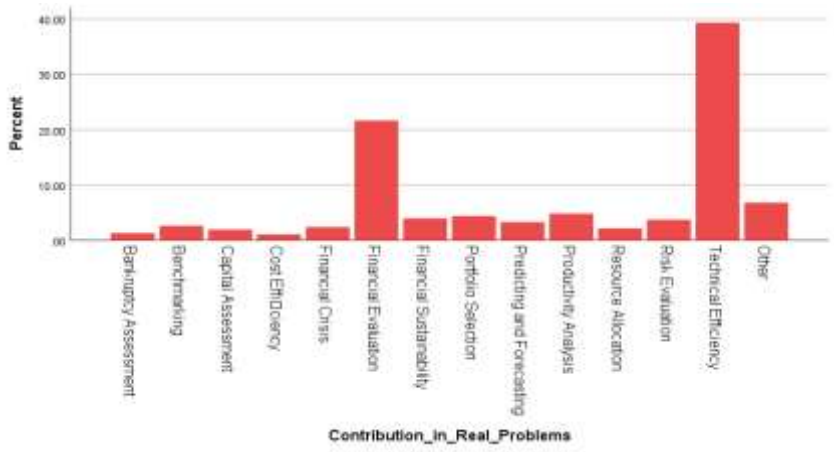


Fig. 22: Percentage of Contributions in Real Problems

4.2 Categorize Functions into Real Problems

A deeper study of the articles under review in the field of financial evaluation of organizations, indicates the fact that twenty-seven different categories and different types of evaluation have been done with the help of data envelopment analysis models. Table 10 summarizes these different categories. According to the table, it can be seen that the largest shares belong to Technical Efficiency, Financial Evaluation, Productivity Analysis, Portfolio Selection, and Financial Sustainability, respectively. Fig. 22 illustrates the contribution of different applications and functions of data envelopment analysis methods in financial evaluation. In this figure, applications with less than 1% are displayed with the aggregated title "Other".

Table 10: Contribution in Real Problems

No.	Contribution in Real Problems	No. of Documents	Percent
1	Asset Assessment	1	0.22
2	Bankruptcy Assessment	6	1.33
3	Risk Evaluation	17	3.76
4	Predicting and Forecasting	15	3.32
5	Electronic Evaluation	4	0.88
6	Capital Assessment	9	1.99
7	Cluster Analysis	2	0.44
8	Cost Efficiency	5	1.11
9	Financial Crisis	11	2.43
10	Benchmarking	12	2.65
11	Credit Evaluation	4	0.88
12	Economic Efficiency	4	0.88
13	Technical Efficiency	178	39.38
14	Financial Evaluation	98	21.68
15	Financial Distress	4	0.88
16	Resource Allocation	10	2.21
17	Financial Sustainability	18	3.98
18	Investment Analysis	1	0.22
19	Productivity Analysis	22	4.87
20	Loans Efficiency	1	0.22
21	Marketability Performance	3	0.66
22	Profitability Performance	3	0.66
23	Portfolio Selection	20	4.42
24	Measuring Congestion	1	0.22
25	Target Setting	1	0.22
26	Strategic Partner Selection	1	0.22
27	Reliability	1	0.22

This review examines the types of applications that fall into categories Risk Evaluation, Predicting and Forecasting, Capital Assessment, and Electronic Evaluation, are summarized in Table 11. It can be seen

that different types of financial analysis and evaluation can be implemented in organizations with the help of data envelopment analysis models. The interesting point is the types of forecasts with the help of data envelopment analysis models in the financial field.

Table 11: Different actions in each cluster

Risk Evaluation	**Predicting and Forecasting**	**Capital Assessment**	**Electronic Evaluation**
Risk Management	Forecasting Financial Failure	Venture Capital Assessment	E-business Evaluation
Evaluation of Audit Risk	Corporate Disaster Prediction	Capital Valuation	E-Commerce
Predicting Financial Risks	Predicting Bank Performance	Capital Management	E-Governance
Risk Analysis	Predicting Financial Risks	Capital Allocation	
Financial Risks	Prediction of Effective Customers		
Credit Risk	Bankruptcy Prediction		
Risk Efficiently	Prediction of Technical Efficiency		
	Stock Market Forecasting		
	Prediction of Financial Distress		
	Forecasting Financial Troubles		

5 Conclusions

In recent years, a growing number of researches have focused on evaluating and measuring the financial e*ffi*ciency, which is considered a crucial approach to monitor the economic performance of various firms. Also, data envelopment analysis method is a powerful mathematical model - which has received great attention during recent years as can be observed in the growing number of articles reviewed in this manuscript – for evaluating the financial performance of individual firms and companies. For this reason, a comprehensive review is necessary to show the complete scope of this methodology and to support researchers and practitioners in their studies. This study aimed to review papers that used the DEA methods for the evaluation different firms from the financial perspectives. In doing so, we try to identify the leading sources of knowledge in the forms of the most influential journals, authors, and papers. From the analysis of 455 articles, which were identified by a systematic search process from the Scopus database, we observe that many methods from data envelopment analysis are increasingly used to address challenges in financial assessment. The use of MADM, MODM, statistics and regression analysis, Bootstrap approach and other methods has introduced new perspectives into traditional financial assessment, increasing its comprehensiveness and providing new ways of communicating results, instead of merely presenting a list of performance indicators for the alternatives considered.

By considering both, purpose and the gaps in earlier literature, this paper has found the following important results. First, this study finds that financial efficiency and performance literature has been growing rapidly since the first attempt on 1994. Second, this study finds that the European Journal of Operational Research is the leading journal in terms of the number of publications and number of citations. The most prolific author is Sueyoshi T. based on the number of related publications. With regard to leading paper, the paper titled, “The efficiency of Australian universities: a data envelopment analysis” by Abbott and Doucouliagos [1] is found to be the most cited article. Third, the content analysis of the

selected 455 papers revealed seven most important themes: Cross Efficiency (0.78%), Dynamic Efficiency (1.30%), Extending DEA Models (22.54%), Malmquist Model (12.69%), Multi-Objective DEA (3.63%), Network DEA (6.48%), and Traditional DEA (52.59) %). In addition, 89% of the selected studies have used radial DEA models while the non-radial DEA models are used by 11%. Moreover, this study attempted to categories these papers into fifteen application areas: Agriculture, Airport, Bank, Business Sector, Energy sector, Hospital, Industry, Marketing, Portfolio, School, Simulation, Stock Exchange, Supply chain, Transport, University, and other application areas. Finally, regarding to the nationality-based classi*fi*cation, it was shown that 20 nationalities and countries applied DEA methods to the evaluation of the financial e*ffi*ciency with at least seven publications. Finally, China was shown to have the highest number of contributions to the publication of DEA-related papers in the evaluation of the financial e*ffi*ciency.

Several contributions have been done by this study. First, this study showed that a large number of DEA models exist and many of these methods are applicable to the solution of problems related to the evaluation of the financial performance. The number of paper reviewed in this study are 455, which consists of all published papers based on Scopus database. Second, to the best of our knowledge, this is the first time a comprehensive literature review about using DEA for evaluating financial efficiency is undertaken. Third, this study identifies most prolific authors, leading journals, and publishers in this field of measuring financial performance using DEA methodology which could help future researchers. Most important keywords used in the research under review for evaluating financial performance based on data envelopment analysis models are listed. Fourth, this study indicated that the most common applications of data envelopment analysis in financial matters are related to Bank, Business Sector, and Industry. Next, this review revealed that, in addition to the exact data, other types of data such as uncertain, random, fuzzy, and interval data are employed in financial evaluation using DEA models. Additionally, current research detected the methods Regression, Statistics, and Malmquist index as the most participant assistant methods in financial assessment with DEA models. Finally, according to the study, Technical Efficiency, Financial Evaluation, Productivity Analysis, Portfolio Selection, and Financial Sustainability, have been recognized as the five functions with the most contribution.

Of course, there are few limitations exists in the analysis, which could be overcome in future research. We used citations from Scopus index journals, however, as a robustness check, one can use Google scholar citations or citations in the WOS. Also, Co-citation and network analysis is also an under-researched area in literature survey, which could be covered in the future. Moreover, it would be worthwhile to conduct a content analysis by increasing the number of top-ranked papers. Additionally, future work might improve our study incorporating the analysis of criteria and the practical implications of the proposed approaches, and other papers that may have been omitted from our review.

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