

# International Journal of Forecasting 1985-2018: A retrospective based on bibliometric and knowledge diffusion analysis

Dejian Yu<sup>a</sup>, Rob J Hyndman<sup>b</sup>, Shunshun Shi<sup>\*,c</sup>

<sup>a</sup>Business School, Nanjing Audit University, Nanjing 211815, China

<sup>b</sup>Department of Econometrics & Business Statistics, Clayton, VIC 3800, Australia

<sup>c</sup>Information School, Zhejiang University of Finance and Economics, Hangzhou 310016, China

## Abstract

As one of the leading journals in the forecasting field, International Journal of Forecasting (IJF) has continually contributed to the field over 30 years. In this study, a retrospective analysis is conducted to evaluate the merits of IJF from 1985 to 2018 based on the raw data harvested from Scopus. The retrospective analysis consists of two parts. One is a bibliometric analysis of IJF based on a science mapping technique which focuses on the level of paper, author and country. The citation network, co-citation network, co-author network and country collaboration network are mapped based on IJF's publications. Multiple relationships between different scientific entities can be explored from these networks. The other is a knowledge diffusion analysis based on the forecasting papers and their citing papers. The discipline distribution of citing papers can be obtained with the citation relationship between forecasting papers and their citing papers. A deeper investigation about the knowledge diffusion outside of the forecasting journals is conducted for better elaborating the performance of IJF in knowledge diffusion outside the forecasting field. These two kinds of analyses directly depict a landscape about the development track of IJF based on the endorsements it obtained and the knowledge it spread abroad.

Key words: Forecasting research, Bibliometrics, Science mapping, Knowledge diffusion

---

\*Corresponding Author

Email addresses: [yudejian62@126.com](mailto:yudejian62@126.com) (Dejian Yu), [Rob.Hyndman@monash.edu](mailto:Rob.Hyndman@monash.edu) (Rob J Hyndman), [shishunshun1993@126.com](mailto:shishunshun1993@126.com) (Shunshun Shi)

## 1. Introduction

International journal of forecasting (IJF), one of the leading journals in the forecasting field, was issued by International Institute of Forecasters (IIF) in 1985, and then continued to contribute the forecasting field up to now. According to its website, the main purpose of the journal is to “make forecasting useful and relevant for decision and policy makers”, and all kinds of forecasting methods are welcomed by the journal for better bridging the gap between theory and practice. Many of the IJF papers involved the topics in the fields of business, economics, and management (BEM) for promoting the forecasting research in these fields. An existing overview about the forecasting journals which consist of IJF and Journal of Forecasting (JF) was conducted based on citation analysis and expert opinion, and an important part of the overview was elaborated under a background of BEM applications (Fildes 2006). The overview was and remains a valuable conclusion about the evaluation of the IJF and JF through examining how they have met their initial objectives successfully, and the content of the overview is informative. However, the bibliometric techniques which are used by the overview are sort of simple and not effective enough. The overview only used one bibliometric technique (i.e., citation analysis) to analyze the data of IJF, which has left a wide space for the performance of other bibliometric techniques. Many other overviews are conducted for evaluating the merits of a certain journal based on various bibliometric techniques, and a brief summary is provided as below.

Merigó et al. (2015) conducted an overview of the Journal of Business Research based on some basic bibliometric techniques, for example, identifying citation structure, highly cited papers, the most prolific authors, institutions, and countries. All of them were regarded as the main factors that affect the performance of the journal, and measured by the number of publications and citations. Calma and Davies (2016) provided an overview of Academy of Management Journal using some similar bibliometric techniques. According to the number of publications the journal published and citations the journal received, the most prolific author, countries, organizations, years and highly cited papers, authors were obtained. Moreover, based on the data of journal papers and their references, science mapping technique was used to construct the networks of most prolific authors and most cited authors. Due to the advantage of delineating relationships between scientific entities, science mapping has become a frequently-used bibliometric technique for visualizing different kinds of academic relationships. Wichaisri and Sopadang (2018) used the data of Sustainable Development to extract the co-citation relationship between the cited papers, and then determined four main clusters from the co-citation relationships based on the science mapping technique.

As stated above, many of the existing overviews have proven the effectiveness of bibliometric techniques, especially the combination of basic bibliometric indicators and the science mapping techniques. In our previous work, this combination has been used in many bibliometric studies. Our first try of the combination is the study to analyze the development of Atanassov intuitionistic fuzzy set (Yu and Shi 2015). Then, this research pattern was successfully applied in aggregation operator research (Yu 2015). Moreover, an overview of Information Science (INS) was conducted based on this research pattern to explore the structures and trends of the INS publications (Yu et al. 2017). Basically, the majority of the most important factors which affect the performance of journal can be identified under this research pattern. Further, some internal relationships between different kinds of scientific entities can be recognized and expressed by science mapping techniques. Highly cited paper, author, countries, and prolific author, country are common factors that can affect the performance of the journal. Co-citation relationship, co-author relationship, country collaboration relationship are some common internal relationships embedded in the journal. The status quo of journal can be elaborated by these factors and relationships. Moreover, the development track of journal can be delineated based on a dynamic bibliometric analysis. However, under this research pattern, the research is limited inside the journal, which means the academic activities outside but related to the journal are difficult to recognize. To settle this problem, the knowledge diffusion analysis is a good choice.

In bibliometrics, knowledge flow can be constructed based on the citing and cited behaviors which correspond to the knowledge integration and knowledge diffusion (Shi et al. 2018), respectively. Knowledge integration means the knowledge transfer from the cited papers to the given papers, while knowledge diffusion is from the given papers to the citing papers. In this study, the raw data of IJF is harvested from Scopus. However, information about cited papers of IJF publications is largely missing in Scopus. Therefore, the knowledge integration cannot be conducted in this study, and we select the knowledge diffusion analysis as the primary content.

Porter and Chubin (1985) first defined the proportion of citations falling outside the category as a cross-discipline indicator to delineate how the knowledge diffuses from the target category to the outside categories. In Web of Science, the journals are classified based on the predefined categories, while in Scopus, subject area is used to replace the concept of category. Therefore, in this study, we use subject area equaling to the concept of category in the knowledge diffusion research. IJF and JF are two leading and authoritative journals in the forecasting field, therefore, IJF papers and JF papers are all included in the knowledge diffusion analysis. The raw data of IJF papers, JF papers and their citing papers are harvested from Scopus. The citation relationships between the IJF papers and their citing papers are extracted to explore what subject areas are most interested in the forecasting researches. The same work will be conducted between JF papers and their citing papers. Then, a rough result about the knowledge diffusion can be obtained at the level of subject area. Moreover, top three citing subject areas are selected in a further investigation and the journal citation relationships between IJF/JF and their citing journals are extracted. Therefore, more detailed findings can be obtained at the level of journal.

The remainder of this paper is organized as follows. Section 2 presents a bibliometric analysis of IJF to identify the publication/citation structure of IJF and the most contributing papers, authors and countries. Section 3 offers a knowledge diffusion analysis of the forecasting journals. Section 4 states some discussion and conclusion of this study.

## 2. Bibliometric analysis of IJF

In this section, some frequently-used bibliometric techniques are applied into analyzing the IJF papers. First, a basic statistics of IJF papers is provided from the angle of output and citation. Some interesting findings can be obtained through exploring the relationships between the curves of annual output and annual citation. Then, paper, author, and country are selected as the three factors influencing the performance of the journal. The most cited, co-cited papers, the most prolific authors, the most cited authors, the most prolific countries, the most cited countries are all identified. Further, the citation, co-citation relationships, the co-author relationship, and the country collaboration relationship are depicted based on science mapping techniques.

### 2.1. Basic statistics of IJF

Annual evolutions of papers and citations are depicted in Fig. 1, and the detailed data is stated in the table 1. The Panel A of Fig 1 provides a view of the overall trend to analyze the dynamic of papers and citations. Observing from the paper curve, there is a decrease of the yearly output from 1996 to 2001, but, by the large, the yearly output increased over time. The most prolific year is 2016 with 105 papers, and the least productive year is the initial year with 27 papers. As for the annual evolution of citations, the situation is similar to that of paper. By the large, the number of citations increased over time, but with a little drop in the period of 1996-2001. The number of citations in the year of 2006 is the highest, which largely owes to a special issue containing largely review papers which aims at looking at the 25 years since the journals and institute began. Among this special issue, the top four highly cited review papers are identified: the work of Gooijer and Hyndman (2006), Gardner (2006), Lawrence et al. (2006), and Booth (2006). Moreover, there is a highly cited article paper published in 2006 (i.e., received 1198 citations) written by Hyndman and Koehler (2006). After the year of 2006, the number of citations had a wavy decrease. In addition, the shape of citation curve is quite similar to that of paper curve, especially the periods of 1984-1994 and 2010-2018.

Further, in the periods of 1985-1994 and 2010-2018, the authors find their trends of paper and citation are quite similar, which is reflected in every peak point and valley point. However, the interspace between the paper curve and citation curve is bigger in 2010-2018 than in 1985-1994, which indicates the ratio of citations per paper is dropping from the initial years to the latest years. This phenomenon may result from two reasons. One is the increased academic output around the world. Another is the shorter citation time window, which means the papers published in the latest years do not have enough time to accumulate their citations.

From 1996 to 2001, the shapes of paper curve and citation curve are still kind of similar, but the ratio of citations per paper from 1997 to 2000 is much higher than the remaining years, which indicates the papers published in 1997, 1998, 1999 and 2000 attracted more citations than others. To better investigate why these papers can attract more citations, the authors have a closer look at the raw data of these papers, and find

each year has one or two highly cited papers. A highly cited paper with 564 citations was published in 1997, and focused on testing the equality of prediction mean squared errors (Harvey, Leybourne, and Newbold 1997). In 1998, Zhang et al. proposed to investigate the effect of key factor on forecasting performance of artificial neural network (Zhang, Patuwo, and Hu 1998), and this research has accumulated 2007 citations. In 1999, a research analyzing the Delphi technique as a forecasting tool was conducted (Rowe and Wright 1999), and received 941 citations. In 2000, Makridakis and Hibon (2000) describes a M3-Competition, and compare the results of the latest M3-Competition with previous M-Competitions. The research of Makridakis and Hibon received 669 citations. Based on the raw data from 1985 to 2018 harvested from Scopus, only eight papers have more 500 citations, and four of eight occurred in the period of 1996-2001.

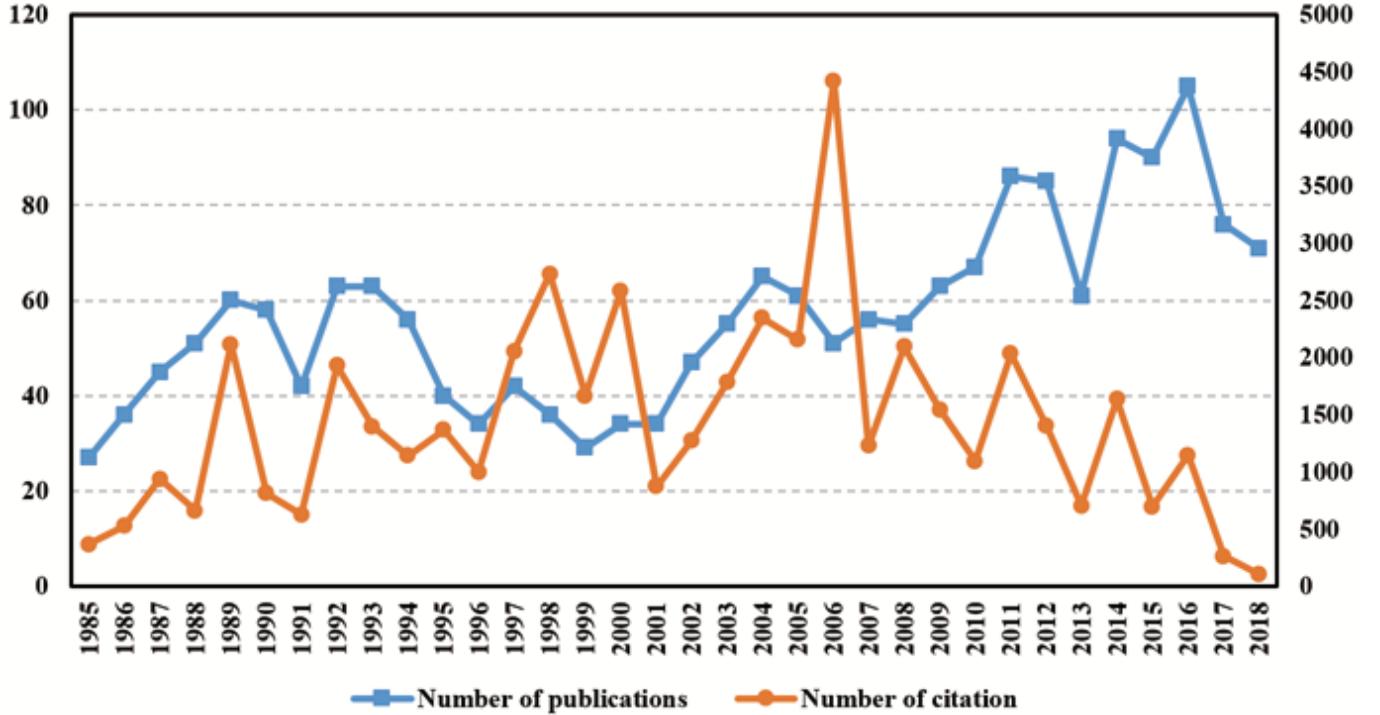


Figure 1: Annual evolutions of IJF papers and citations from 1985 to 2018

## 2.2. Citation network and co-citation network

After an overall review about the total IJF papers from 1985 to 2018, we focus on evaluating the performance of single IJF paper. The top 20 most cited IJF papers are listed in table 1 with the information about the citation number, author names, publication year, etc. Note that the country in table 1 refers to the country of first author and UK contains England, Scotland, Walsh, and North Ireland. TC, Nau, Nin refer to the number of citations the paper received, the number of authors that the paper has, the number of institutions that the paper belongs to, respectively. The top three most cited papers all receive over 1000 citations, and the first one even possesses over 2000 citations. These three papers already appear in the subsection 2.1 as the important contributors for promoting the citations of their publication years. The first one is the paper written by Zhang, Patuwo, and Hu (1998) which investigateded the research on forecasting with artificial neural networks. The second is the work of Hyndman and Koehler (2006) which considered the mean absolute scaled error as the standard measure based on comparing the accuracy of multiple forecasting methods. The third is Clemen (1989) which provided a review about the research on forecast combination and suggestions for the future work.

Besides, a citation network is mapped based on the citation relationship between IJF papers. The citation network consists of nodes and links, where some nodes are connected with links and some are isolated. A node represents a paper and a link represents the citation relationship between any two connected papers. The size of node is denoted as the number of citations a paper received. Through this citation network, the citation relationships between any connected IJF papers can be visually obtained and deeper investigations like highly cited publications are cited by what papers can be conducted easily. The number of citations no less than 80 is set as the limitation, then 111 qualified IJF papers are derived. 29 of the 111 papers are discarded because they are isolated. Finally, 82 IJF papers are used to construct this citation map, as

Table 1: Information about top 20 most cited IJF papers

Rank	Paper	TC	TC/Year	Country	Nau	Nin
1	ZHANG et al. (1998)	2007	95.57	USA	3	1
2	HYNDMAN and KOEHLER (2006)	1198	92.15	Australia	2	2
3	CLEMEN (1989)	1105	36.83	USA	1	1
4	ROWE and WRIGHT (1999)	941	47.05	UK	2	2
5	MAKRIDAKIS and HIBON (2000)	669	35.21	France	2	1
6	DE GOOIJER and HYNDMAN (2006)	612	47.08	Netherlands	2	2
7	ARMSTRONG and COLLOPY (1992)	573	21.22	USA	2	2
8	HARVEY et al. (1997)	564	25.64	UK	3	1
9	WITT and WITT (1995)	468	19.50	UK	2	2
10	THOMAS (2000)	390	20.53	UK	1	1
11	MEADE and ISLAM (2006)	381	29.31	UK	2	2
12	GARDNER (2006)	377	29.00	USA	1	1
13	DIEBOLD and YILMAZ (2012)	375	53.57	USA	2	3
14	HOLT (2004)	372	24.80	USA	1	1
15	WERON (2014)	345	69.00	Poland	1	1
16	HYNDMAN et al. (2002)	310	18.24	Australia	4	2
17	CONEJO et al. (2005)	282	20.14	Spain	4	2
18	TAYLOR et al., (2006)	265	20.38	UK	3	3
19	BROWN (1993)	221	8.50	USA	1	1
20	LAWRENCE (2006)	212	16.31	Australia	4	4

shown in Fig. 2. Distance between any pair of papers denotes their similarity calculated by the association strength method (Eck and Waltman 2009). The longer distance is the more dissimilar the two connected papers are. Papers with high similarity values are clustered and represented as the same color. Among the 82 IJF papers, 70 of them have citations, while the remaining 12 papers have no citations, but cite to some of the 70 papers. From Fig. 2, Zhang, Patuwo, and Hu (1998) is the biggest node because it is the most cited paper among the total IJF papers, but among these 82 IJF papers, it is not the paper that has the most citations from the 82 IJF papers. The 82 IJF papers in Fig. 2 are all highly cited papers, so their endorsements are pretty authoritative. Winning an endorsement from these 82 papers helps a lot to promote the prestige of the paper, so a further investigation is conducted to derive the highly cited papers, where their citations are from these 82 papers. We define the citation from the IJF papers as the local citation (LC). The papers having no less than 5 local citations are extracted, as shown in table 2. Paper written by Gooijer and Hyndman (2006) is the most cited among these 82 IJF papers, and the paper is about a 25 review on time series forecasting based on the papers of JIF and Journal of Forecasting (JF). According to the local citation percentage (LC/TC), the research of Crone, Hibon, and Nikolopoulos (2011) ranks the first, which indicates the high quality of its citations. Zhang, Patuwo, and Hu (1998) is top one highly cited in the total IJF papers, but its performance in local citation percentage is not that remarkable.

Table 2: Information about the most local cited IJF papers

Rank	Paper	LC	TC	LC/ TC
1	DE GOOIJER and HYNDMAN (2006)	33	612	5.39%
2	WERON (2014)	17	345	4.93%
3	GARDNER (2006)	16	377	4.24%
4	MAKRIDAKIS and HIBON (2000)	16	669	2.39%
5	ZHANG et al. (1998)	12	2007	0.60%
6	CLEMEN (1989)	11	1105	1.00%
7	CRONE et al. (2011)	10	108	9.26%
8	TAYLOR et al. (2008)	10	124	8.06%
9	LAWRENCE et al. (2006)	10	212	4.72%
10	DARBELLAY and SLAMA (2000)	10	207	4.83%
11	MAKRIDAKIS (1993)	10	133	7.52%

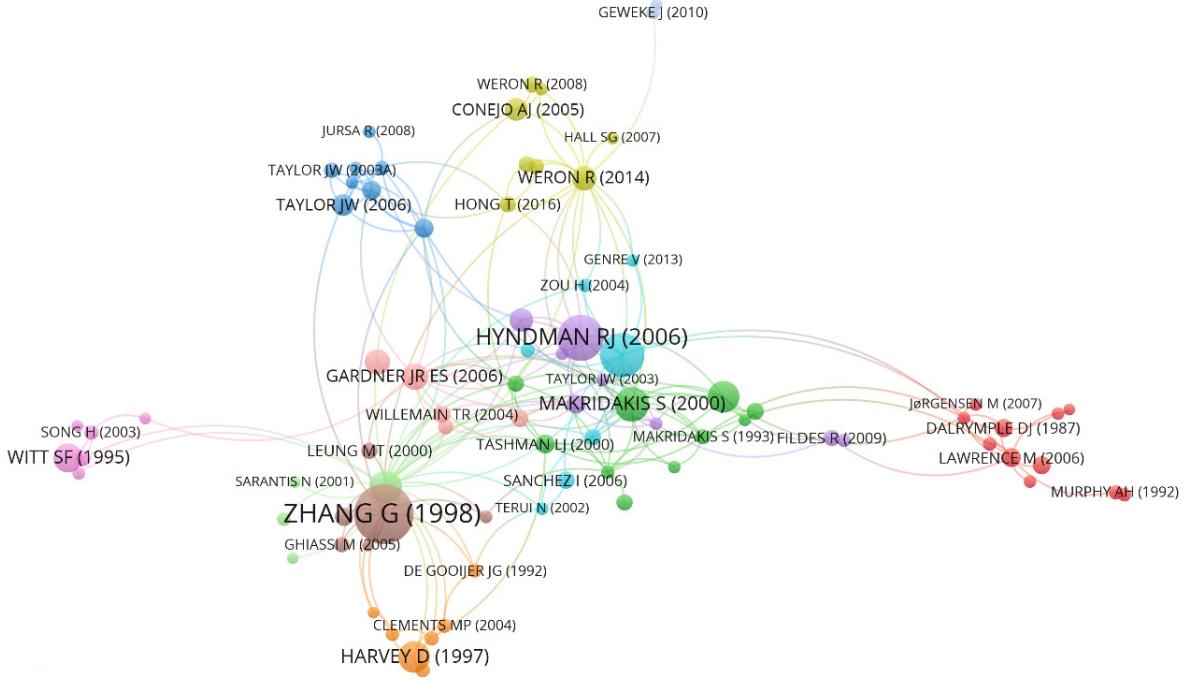


Figure 2: Citation network of 82 most cited IJF papers

Co-citation analysis is one of the useful bibliometric methods. As the name suggested, the co-citation relationship describes the relations between any two co-cited papers, and the co-cited papers means papers that are cited by the same paper. If two papers are cited by one same paper, then these two papers are in a co-citation relationship and the co-citation strength they possess is one. Based on the IJF papers harvested from Scopus, the co-citation relationships between them and citing papers are extracted. Note that 122 IJF papers are excluded because of the missing data and format errors. Finally, 1816 IJF papers and 33204 references are included in this co-citation network, shown in Fig. 3. IJF papers published in the same year are divided into one group to better straighten out their co-citation evolution trajectory. Moreover, three groups of thresholding are used to control the filtration of the qualified papers. Each group of thresholding has three criterion which are the minimum citations, minimum co-citations, and minimum normalized co-citations. The first thresholding is set in the year of 1985, the second in 2002, and the last is in 2018. After some trail runs, the first thresholding is set with 50, 3, 15, the second is 3, 3, 20, and the third is 3, 3, 20.

The color in the Fig. 3 denotes the publication year of papers, and the warm color represents the latest year, while the cold color represents the old year. The size of node denotes the co-cited times of each paper, and the bigger the size is the more the co-cited times are. From Fig. 3, we can see that the coldest color is green (i.e., approximately corresponds to the year of 1998), which means the papers published earlier are excluded according to the thresholding. The top 10 most co-cited papers which have the biggest nodes are extracted and listed in table 3. The most co-cited research conducted by Timmermann (2006) elaborated on the advantages of forecast combination, and analyzed the factors that can determine the advantages. The second most co-cited work (Giannone, Reichlin, and Small 2008) provided a framework which was useful for the real-time forecast selection based on conditional expectations of forecasts, and applied this framework into a testing problem. The third most co-cited work is an IJF paper written by Makridakis and Hibon (2000) which described a M3-Competition. This IJF paper also is the main contributor for the high citations in the year of 2000. Including the work of Makridakis and Hibon (2000), we find that four of the ten most co-cited papers are IJF papers, which means these four IJF papers possess the most co-endorsements from IJF papers.

In table 3, except for the co-citation (Co), the information about the first co-cited year (FY), the last co-cited year (LY), the whole co-cited duration (Y), and the average co-citation per year (Ave-Co) about each top ten co-cited papers are provided. In table 3, we use the abbreviations of journals, which are Handbook of economic forecasting (HEF), International Journal of Forecasting (IJF), Journal of Monetary Economics (JME), Principles of Forecasting: A Handbook for Researchers and Practitioners (PF: AHRP),

and Journal of the American College of Cardiology (JACC). Among these four IJF papers, we find the research conducted by Hong et al. (2016) has the shortest co-cited duration, but the highest average co-citation per year, which denotes the research (Hong et al. 2016) is very frequently co-cited by others in recent years. From the Fig. 3, we can see the study (Hong et al. 2016) is in a co-citation relationship with his another research (Hong, Pinson, and Fan 2014), and these two researches are both related to the energy forecasting. Another two IJF papers are the work of Hyndman and Koehler (2006) and the work of Fildes et al. (2009) which both possess relatively low average co-citation per year, and it denotes they are behind Hong's work (Hong et al. 2016) in co-cited activity. One thing is interesting that the node of Fildes et al. (2009) is wrapped with a purple ring in Fig. 3, where the purple ring means the node enjoys a high betweenness centrality. The between-ness was proposed by Freeman (1977) and depicts the structural property of communication of nodes between connected networks. A node with high betweenness centrality denotes it is more inclined to be positioned between some connected networks. In Fig. 3, the node of Fildes et al. (2009) is between a red cluster and a yellow cluster, which means the node of Fildes et al. (2009) linked the researches published earlier than 2009 and later than 2009. Fildes et al. (2009) plays an important role in expressing the connected co-citation relationships between these two clusters of researches. Besides, another work called burst detection is conducted to identify papers with abrupt change (Kleinberg 2003), as shown in table 4. The papers with abrupt change usually are the milestone papers of the science mapping research. From Fig. 4, we can find that the same four IJF papers having high co-citations are also remarkable in this burst detection, especially, the work of Makridakis (Makridakis and Hibon 2000) has the strongest burst power, which means it is the most important milestone in this co-citation mapping.

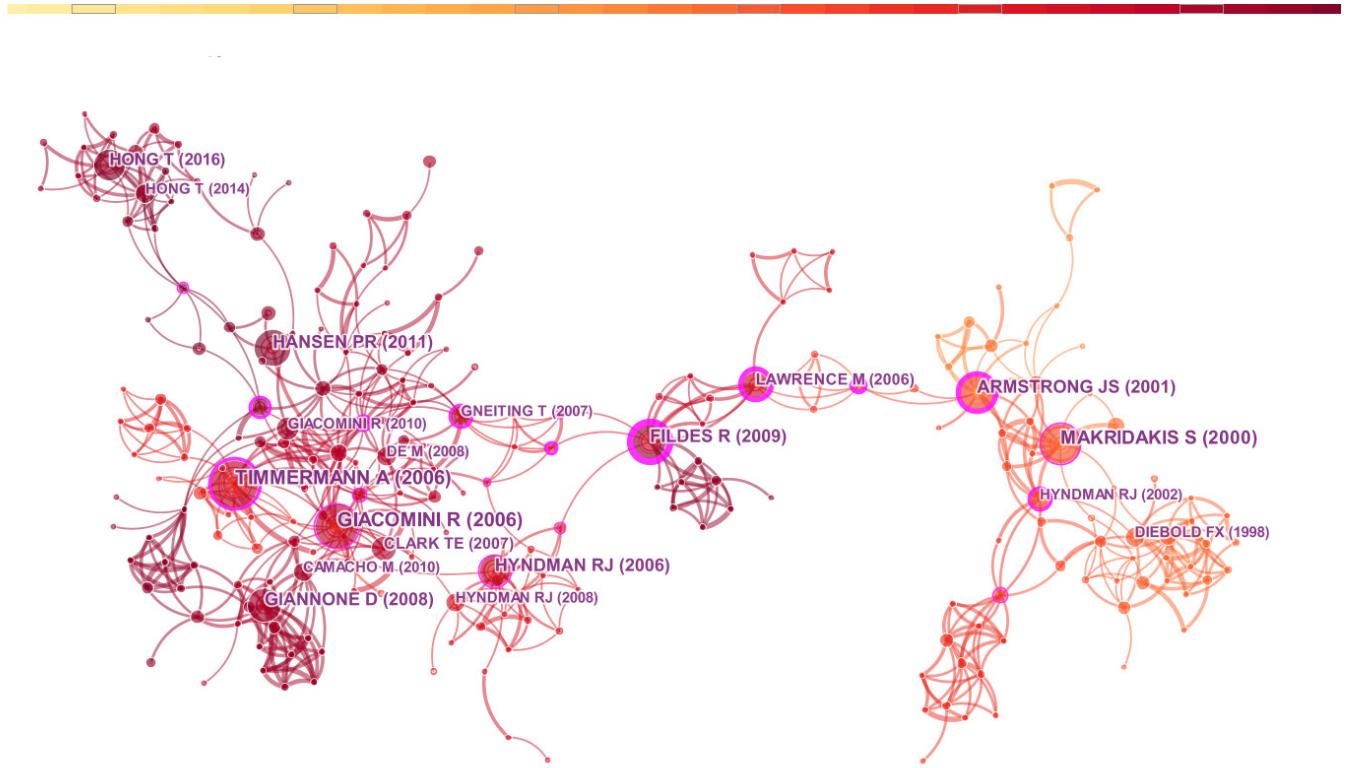


Figure 3: Co-citation network of IJF papers and their citing papers

Table 3: Information about the most co-cited papers in the co-citation network

Rank	Co	Paper	Source	FY	LY	Y best	year (number)	Ave-Co	Citation
1	26	TIMMERMANN (2006)	HEF	2009	2014	6	2009(9)	4.33	1247
2	24	GIACOMINI and WHITE (2006)	Econometrica	2007	2014	8	2009/2011/2013(5)	3.00	1231
3	22	MAKRIDAKIS and HIBON (2000)	IJF	2003	2008	6	2006(7)	3.67	1325
4	20	HANSEN et al. (2011)	Econometrica	2012	2018	7	2018(7)	2.86	1036
5	18	GIANNONE et al. (2008)	JME	2013	2018	6	2016(8)	3.00	793
6	17	HYNDMAN and KOEHLER (2006)	IJF	2009	2014	6	2011(6)	2.83	2338
7	16	ARMSTRONG (2001)	PF: AHRP	2001	2007	7	2002/2006(6)	2.28	1740
8	15	FILDES et al. (2009)	IJF	2011	2017	7	2013(7)	2.14	299
9	14	HONG et al. (2016)	IJF	2016	2018	3	2016(8)	4.67	251
10	14	LAWRENCE (2006)	JACC	2007	2013	7	2013(6)	2.00	379

Table 4: Information about the papers with the strongest power in the burst detection

References	Strength	Begin	End
MAKRIDAKIS S, 2000, International Journal of Forecasting, V16, P451-476	10.3456	2003	2008
Timmermann A, 2006, Book	9.4891	2009	2014
ARMSTRONG JS, 2001, Book	7.7619	2002	2007
GIACOMINI R, 2006, Econometrica, V74, P1545-1578	7.4779	2008	2014
HYNDMAN RJ, 2006, International Journal of Forecasting, V22, P679-688	6.1442	2009	2014
HANSEN PR, 2011, Econometrica, V79, P291-311	6.1267	2016	2018
CLARK TE, 2007, Journal of Econometrics, V138, P291-311	6.0076	2013	2015
GIANNONE D, 2008, Journal of Monetary Economics, V55, P665-676	5.9896	2013	2016
HONG T, 2016, International Journal of Forecasting, V32, P896-913	5.7396	2016	2018
HYNDMAN RJ, 2002, International Journal of Forecasting, V18, V18, P439-454	5.7064	2006	2008

### 2.3. Authors analysis in IJF and co-author network

Prolific authors can be regarded as the experts of the field or the important contributors of the journal. After a preliminary review, some prolific associate editors who published in IJF are excluded because the researches of associate editors are more inclined to be highly cited than those of normal IJF authors. The top ten prolific authors in IJF are selected from the remaining IJF authors, as shown in table 5. The information about their first paper year, and last paper year is stated in table 5. We find that most of the ten prolific authors possess a long academic career, especially Koehler and Ord whose papers covering at least 30 years. Five of the ten authors affiliated in USA, which indicates the USA scholars form a leading and active community in IJF. Generally speaking, first author is the main contributor of a paper, and corresponding author is responsible for a paper. Therefore, we calculate the number of papers that the authors are responsible for the first authors or the corresponding authors. Four indicators are used: 1st (the number of papers that are first-authored), 1st % (1st/TP), Cor (the number of papers that are corresponding-authored), and Cor % (Cor/TP). From table 4, Chatfield's first author percentage is 86.67% which is the highest among the ten authors, followed by Taylor and Lahiri. O'Connor and Ord are two authors who have relatively weak performance in first author percentage and corresponding author percentage. It means that they are prolific authors in IJF, but in most cases, they acted as a collaborator of the papers, rather than the main contributor.

The number of citations an author received is a useful indicator to evaluate the prestige of authors, therefore, the top ten most cited authors are selected in table 6. Similar to the table 5, the associate editors are excluded in table 6. Koehler is the most cited author due to his relatively high output. Wright has the highest TC/TP value, which is largely due to his highly cited paper, "The Delphi technique as a forecasting tool: Issues and analysis" (Rowe and Wright 1999). Franses is the most prolific author, but ranks the last in TC, which indicates his researches are not as attractive as those of the other nine authors. Besides, the number of citations from the IJF and outside the IJF are calculated. Goodwin, Collopy, Hibon and O'Connor receive higher local citation percentage, which means the IJF endorsements their researches obtained are more than those of the remaining authors.

Table 5: Information about the top ten prolific authors in IJF

Rank	Author	TP	Country	FY	LY	Y	1st	1st %	Cor	Cor %
1	ARMSTRONG JS	50	USA	1985	2014	30	35	70.00%	34	68.00%
2	FILDES R	42	UK	1985	2017	33	31	73.81%	31	73.81%
3	FRANSES PH	26	Netherlands	1991	2017	27	12	46.15%	13	50.00%
4	HYNDMAN RJ	24	Australia	1992	2018	27	11	45.83%	13	54.17%
5	STEKLER HO	24	USA	1988	2015	28	10	41.67%	12	50.00%
6	GOODWIN P	22	UK	1993	2017	25	10	45.45%	13	59.09%
7	MAKRIDAKIS S	22	Cyprus	1985	2018	34	17	77.27%	15	68.18%
8	CLEMENTS MP	20	UK	1997	2018	22	18	90.00%	11	55.00%
9	KOEHLER AB	19	USA	1985	2017	33	6	31.58%	10	52.63%
10	O'CONNOR M	18	Australia	1989	2007	19	5	27.78%	7	38.89%

Table 6: Information about the top ten most cited IJF authors

Rank	Author	TC	TP	TC/TP	LC	%	OC	%
1	HYNDMAN RJ	2547	24	106.13	121	4.75%	2426	95.25%
2	ZHANG G	2075	1	2075.00	27	1.30%	2048	98.70%
3	KOEHLER AB	1728	19	90.95	82	4.75%	1646	95.25%
4	ARMSTRONG JS	1514	44	34.41	149	9.84%	1365	90.16%
5	MAKRIDAKIS S	1338	22	60.82	178	13.30%	1160	86.70%
6	WRIGHT G	1217	9	135.22	47	3.86%	1170	96.14%
7	CLEMEN RT	1182	6	197.00	107	9.05%	1075	90.95%
8	HIBON M	1057	11	96.09	140	13.25%	917	86.75%
9	ROWE G	1027	3	342.33	20	1.95%	1007	98.05%
10	DE GOOIJER JG	770	9	85.56	31	4.03%	739	95.97%

A co-author network is constructed based on the co-author relationship between IJF authors. Authors who publish less than eight papers are discarded, then 38 qualified authors are derived. Among the 38 authors, 6 authors are isolated, so finally 32 authors are mapped into the co-author network, as shown in Fig.4.

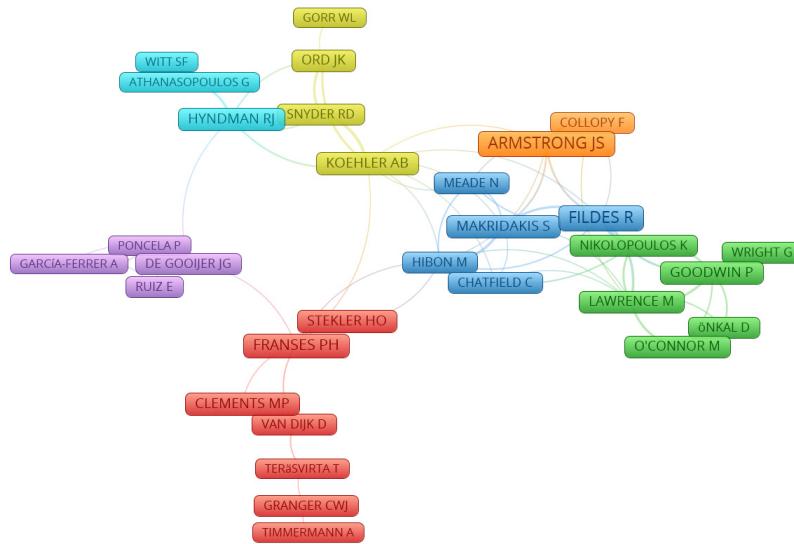


Figure 4: Co-author network of the most prolific IJF authors

#### 2.4. Country analysis and country co-occurrence network

In this subsection, we extract some prolific countries and most attractive countries according to the number of publications and citations. Based on this analysis, we can identify what countries are the biggest providers of IJF and what countries possess the highest authority in IJF. Besides, a country co-occurrence network is provided to express the collaboration relationships among different countries.

Table 7: Information about the top ten prolific countries

Rank	Country	TP	FY	LY	Y	TP/Y	% of total
1	USA	798	1985	2018	34	23.47	41.18%
2	UK	420	1985	2018	34	12.35	21.67%
3	Australia	178	1985	2018	34	5.24	9.18%
4	Germany	110	1988	2018	31	3.55	5.68%
5	Netherlands	99	1988	2018	31	3.19	5.11%
6	Spain	93	1986	2018	33	2.82	4.80%
7	Canada	84	1985	2018	34	2.47	4.33%
8	Italy	70	1987	2018	32	2.19	3.61%
9	France	67	1986	2018	33	2.03	3.46%
10	Belgium	36	1989	2018	30	1.20	1.86%

Country is a geographical community producing the academic researches, and the large academic output of a country declares the high academic productivity of the country. Therefore, country is selected as the objective of this subsection, and analyzed based on the number of papers each country produced and the number of citations they received. Information about the top ten prolific countries are listed in table 7. USA, UK, and Australia rank the top places, and their durations range the whole issue period of IJF. USA is the dominant country whose papers occupy around 41% of the total IJF papers. Moreover, most of the prolific countries belong to Europe and North America, which indicates the developed countries in Europe and North America are still the main producers of IJF papers.

Besides, a dynamic analysis is conducted based on the output of top three countries which are USA, UK, and Australia, as shown in Fig. 5. Two indicators are used: percent 1 (the ratio of the yearly IJF papers produced by certain country to the yearly number of total IJF papers), and percent 2 (the ratio of the yearly IJF papers produced by certain country to the total number of IJF papers produced by certain country). Observing from the percent 1, although USA is in a leading position, its dominance has been gradually weakened from 1985 to 2018. However, the values of percent 1 of UK and Australia keep on increasing from 1985 to 2018. From the percent 2, the values of USA is relatively stable, but with a short-time drop during 1995 to 2001. The values of UK and Australia are increasing overall. The value of percent 2 of Australia in 2016 have an obvious peak. In the IJF papers produced by Australia, the number in 2016 occupies 9.55% of the number in total.

The number of citations a country possesses is an important indicator to evaluate the prestige of it, and also is a sign of knowledge spreading from the country. Therefore, the top ten most cited countries are selected in table 8. USA is the most highly cited country, and its citations are nearly double of the UK' citations. Compared to the table 6, Belgium drops out of the list of top ten most cited countries, and Turkey replaces Belgium as the member of top most cited countries. Except for the number of citations, the number of citations per paper is provided, and it reveals the attraction of single paper. One thing is interesting that USA dominates the advantage in the total number of citations, but it is behind Australia, France, Turkey and UK in the number of citations per paper. What is more, we calculate the number of citations from the IJF (In-TC) and the number of citations outside the IJF (Out-TC). The former demonstrates how many IJF researches pay attention to the papers of the country, and the latter shows the prestige that the papers of the country possesses outside the IJF. USA is the most prolific country, but its citation percentage from the IJF is the lowest, which means its researches caught more attention from journals outside the IJF. On the contrary, Italy, France, and Germany possess a relatively high citation percentage from the IJF, which means these countries receive more endorsements from the researches in IJF compared with the remaining countries.

Table 8: Information about the top ten most cited countries

Rank	Country	TC	TP	TC/TP	In-TC	In%	Out-TC	Out%
1	USA	22875	798	28.67	901	3.94%	21974	96.06%
2	UK	12899	420	30.71	646	5.01%	12253	94.99%
3	Australia	6540	178	36.74	352	5.38%	6188	94.62%
4	Netherlands	2635	99	26.62	150	5.69%	2485	94.31%
5	France	2417	67	36.07	226	9.35%	2191	90.65%
6	Germany	2023	110	18.39	164	8.11%	1859	91.89%
7	Spain	1876	93	20.17	128	6.82%	1748	93.18%
8	Canada	1850	84	22.02	121	6.54%	1729	93.46%
9	Italy	1122	70	16.03	122	10.87%	1000	89.13%
10	turkey	1061	33	32.15	57	5.37%	1004	94.63%

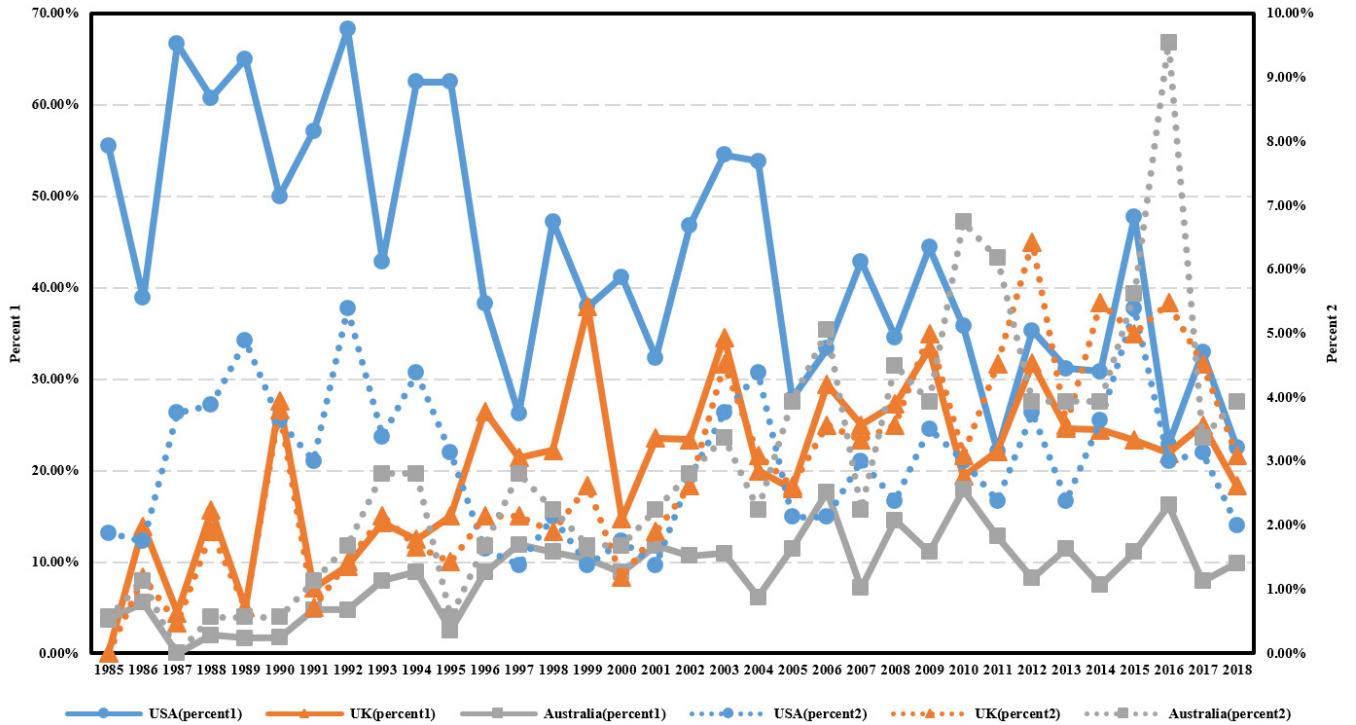


Figure 5: The dynamic of the academic productivity of the prolific countries

What is more, a country collaboration network is mapped in Fig. 6. The size of label denotes the number of papers a country produced, and the links between any connected labels indicates the collaboration relationships between connected countries. 25 countries that published no less 15 times are extracted to construct the country collaboration network. The detailed information including Link (the collaboration times a country possesses), CM (the country that collaborate most with the target country), Number (the collaboration times that CM collaborates with the target country) and N/L (the percentage that divides Number by Link) is stated in table 8. USA ranks the first in table 8 with 217 collaboration times, followed by UK with 201 collaboration times. Moreover, USA and UK are the countries that cooperate with each other the most. Besides, 11 countries cooperate with USA the most, and 9 countries cooperate with UK the most. Australia ranks the third in table 9, but it is not the most collaborated country to any of the countries in table 8, while Netherlands is the most collaborated country to Belgium, Denmark, and Austria.

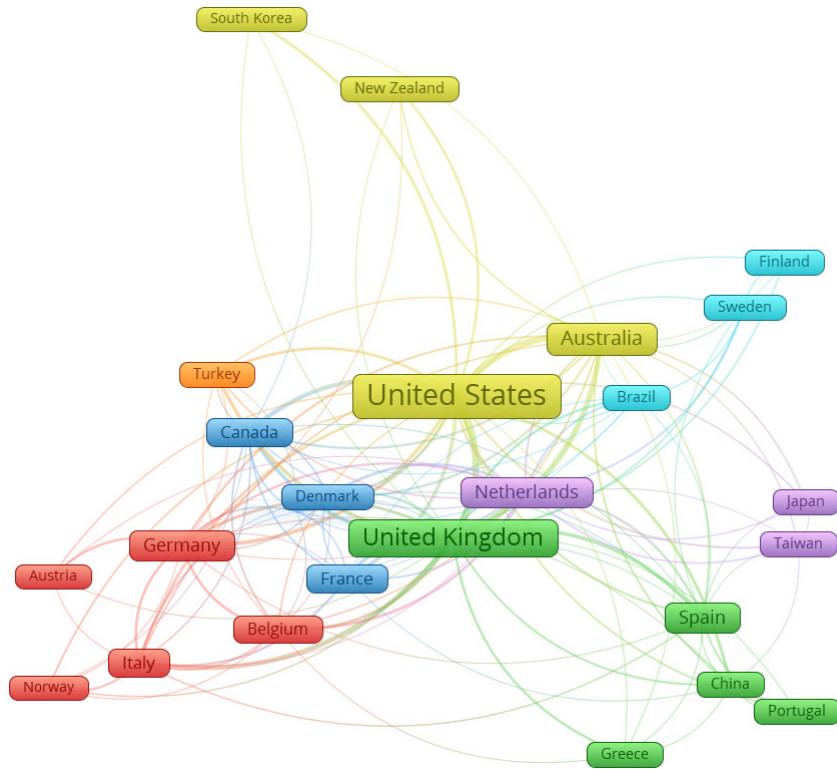


Figure 6: Country collaboration network

Table 9: Information about the countries in the country collaboration network

Rank	Country	Link	CM	Number	N/L
1	USA	217	UK	44	20.28%
2	UK	201	USA	44	21.89%
3	Australia	116	US	42	36.21%
4	Netherlands	69	USA/Belgium	8	11.59%
5	Germany	61	USA	14	22.95%
6	Italy	57	UK	21	36.84%
7	Canada	54	USA	19	35.19%
8	France	49	UK	15	30.61%
9	Spain	39	UK	13	33.33%
10	Belgium	34	Netherlands/UK	8	23.53%
11	Denmark	32	Netherlands	7	21.88%
12	Turkey	30	UK	12	40.00%
13	Switzerland	20	USA	4	20.00%
14	Brazil	19	UK	6	31.58%
15	China	19	USA	9	47.37%
16	Sweden	15	Netherlands	4	26.67%
17	Taiwan	14	USA	5	35.71%
18	Norway	12	Italy	4	33.33%
19	Greece	11	UK	6	54.55%
20	New Zealand	11	USA	6	54.55%
21	South Korea	11	USA	8	72.73%
22	Austria	10	Germany	5	50.00%
23	Japan	10	USA/Japan	3	30.00%
24	Portugal	8	Spain/USA	3	37.50%
25	Finland	7	Sweden/UK/USA	2	28.57%

### 3. Knowledge diffusion analysis of the forecasting journals

In academics, knowledge diffuses along with the citing behaviors of papers, and papers belong to different subject areas according to their research contents. In Scopus, subject areas are usually considered as the labels to classify the different kinds of knowledge. In this study, subject areas are used for conducting the knowledge diffusion analysis. However, categorizations on subject areas exist deviations because of the informal acquisition (Leydesdorff and Goldstone 2014), therefore, the analysis only relying on the level of subject areas is easily to be subject to a biased result. For this reason, the knowledge diffusion analysis is conducted both at the subject area level and the journal level.

As one of the leading forecasting journal, IJF was launched in 1985 following another authoritative forecasting journal, Journal of Forecasting (JF). These two leading forecasting journals are the important members in the International Institute of Forecasting (IIF). Therefore, in this study, in order to have a broader overview about the knowledge fertilization in the forecasting field, both of IJF and JF are included in the knowledge diffusion analysis.

#### 3.1. Analysis at the level of subject area

In this subsection, papers cited IJF and JF papers are selected, respectively, as the raw data. A static analysis about the subject area distribution is provided to figure out which subject areas pay attention to the forecasting papers. Moreover, a dynamic analysis is supplemented to describe how the subject area distribution evolves over time. Forecasting papers in different periods may attract researches from different subject areas.

In Scopus, IJF papers ranging from 1985 to 2018 was retrieved, and then 29464 citing papers ranging from 1985 to 2019 were harvested. Similarly, 16419 citing papers are obtained based on JF papers from 1982 to 2018. The top ten most prolific subject areas among the citing papers are stated in table 10. Four indicators are used: the number of citations that the IJF papers belonging to the subject area received (NP1), NP1/29464 citing papers of IJF (Percent1), the number of citations that the JF papers belonging to the subject area received (NP2), and NP2/16419 citing papers of JF (Percent2). We find that IJF citing papers and JF citing papers possess the same prolific subject areas, which denotes both of the journals have very similar audiences. IJF and JF were set with an aim that become an output for the BEM forecasting researches (Fildes 2006). From the angle of knowledge diffusion, this aim has been successfully achieved because Computer Science, Economics, Econometrics and Finance, and Business, Management and Accounting have become the three dominant subject areas based on the forecasting citing papers.

Table 10: Information about the top ten most prolific subject areas

29464 citing papers of IJF				16419 citing papers of JF			
Rank	Subject area	NP1	Percent1	Rank	Subject area	NP2	Percent2
1	Computer Science	7586	25.75%	1	Economics, Econometrics and Finance	5184	31.57%
2	Economics, Econometrics and Finance	7487	25.41%	2	Business, Management and Accounting	4891	29.79%
3	Business, Management and Accounting	7449	25.28%	3	Mathematics	3946	24.03%
4	Engineering	5888	19.98%	4	Computer Science	3791	23.09%
5	Mathematics	5482	18.61%	5	Decision Sciences	2971	18.09%
6	Social Sciences	4277	14.52%	6	Engineering	2305	14.04%
7	Decision Sciences	3665	12.44%	7	Social Sciences	2179	13.27%
8	Energy	2222	7.54%	8	Environmental Science	1109	6.75%
9	Environmental Science	2070	7.03%	9	Energy	641	3.90%
10	Earth and Planetary Sciences	969	3.29%	10	Earth and Planetary Sciences	588	3.58%

#### 3.2. Analysis at the level of journal

Based on the subsection 3.1, the knowledge flow analysis at the level of subject area has been completed, but the scope of subject area is kind of wide-ranging. Therefore, the research scope is narrowed to the level of journal to conduct a further knowledge flow analysis. The subject areas which have a special performance

in subsection 3.1 will be analyzed as the primary research objectives, and the citation relationships between different journals within the same subject area will be elaborated and visualized in citation networks. Moreover, all of the analysis is dynamic to better elaborate the evolution progress of the knowledge flow among the different journals. Considering the authority of IJF and JF in the forecasting field, the knowledge diffusion processes starting from IJF and JF are both delineated based on their citations relationships. The forecasting-related applications published in the journals outside the forecasting journals are investigated. Note that only the top three subject areas in IJF and JF respectively are elaborated in the following content, only we only display the journal citation networks of the top three subject areas. The remaining seven subject areas in IJF and JF and their journal citation networks are given in the Appendix.

### 3.2.1. Knowledge diffusion within the same subject area starts from IJF

Knowledge diffusion starts from IJF has been investigated in 3.1.2, and the top three subject areas are Computer Science, Economics, Econometrics and Finance, and Business, Management and Accounting. All of the citing papers belonging to these three subject areas are harvested, respectively, then aggregate them into the level of journal, and the journal citation relationships between different journals within the same subject area are extracted and mapped in journal citation networks. Four parameters are used to evaluate the journal citation network, including clusters (the number of groups containing the same color nodes), local links (the number of links), link strength (the total strength that each link possesses), and items (the number of nodes). Note that the size of node in the network represents the number of publications that the journal published, and the thickness of link between connected nodes represents the number of citations between the connected journals.

#### 3.2.1.1. Journal citation network in Computer Science

All the citing papers belonging to Computer Science are harvested. 21 Journals that have no less than 50 publications and 700 citations are selected to map the IJF journal citation network in Fig. 7, and the journal citation structure can be intuitively observed from Fig. 7. 21 Journals that have no less than 40 publications and 200 citations are selected. Four parameters are clusters (7), local links (169), link strength (6146), and items (21). The top ten journals that have the most citation connections in this journal citation network are extracted. Note that the information about the top ten journals is stated in table 11.

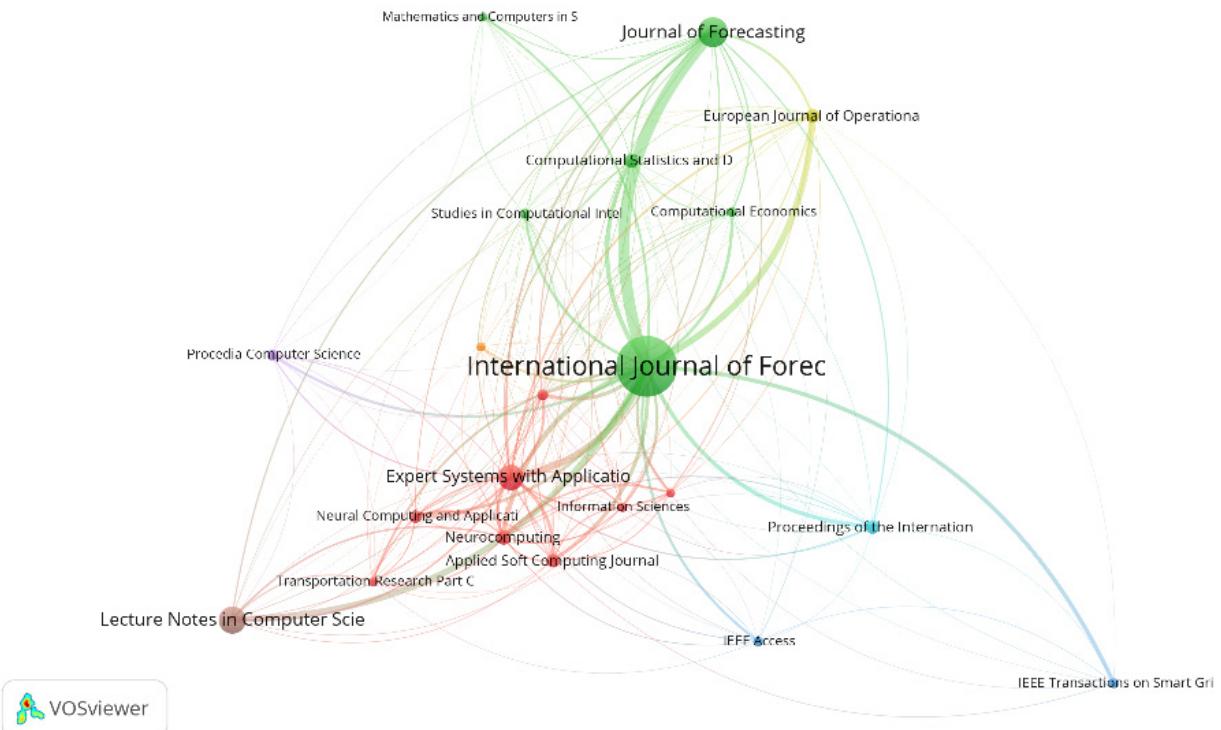


Figure 7: IJF Journal citation network in Computer Science

Observing from the Fig. 7, IJF occupies a central place in network with other journals around it. The link between IJF and JF is the thickest in this journal citation network, which indicates JF has the most

citation connection with IJF. The node size of JF, Expert Systems with Applications, and Lecture Notes in Computer Science is similar, which indicates these three journals published a similar number of publications within the range of IJF citing papers. However, the thickness of the links which are between IJF and Expert Systems with Applications as well as between IJF and Lecture Notes in Computer Science is thinner than that of the link which is between IJF and JF. In the table 11, two indicators are provided: Links (the number of citations that journal has within selected IJF citing papers in Computer Science), Links with IJF (the number of citations that are between the journal and IJF), and % (Links/ Links with IJF %). JF, European Journal of Operational Research, Computational Statistics and Data Analysis, and Proceedings of The International Joint Conference on Neural Networks have a high percentage, which demonstrates most of their citations are related to IJF.

Table 11: Information about the IJF journal citation network in Computer Science

Rank	Journal	Links	Links with IJF	%
1	Journal of Forecasting	1814	1464	80.71%
2	Expert Systems with Applications	1279	553	43.24%
3	Neurocomputing	686	259	37.76%
4	European Journal of Operational Research	647	462	71.41%
5	Lecture Notes in Computer Science	609	444	72.91%
6	Applied Soft Computing	446	160	35.87%
7	Decision Support Systems	345	149	43.19%
8	Computational Statistics and Data Analysis	341	214	62.76%
9	Neuro Computing and Application	286	99	34.62%
10	Proceedings of The International Joint Conference on Neural Networks	260	173	66.54%

### 3.2.1.2. Journal citation network in Economics, Econometrics and Finance

21 Journals that have no less than 35 publications and 400 citations are selected to map the IJF journal citation network in Economics, Econometrics and Finance. The journal citation relationships based on the citing papers belonging to Economics, Econometrics and Finance are depicted in the Fig. 8, and the detailed information is stated in table 12. From the structure of the network, IJF is a dominating center. International Journal of Production Economics locates far from the other journals in the journal network, and the links between International Journal of Production Economics and related journals is much less than that of other connected journals in the journal network. In the table 11, most journals have a percentage less 50%, however, International Journal of Production Economics has a very high percentage (i.e., 95.27%). We can find that 403 of the 423 citing papers of International Journal of Production Economics are linked to IJF. Journal of Applied Economics ranks third in the table 12, but only 350 citing papers are linked to IJF.

Table 12: Information about the IJF journal citation network in Economics, Econometrics and Finance

Rank	Journal	Links	Links with IJF	%
1	Journal of business and economic statistics	1535	638	41.56%
2	Journal of Economics	1227	497	40.51%
3	Journal of Applied Economics	908	350	38.55%
4	Applied Economics	891	459	51.52%
5	Energy Economics	890	454	51.01%
6	Economic Modeling	836	346	41.39%
7	Empirical Economics	656	311	47.41%
8	Oxford Bulletin of Economics and Statistics	436	184	42.20%
9	International Journal of Production Economics	423	403	95.27%
10	Journal of Empirical Finance	336	121	36.01%

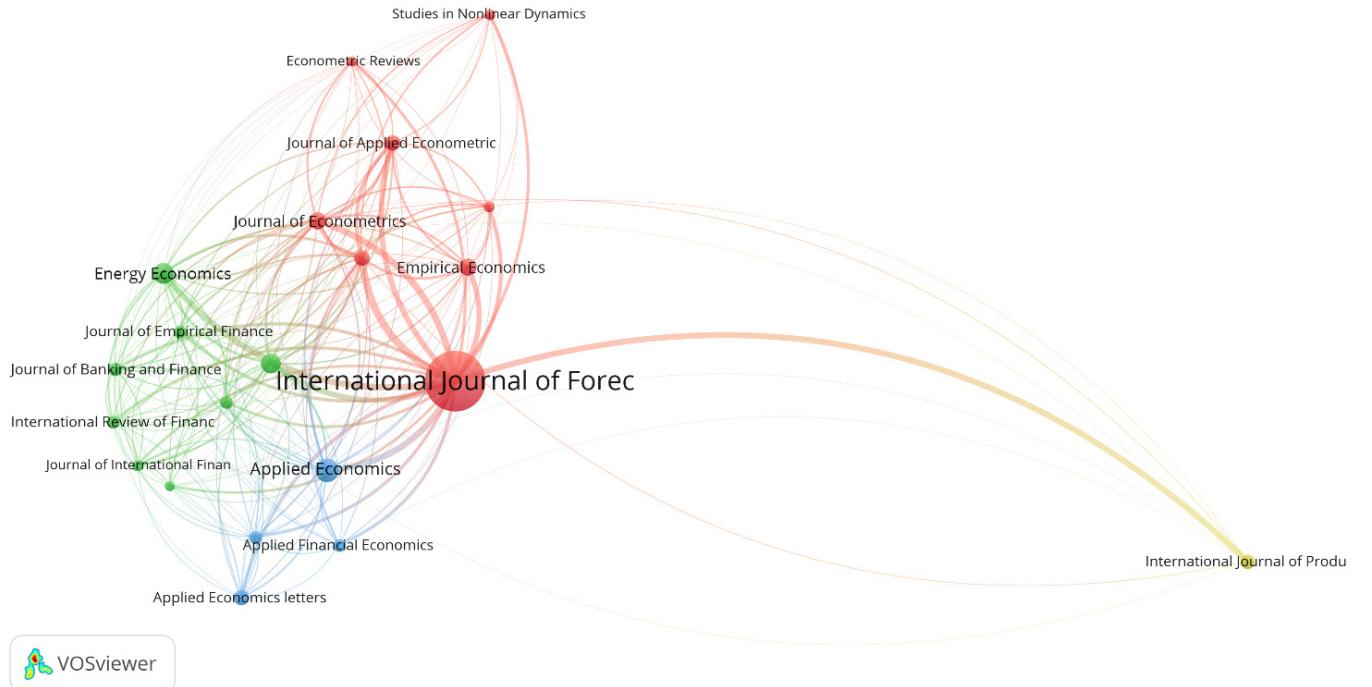


Figure 8: IJF Journal citation network in Economics, Econometrics and Finance

### 3.2.1.3. Journal citation network in Business, Management and Accounting

21 Journals that have no less than 20 publications and 300 citations are selected to map the IJF journal citation network in Business, Management and Accounting. The journal citation relationships based on the IJF papers and citing papers belonging to Business, Management and Accounting are depicted in the Fig. 9, and the detailed information is stated in table 13. From the Fig. 9, IJF is the absolute center in the network, and JF is the most citing journal. Some Tourism-related journals locate in the right of the network, which are far away from the remaining journals. In the table 13, some journal have many papers citing IJF papers, while others only have a few papers citing IJF papers. JF (81.81%) and Technological Forecasting and Social Change (70.42%) are two journals that have the highest percentages of citing papers. Annals of Tourism Research (19.63%), Tourism Management (22.32%), Journal of Travel Research (22.47%), and Tourism Economics (29.86%) have the lowest percentages of citing papers, which are all Tourism-related journals.

Table 13: Information about the IJF journal citation network in Business, Management and Accounting

Rank	Journal	Links	Links with IJF	%
1	Journal of Forecasting	1891	1547	81.81%
2	Tourism Management	981	219	22.32%
3	Tourism Economics	921	275	29.86%
4	International Journal of Production Economics	785	421	53.63%
5	Journal of Travel Research	721	162	22.47%
6	Journal of the Operational Research Society	709	387	54.58%
7	Technological Forecasting and Social Change	612	431	70.42%
8	Annals of Tourism Research	591	116	19.63%
9	Organizational Behavior and Human Decision Processes	412	193	46.84%
10	Omega	378	208	55.03%

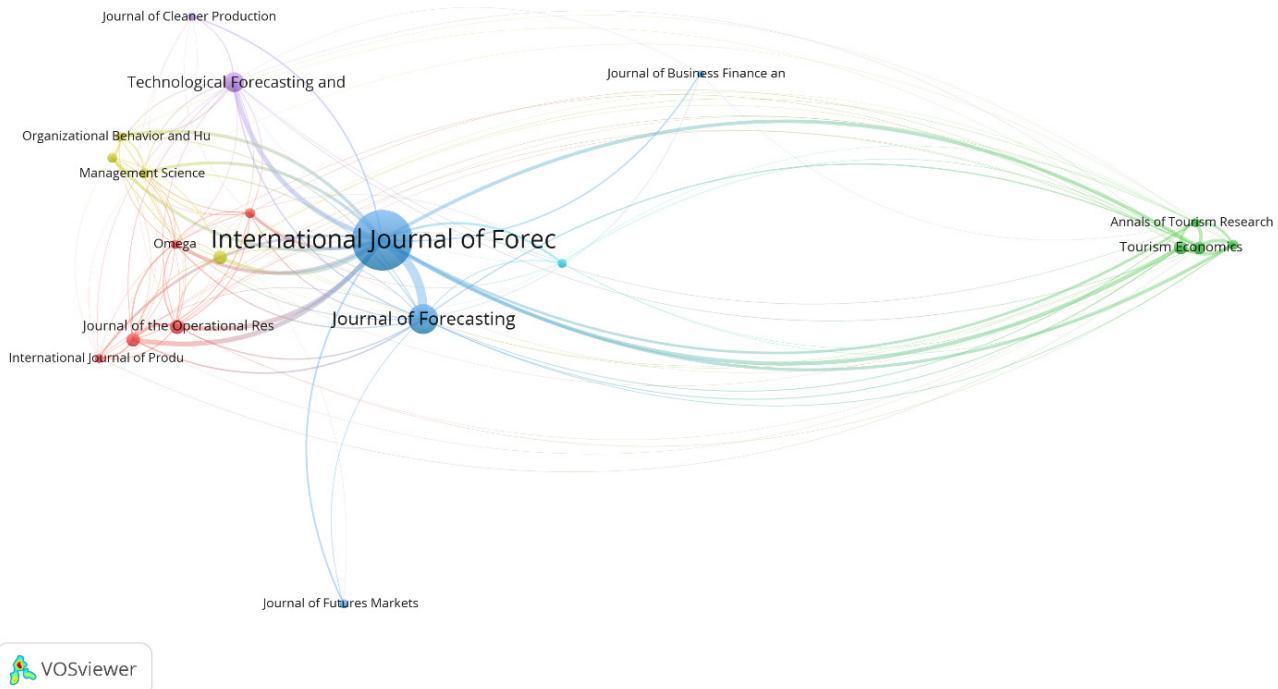


Figure 9: IJF Journal citation network in Business, Management and Accounting

### 3.2.2. Knowledge diffusion within the same subject area starts from JF

Knowledge diffusion starts from JF has been investigated in 3.1.2, and five subject areas have a special performance, which are Business, Management and Accounting, Economics, and Mathematics. All of the citing papers belonging to these five subject areas are harvested, respectively, then are aggregate them into the level of journal, and the journal citation relationships between different journals within the same subject area are extracted and mapped in journal citation networks. The citation connection between IJF and JF is very strong in the journal citation networks of IJF, however, in the journal citation networks of JF, their citation connection becomes much weaker, which denotes that the knowledge diffusing strength starting from JF to IJF is weaker than from IJF to JF.

#### 3.2.2.1. Journal citation network in Business, Management and Accounting

21 Journals that have no less than 20 publications and 300 citations are selected to map the JF journal citation network in Business, Management and Accounting. JF papers and their citing papers belonging to Business, Management and Accounting are selected and the journal citation network is extracted in Fig. 10. The detailed information about the journal network is stated in the table 14. In the Fig. 10, the link of JF and IJF is the thickest in the journal network, which means IJF has the most citations citing JF papers. Similar as the journal network of the subsection 3.2.1.3, Tourism-related journals still exist in this journal network of Fig. 10. From the table 14, these tourism-related journals all have a lower percentage of citing papers. Except for IJF, the remaining nine journals in the table 14 all have a percentage lower than 50%.

Table 14: Information about the JF journal citation network in Business, Management and Accounting

Rank	Journal	Links	Links with IJF	%
1	Journal of Forecasting	3391	1887	55.65%
2	Technological Forecasting and Social Change	411	172	41.85%
3	International Journal of Production Economics	408	113	27.70%
4	Journal of the Operational Research Society	351	146	41.60%
5	Tourism Management	327	70	21.41%
6	Organizational Behavior and Human Decision Processes	316	68	21.52%
7	Tourism Economics	309	51	16.50%
8	Omega	299	80	26.76%
9	Journal of Behavioral Decision Making	225	69	30.67%
10	Annals of Tourism Research	213	48	22.54%

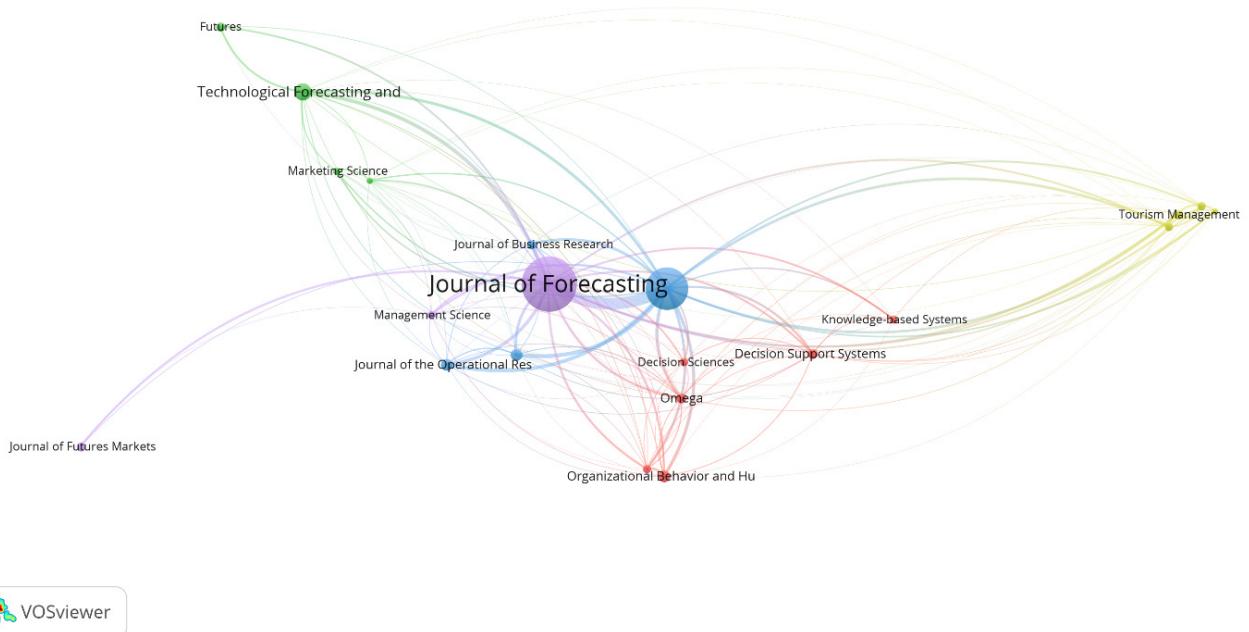


Figure 10: JF Journal citation network in Business, Management and Accounting from 1982 to 1994

### 3.2.2.2. Journal citation network in Economics, Econometrics and Finance

21 Journals that have no less than 40 publications and 500 citations are selected to map the JF journal citation network in Economics, Econometrics and Finance. The citation networks based on the JF papers and their citing papers belonging to Economics, Econometrics and Finance are depicted in Fig. 11, and the detailed information about the journal network is stated in the table 15. JF locates in the center of the journal network with other journals around it. International Journal of Production Economics is the citing journal that locates far away from the other journals, which denotes the content similarity between International Journal of Production Economics and other connected journals is much smaller. From the table 15, Applied Economics has the highest percentage of citing papers, while the remaining journal all have percentage lower than 50%.

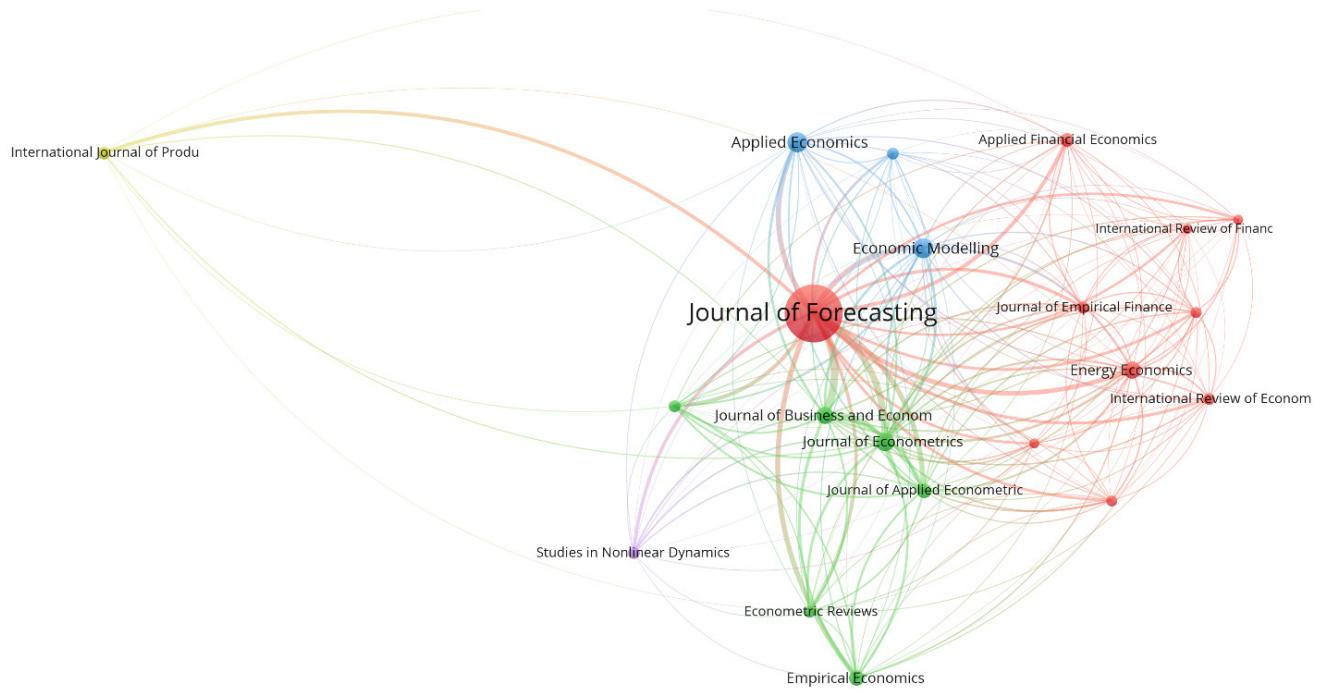


Figure 11: JF Journal citation network in Economics, Econometrics and Finance

Table 15: Information about the JF journal citation network in Economics, Econometrics and Finance

Rank	Journal	Links	Links with IJF	%
1	Journal of Business and Economic Statistics	1319	549	41.62%
2	Journal of Econometrics	1104	408	36.96%
3	Journal of Applied Econometrics	755	232	30.73%
4	Economic Modelling	615	250	40.65%
5	Energy Economics	509	193	37.92%
6	Empirical Economics	502	230	45.82%
7	Applied Economics	466	236	50.64%
8	Oxford Bulletin of Economics and Statistics	369	142	38.48%
9	Econometric Reviews	285	100	35.09%
10	Journal of Empirical Finance	267	93	34.83%

### 3.2.2.3. Journal citation network in Mathematics

20 Journals that have no less than 20 publications and 300 citations are selected to map the JF journal citation network in Mathematics. As shown in Fig. 12, the journal citation relationships between JF papers and their citing papers in Mathematics are mapped based on the journal citation network. In Fig. 12, JF locates in the center of the journal citation network, and the remaining journals are all around JF. No journal exists as a big node or linking with JF thickly, which indicates no citing journal has a prominent performance in this journal citation network. This point also can be confirmed from the table 16. All of the citing journals have less than 1,000 links in this journal citation network, and the majority of them have an approximately 50% of citing papers related to JF. European Journal of Operational Research has the highest percentage of citing papers with 75.84%, and Journal of Applied Statistics ranks second in citing paper percentage with 70.12%.

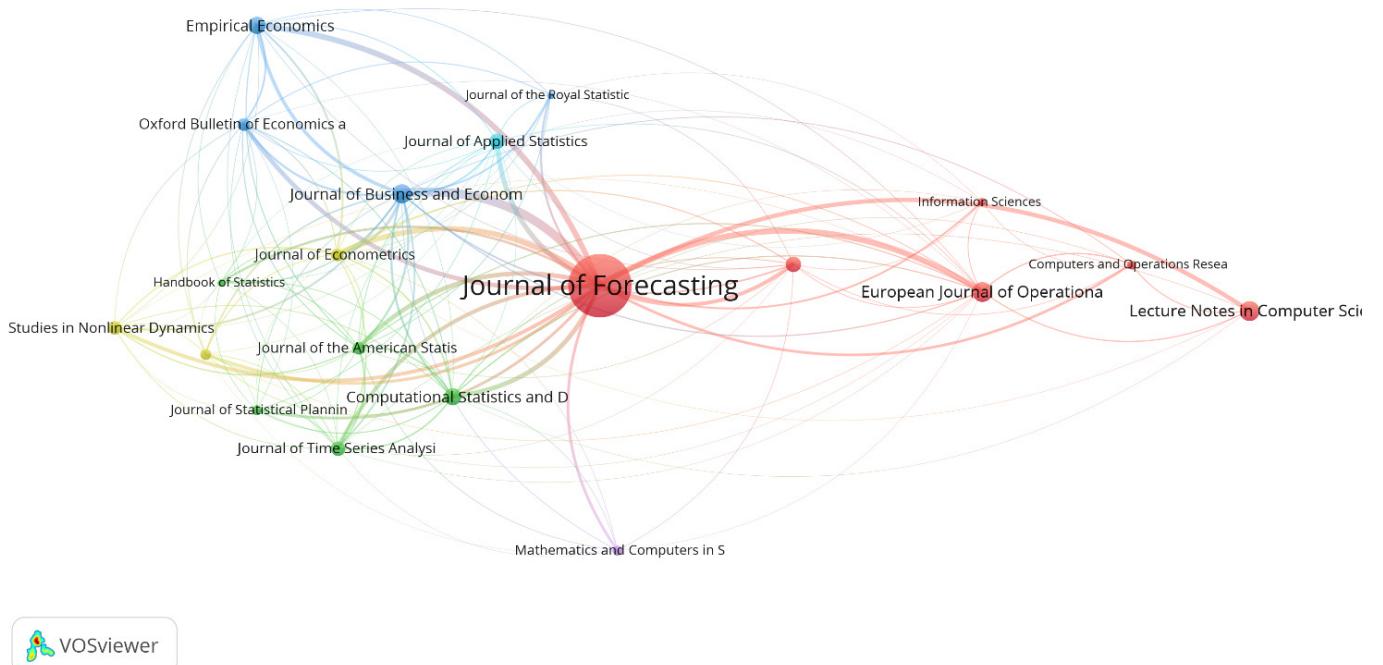


Figure 12: JF Journal citation network in Mathematics

Table 16: Information about the JF journal citation network in Mathematics

Rank	Journal	Links	Links with IJF	%
1	Journal of Business and Economic Statistics	978	563	57.57%
2	Empirical Economics	405	231	57.04%
3	Journal of Econometrics	385	201	52.21%
4	European Journal of Operational Research	327	248	75.84%
5	Computational Statistics and Data Analysis	301	154	51.16%
6	Journal of the American Statistical Association	286	143	50.00%
7	Oxford Bulletin of Economics and Statistics	255	144	56.47%
8	Journal of Applied Statistics	251	176	70.12%
9	Journal of Time Series Analysis	205	109	53.17%
10	Studies in Nonlinear Dynamics and Econometrics	179	98	54.75%

#### 4. Conclusion and discussion

It has been proven that the proposed method combining the basic bibliometric indicators and the science mapping techniques is effective to evaluate the merits of a journal. In this paper, this combination has been used to analyze the state of development of International Journal of Forecasting (IJF) from different angles. Three factors influencing the performance of the journal are identified, and we focus on analyzing the most cited/co-cited papers, the most prolific/cited authors, and the most prolific/cited countries. Moreover, citation/co-citation relationships, co-author relationships, country collaboration relationships between IJF papers and their citing papers are elaborated based on science mapping techniques.

In addition, a knowledge diffusion analysis is conducted to supplement the above proposed method. Based on this knowledge diffusion analysis, the researches outside the forecasting field can be identified through investigating the intellectual radiation impact of the forecasting researches. The analysis supports a valuable direction for the future forecasting researches. As the leading journals in the forecasting field, IJF and Journal of Forecasting (JF) papers are all included. Through investigating the citation relationships between IJF papers and their citing paper, four typical citing subject areas which are Computer Science, Engineering, Psychology, and Decision Sciences have been selected. The journal citation relationships between IJF and the journals belonging to these four citing subject areas are delineated through journal citation

networks. Similar work is conducted between JF papers and their citing papers, and we derive five typical citing subject areas which are Computer Science, Economics, Econometrics and Finance, Engineering, Psychology, and Decision Sciences. Also the journal citation networks are constructed to explore the relationships between JF and the journals belonging to the five citing subject areas. Besides, the citing subject areas which have a special performance both in IJF and JF are chosen as the overlapping citing subject areas, and they are Computer Science, Engineering, Psychology, and Decision Science. We investigate the IJF papers which are cited by the most journals within these four subject area, and the derived findings can answer the question how the IJF researches being cited in the papers outside the forecasting field behave and what kind of forecasting knowledge diffuses more widely to the researches outside the forecasting field.

## Appendix

### Section A: IJF journal citation networks

#### A1: IJF journal citation network in Engineering

21 Journals that have no less than 30 publications and 300 citations are selected to map the IJF journal citation network in Engineering. Four parameters are clusters (6), local links (133), link strength (4376), and items (21).

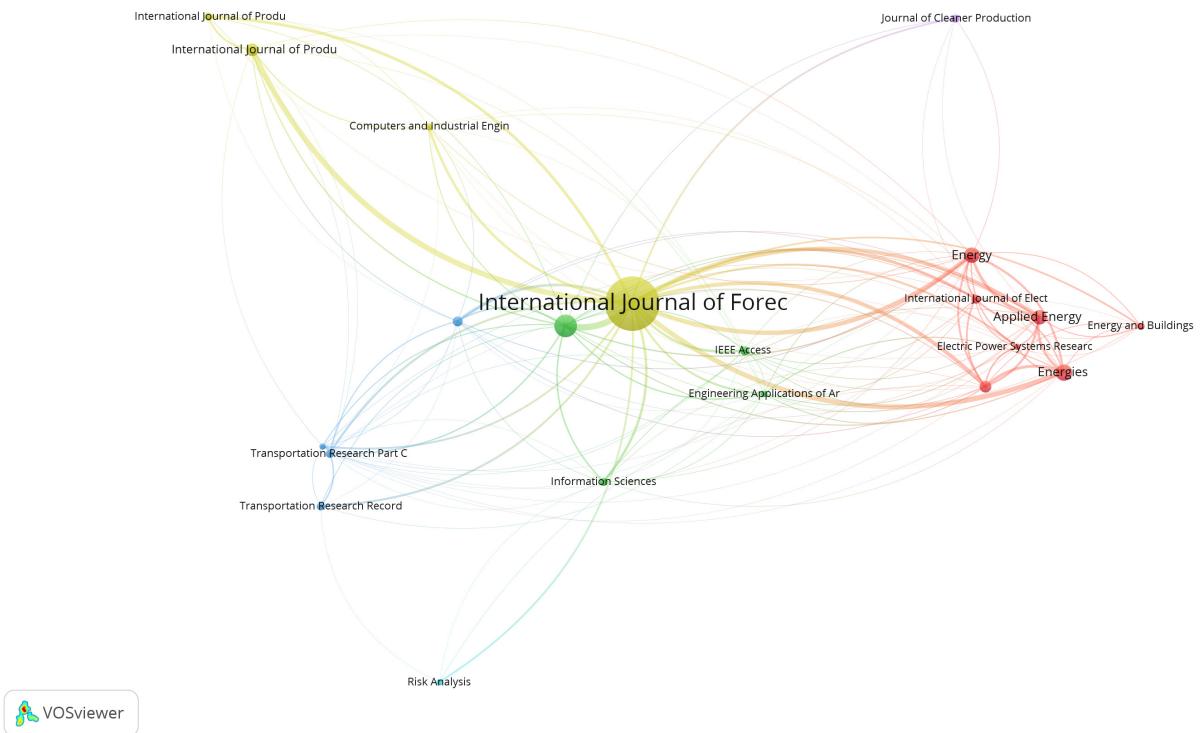


Figure 13: IJF journal citation network in Engineering

Table 17: Information about the IJF journal citation network in Engineering

Rank	Journal	Links	Links with IJF	%
1	Expert Systems with Applications	797	543	68.13%
2	Energies	693	319	46.03%
3	Energy	609	262	43.02%
4	Applied Energy	595	209	35.13%
5	IEEE Transactions on Power Systems	553	196	35.44%
6	International Journal of Production Economics	513	403	78.56%
7	International Journal of Electrical Power and Energy Systems	287	98	34.15%
8	Transportation Research Part C: Emerging Technologies	233	63	27.04%
9	Mathematical Problems in Engineering	203	106	52.22%
10	Electric Power Systems Research	193	57	29.53%

## A2: IJF journal citation network in Mathematics

21 Journals that have no less than 30 publications and 300 citations are selected to map the IJF journal citation network in Mathematics. Four parameters are clusters (6), local links (156), link strength (7607), and items (21).

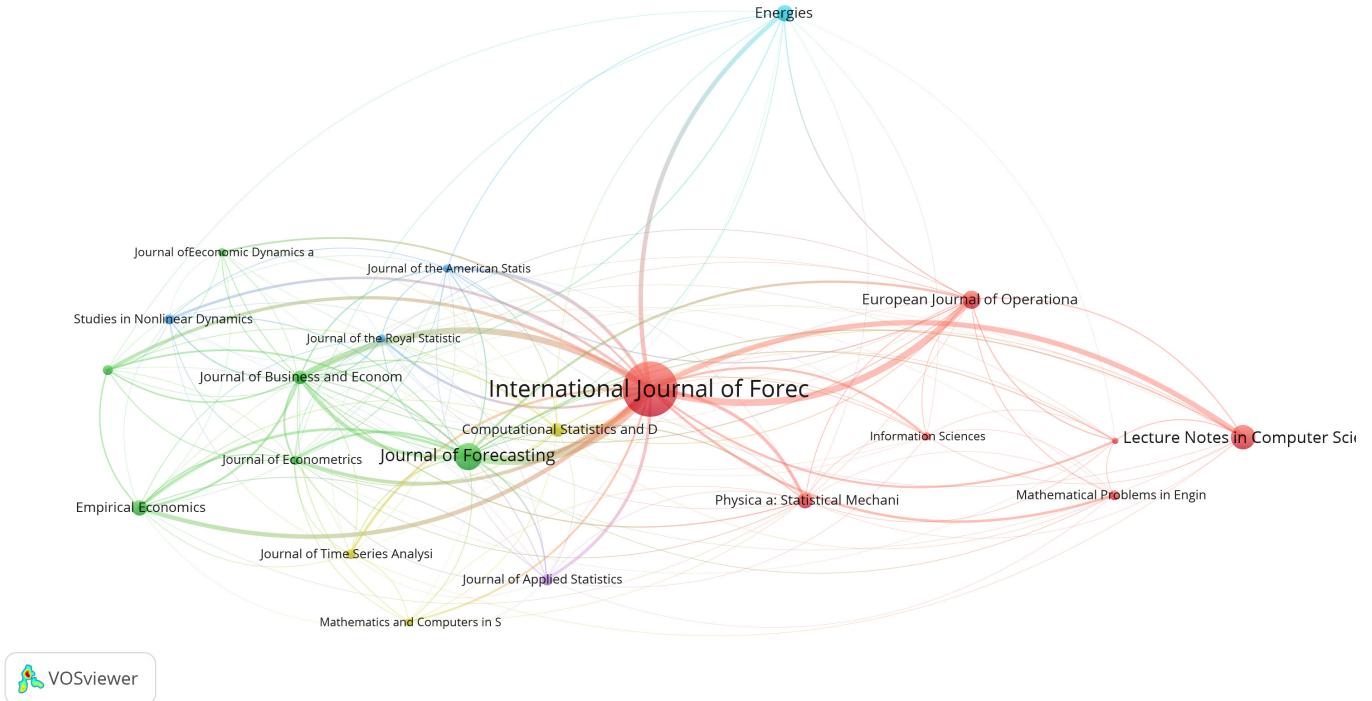


Figure 14: IJF journal citation network in Mathematics

Table 18: Information about the IJF journal citation network in Mathematics

Rank	Journal	Links	Links with IJF	%
1	Journal of Forecasting	2317	1464	63.19%
2	Journal of Business and Economic Statistics	1290	638	49.46%
3	European Journal of Operational Research	1002	757	75.55%
4	Empirical Economics	608	311	51.15%
5	Lecture Notes in Computer Science	525	444	84.57%
6	Journal of Econometrics	463	205	44.28%
7	Computational Statistics and Data Analysis	407	214	52.58%
8	Energies	394	319	80.96%
9	Oxford Bulletin of Economics and Statistics	363	184	50.69%
10	Journal of the American Statistical Association	358	196	54.75%

## A3: IJF journal citation network in Social Sciences

21 Journals that have no less than 20 publications and 300 citations are selected to map the IJF journal citation network in Social Sciences. Four parameters are clusters (8), local links (87), link strength (4971), and items (21).

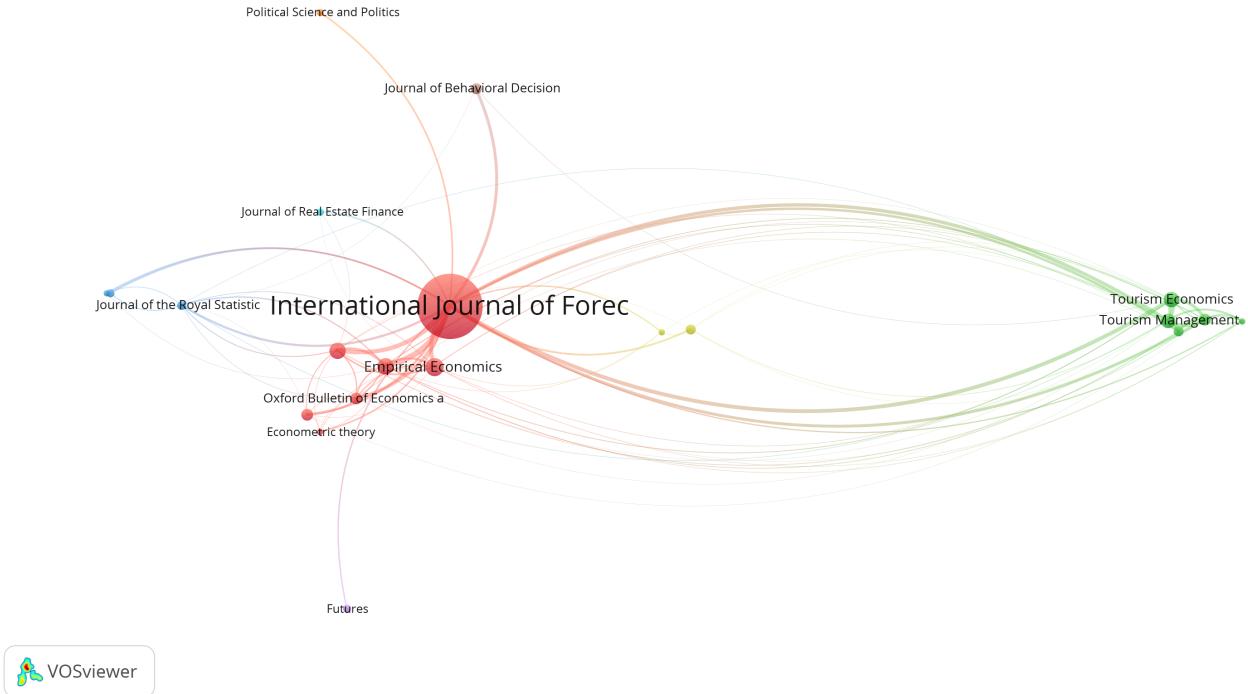


Figure 15: IJF journal citation network in Social Sciences

Table 19: Information about the IJF journal citation network in Social Sciences

Rank	Journal	Links	Links with IJF	%
1	Tourism Management	1016	214	21.06%
2	Journal of Business and Economic Statistics	1012	638	63.04%
3	Tourism Economics	932	275	29.51%
4	Journal of Travel Research	752	161	21.41%
5	Journal of Applied Econometrics	640	350	54.69%
6	Annals of Tourism Research	598	116	19.40%
7	Empirical Economics	514	311	60.51%
8	Oxford Bulletin of Economics and Statistics	309	184	59.55%
9	Journal of the Royal Statistical Society. series a: statistics in society	183	93	50.82%
10	International Journal of Tourism Research	177	27	15.25%

#### A4: IJF journal citation network in Decision Sciences

20 Journals that have no less than 30 publications and 300 citations are selected to map the IJF journal citation network in Decision Sciences. Four parameters are clusters (4), local links (138), link strength (7535), and items (20).

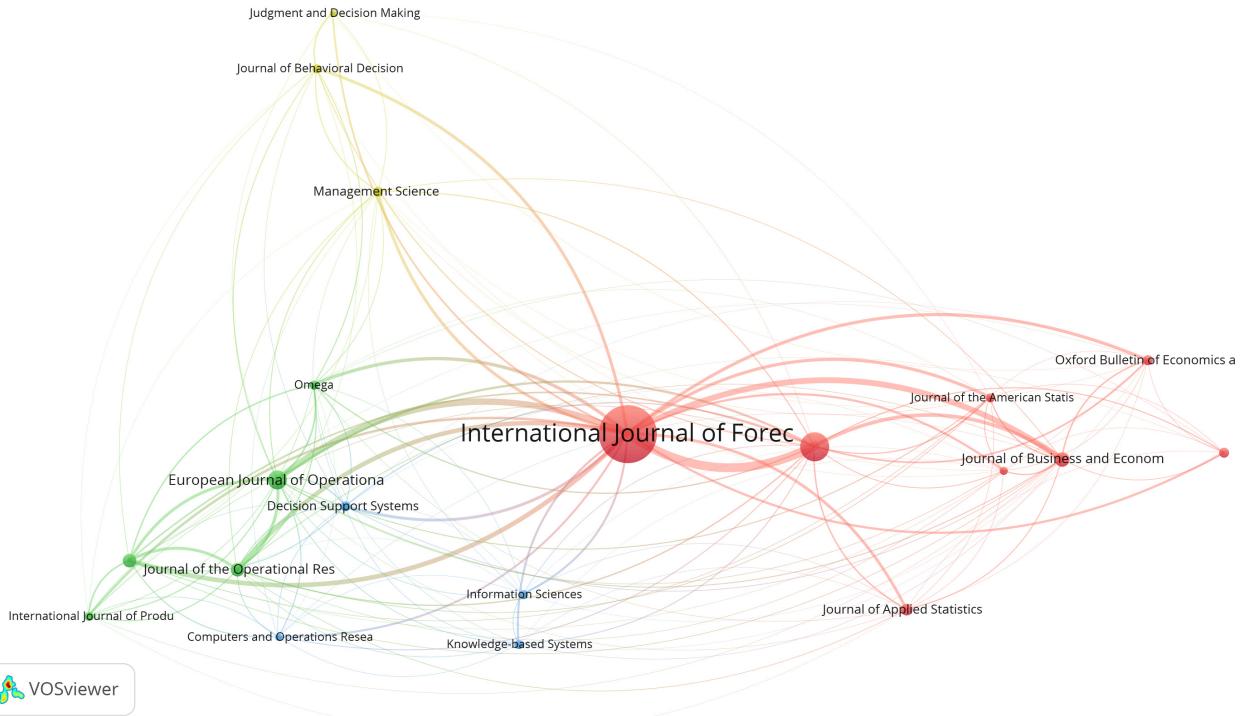


Figure 16: IJF journal citation network in Decision Sciences

Table 20: Information about the IJF journal citation network in Decision Sciences

Rank	Journal	Links	Links with IJF	%
1	Journal of Forecasting	2161	1464	67.75%
2	European Journal of Operational Research	1401	757	54.03%
3	Journal of Business and Economic Statistics	1061	638	60.13%
4	International Journal of Production Economics	914	397	43.44%
5	Journal of the Operational Research Society	860	369	42.91%
6	Omega	413	205	49.64%
7	Journal of Behavioral Decision Making	306	166	54.25%
8	Journal of the American Statistical Association	301	183	60.80%
9	Oxford Bulletin of Economics and Statistics	298	181	60.74%
10	Decision Support Systems	289	149	51.56%

#### A5: IJF journal citation network in Energy

20 Journals that have no less than 15 publications and 200 citations are selected to map the IJF journal citation network in Energy. Four parameters are clusters (4), local links (153), link strength (4734), and items (20).

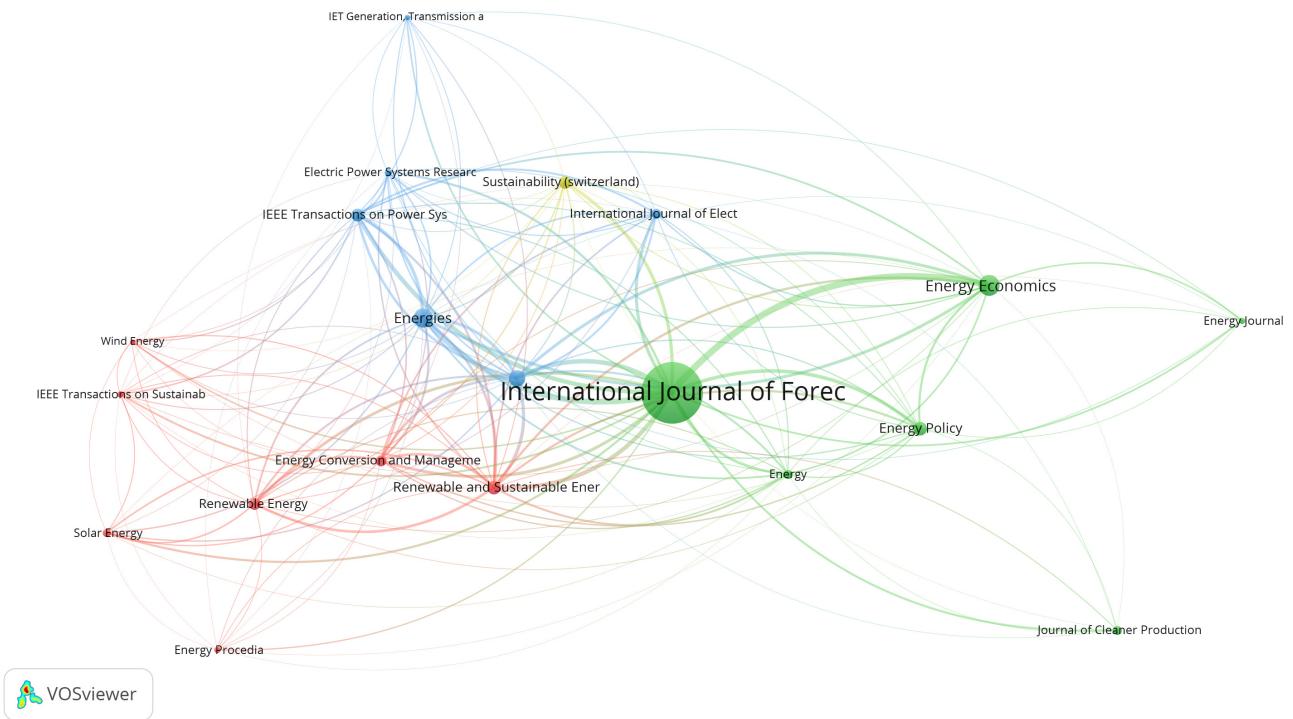


Figure 17: IJF journal citation network in Energy

Table 21: Information about the IJF journal citation network in Energy

Rank	Journal	Links	Links with IJF	%
1	Energies	967	332	34.33%
2	Energy Economics	896	454	50.67%
3	Applied Energy	886	209	23.59%
4	Renewable and Sustainable Energy Reviews	839	183	21.81%
5	IEEE Transactions on Power Systems	671	196	29.21%
6	Energy Conversion and Management	474	92	19.41%
7	Renewable Energy	374	83	22.19%
8	International Journal of Electrical Power and Energy Systems	341	98	28.74%
9	Energy Policy	336	128	38.10%
10	Energy	311	71	22.83%

#### A6: IJF journal citation network in Environmental Science

20 Journals that have no less than 15 publications and 180 citations are selected to map the IJF journal citation network in Environmental Science. Four parameters are clusters (8), local links (79), link strength (1568), and items (20).

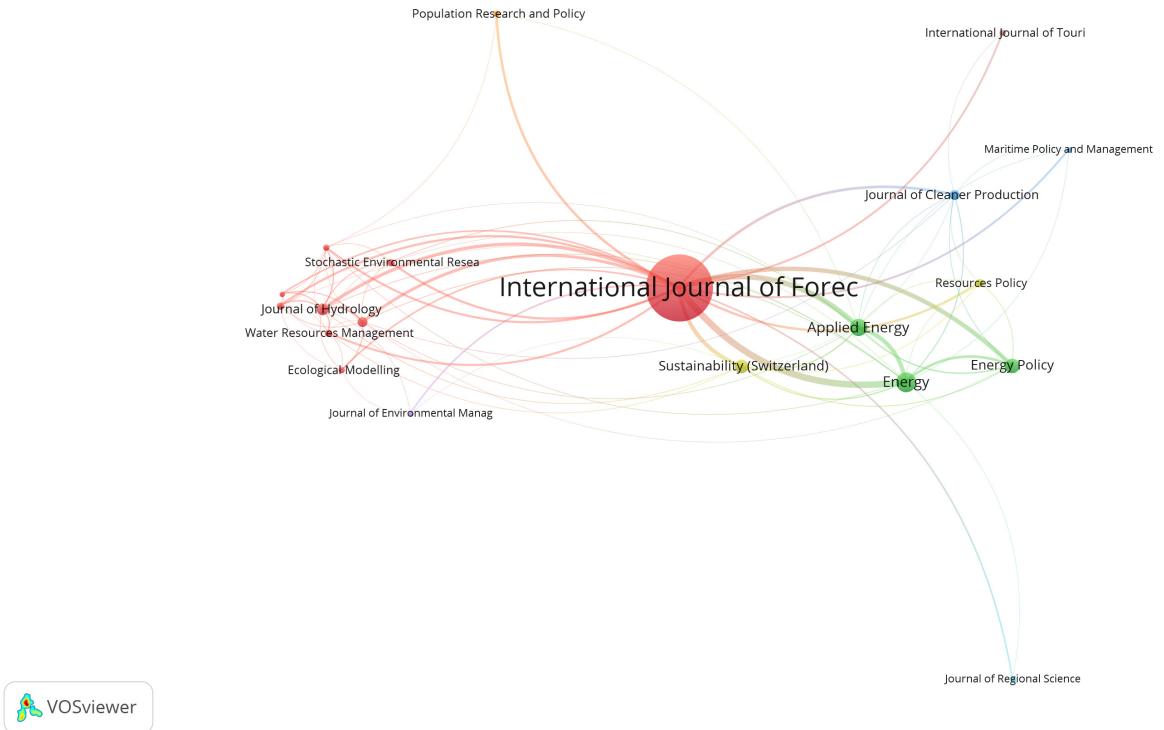


Figure 18: IJF journal citation network in Environmental Science

Table 22: Information about the IJF journal citation network in Environmental Science

Rank	Journal	Links	Links with IJF	%
1	Energy	472	286	60.59%
2	Applied Energy	339	190	56.05%
3	Energy Policy	196	128	65.31%
4	Journal of Hydrology	147	72	48.98%
5	Sustainability	146	107	73.29%
6	Environmental Modelling and Software	103	58	56.31%
7	Journal of Cleaner Production	63	45	71.43%
8	Water Resources Research	57	33	57.89%
9	Journal of Hydrologic Engineering	53	30	56.60%
10	Water Resources Management	50	29	58.00%

#### A7: IJF journal citation network in Earth and Planetary Sciences

20 Journals that have no less than 15 publications and 180 citations are selected to map the IJF journal citation network in Earth and Planetary Sciences. Four parameters are clusters (10), local links (70), link strength (481), and items (20).

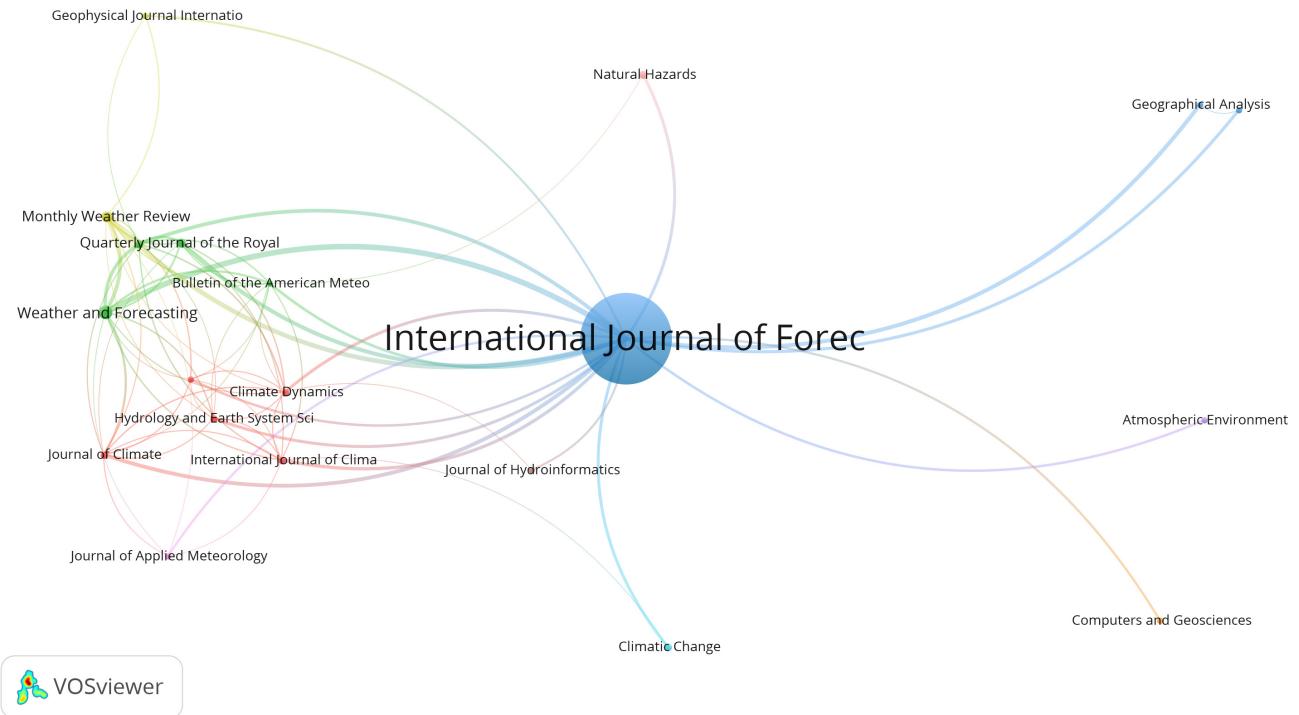


Figure 19: IJF journal citation network in Earth and Planetary Sciences

Table 23: Information about the IJF journal citation network in Earth and Planetary Sciences

Rank	Journal	Links	Links with IJF	%
1	Weather and Forecasting	119	49	41.18%
2	Monthly Weather Review	76	32	42.11%
3	Meteorological Applications	65	22	33.85%
4	Quarterly Journal of the Royal Meteorological Society	52	25	48.08%
5	Journal of Climate	48	23	47.92%
6	International Journal of Climatology	36	17	47.22%
7	Climate Dynamics	35	14	40.00%
8	Bulletin of the American Meteorological Society	34	12	35.29%
9	Hydrology and Earth System Sciences	27	14	51.85%
10	Geographical Analysis	26	25	96.15%

## Section B: JF journal citation networks

### B1: JF journal citation network in Computer Science

21 Journals that have no less than 15 publications and 100 citations are selected to map the JF journal citation network in Computer Science. Four parameters are clusters (10), local links (137), link strength (1947), and items (21).

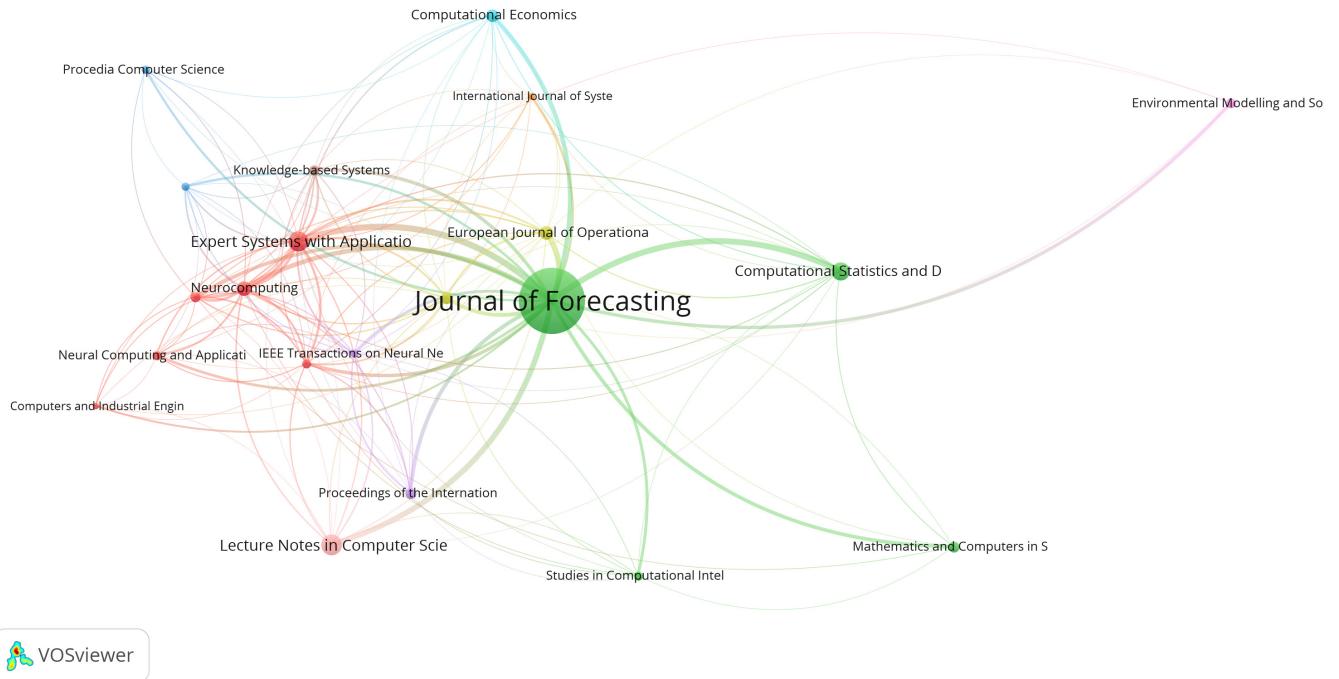


Figure 20: JF journal citation network in Computer Science

Table 24: Information about the JF journal citation network in Computer Science

Rank	Journal	Links	Links with IJF	%
1	Expert Systems with Applications	381	169	44.36%
2	Neurocomputing	266	90	33.83%
3	European Journal of Operational Research	208	136	65.38%
4	Computational Statistics and Data Analysis	186	154	82.80%
5	Lecture Notes in Computer Science	183	133	72.68%
6	Applied Soft Computing Journal	169	58	34.32%
7	Computers and Operations Research	161	51	31.68%
8	Decision Support Systems	148	59	39.86%
9	Knowledge-based Systems	111	50	45.05%
10	Computational Economics	109	83	76.15%

## B2: JF journal citation network in Decision Science

20 Journals that have no less than 20 publications and 300 citations are selected to map the JF journal citation network in Decision Science. Four parameters are clusters (4), local links (125), link strength (2978), and items (20).

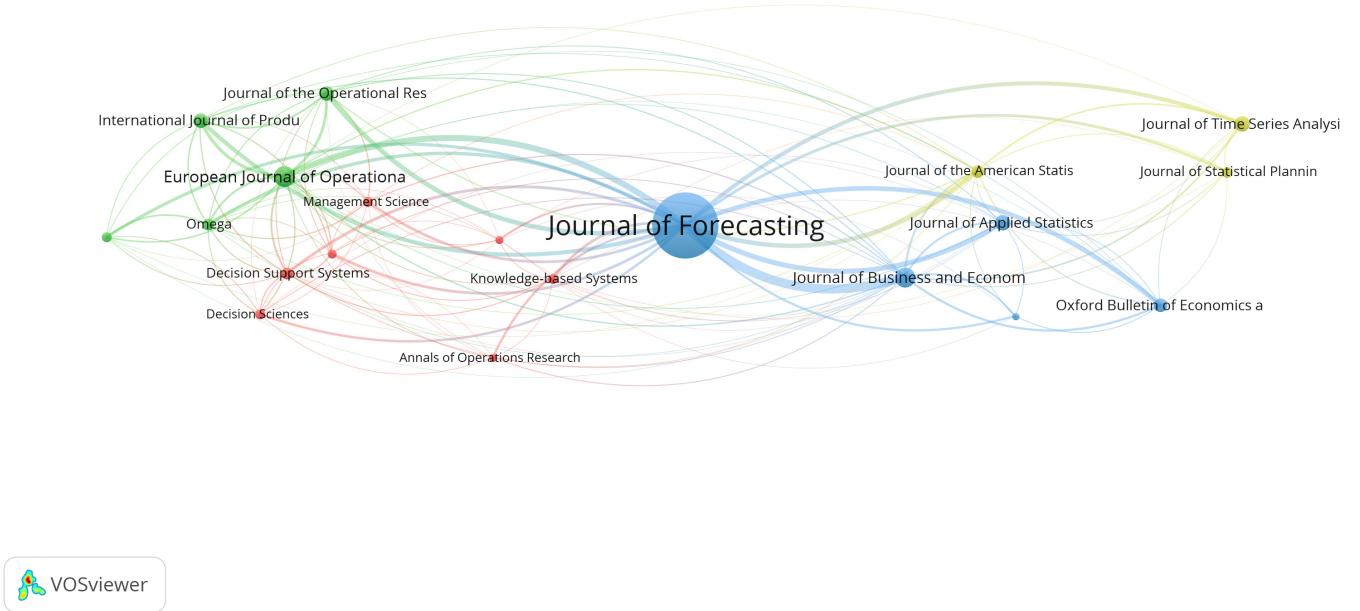


Figure 21: JF journal citation network in Decision Science

Table 25: Information about the JF journal citation network in Decision Science

Rank	Journal	Links	Links with IJF	%
1	Journal of Business and Economic Statistics	759	563	74.18%
2	European Journal of Operational Research	510	248	48.63%
3	Journal of the Operational Research Society	284	146	51.41%
4	International Journal of Production Economics	262	113	43.13%
5	Journal of Applied Statistics	240	176	73.33%
6	Journal of the American Statistical Association	238	140	58.82%
7	Oxford Bulletin of Economics and Statistics	209	144	68.90%
8	Omega	189	80	42.33%
9	Journal of Time Series Analysis	157	107	68.15%
10	Decision Support Systems	150	59	39.33%

### B3: JF journal citation network in Engineering

20 Journals that have no less than 12 publications and 180 citations are selected to map the JF journal citation network in Engineering. Four parameters are clusters (7), local links (57), link strength (760), and items (20).

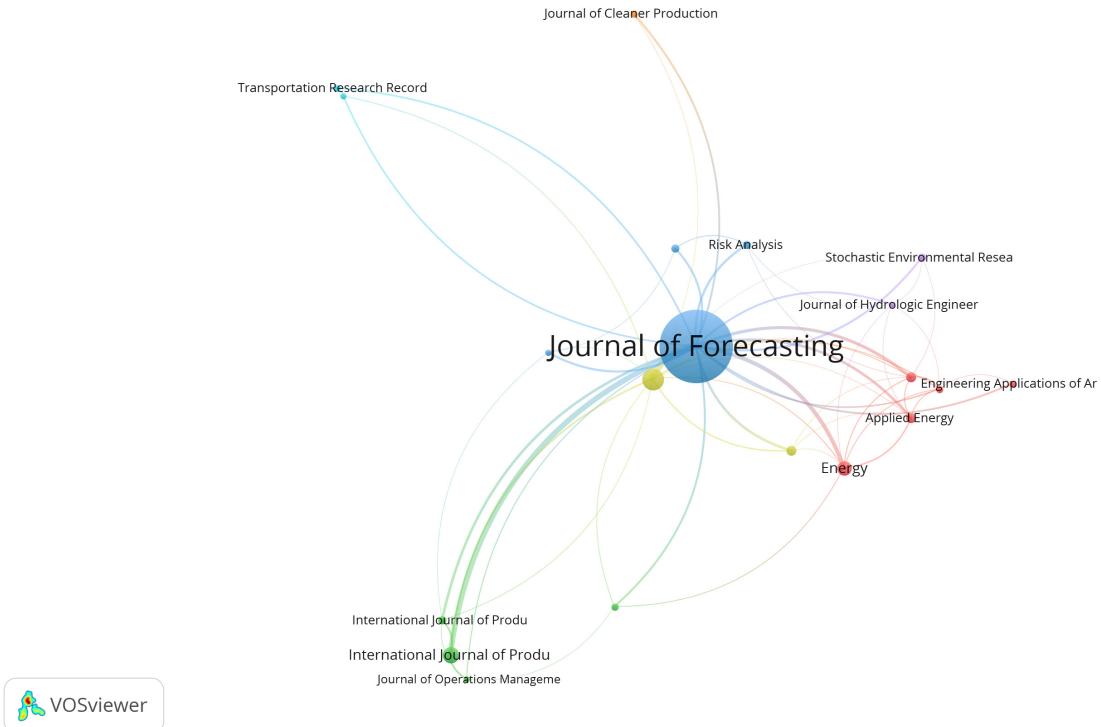


Figure 22: JF journal citation network in Engineering

Table 26: Information about the JF journal citation network in Engineering

Rank	Journal	Links	Links with IJF	%
1	Expert Systems with Applications	210	168	80.00%
2	International Journal of Production Economics	153	115	75.16%
3	Energy	85	61	71.76%
4	IEEE Transactions on Power Systems	56	37	66.07%
5	International Journal of Production Research	46	26	56.52%
6	Applied Energy	45	28	62.22%
7	Information Sciences	37	26	70.27%
8	Risk Analysis	28	23	82.14%
9	International Journal of Electrical Power and Energy Systems	27	9	33.33%
10	Quality and Reliability Engineering International	23	20	86.96%

#### B4: JF journal citation network in Social Sciences

20 Journals that have no less than 10 publications and 150 citations are selected to map the JF journal citation network in Social Sciences. Four parameters are clusters (9), local links (77), link strength (2753), and items (20).

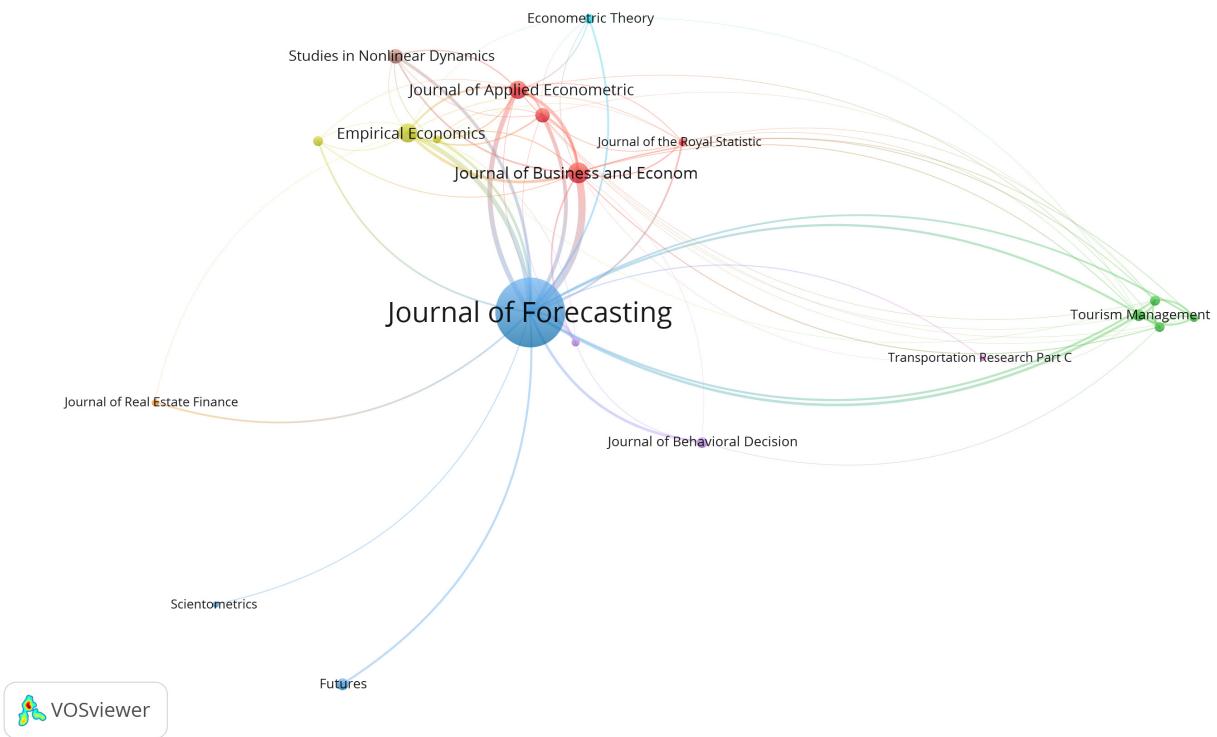


Figure 23: JF journal citation network in Social Sciences

Table 27: Information about the JF journal citation network in Social Sciences

Rank	Journal	Links	Links with IJF	%
1	Journal of Business and Economic Statistics	907	549	60.53%
2	Journal of Applied Econometrics	482	232	48.13%
3	Empirical Economics	403	230	57.07%
4	Tourism Management	261	70	26.82%
5	Oxford Bulletin of Economics and Statistics	259	142	54.83%
6	Tourism Economics	216	51	23.61%
7	Annals of Tourism Research	183	48	26.23%
8	Journal of Travel Research	159	35	22.01%
9	Studies in Nonlinear Dynamics and econometrics	158	98	62.03%
10	Review of Economics and Statistics	128	69	53.91%

#### B5: JF journal citation network in Environmental Science

20 Journals that have no less than 10 publications and 150 citations are selected to map the JF journal citation network in Environmental Science. Four parameters are clusters (7), local links (81), link strength (861), and items (20).

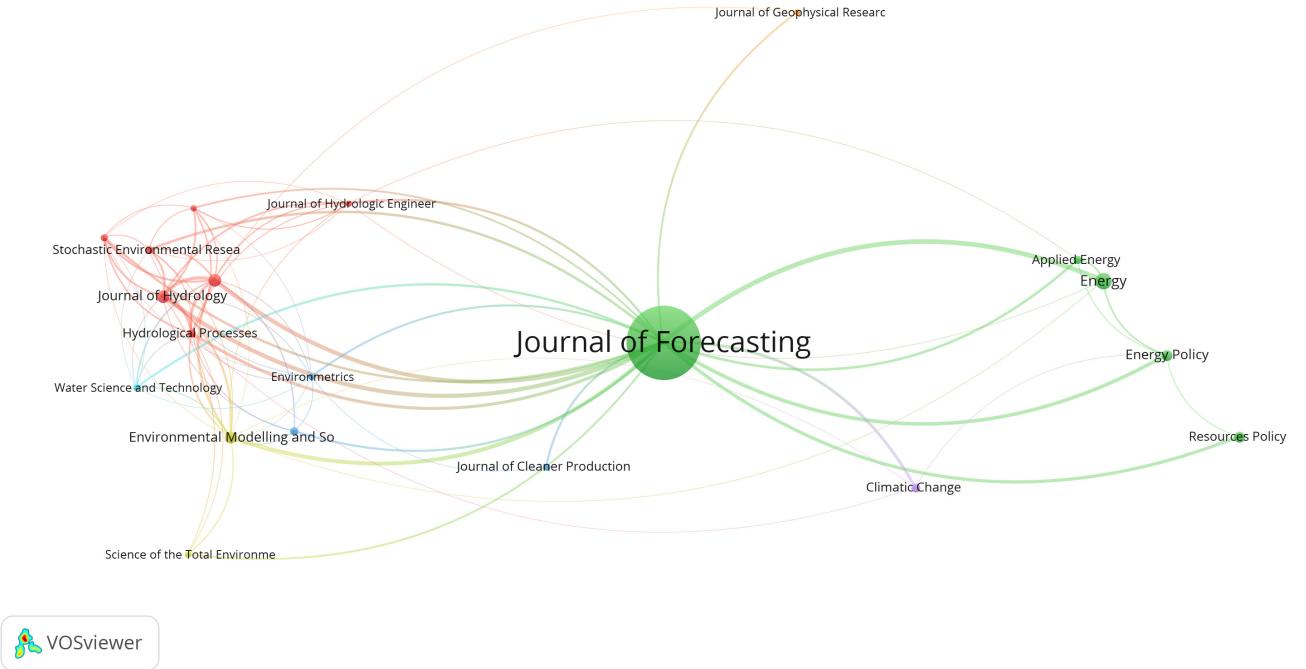


Figure 24: JF journal citation network in Environmental Science

Table 28: Information about the JF journal citation network in Environmental Science

Rank	Journal	Links	Links with IJF	%
1	Journal of Hydrology	189	56	29.63%
2	Water Resources Research	175	53	30.29%
3	Hydrological Processes	122	30	24.59%
4	Environmental Modelling and Software	118	50	42.37%
5	Energy	89	71	79.78%
6	Hydrology and Earth System Sciences	60	19	31.67%
7	Stochastic Environmental Research and Risk Assessment	57	20	35.09%
8	Energy Policy	52	40	76.92%
9	Journal of Hydrologic Engineering	44	16	36.36%
10	Hydrological Sciences Journal	43	10	23.26%

#### B6: JF journal citation network in Energy

20 Journals that have no less than 5 publications and 30 citations are selected to map the JF journal citation network in Energy. Four parameters are clusters (5), local links (96), link strength (793), and items (20).

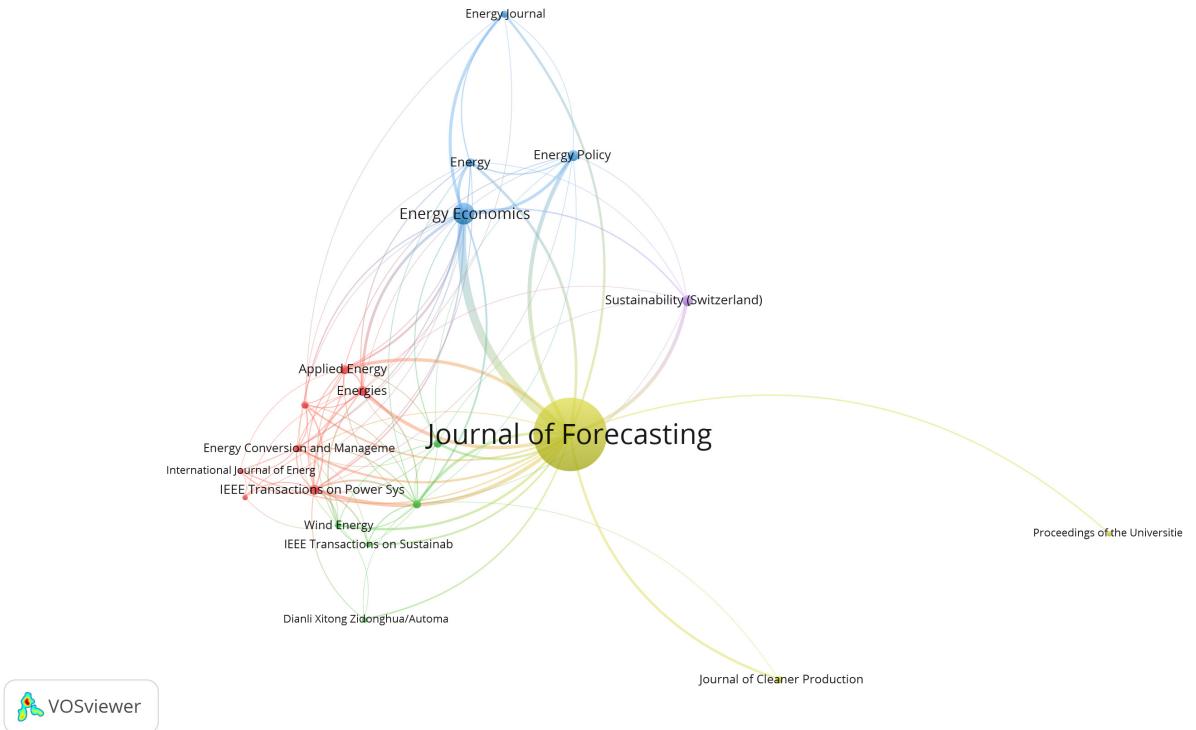


Figure 25: JF journal citation network in Energy

Table 29: Information about the JF journal citation network in Energy

Rank	Journal	Links	Links with IJF	%
1	Energy Economics	324	193	59.57%
2	IEEE Transactions on Power Systems	99	37	37.37%
3	Energies	87	30	34.48%
4	Energy Policy	75	40	53.33%
5	Applied Energy	65	28	43.08%
6	Energy	63	19	30.16%
7	Renewable and Sustainable Energy Reviews	63	19	30.16%
8	Energy Journal	46	14	30.43%
9	Sustainability	42	32	76.19%
10	Wind Energy	39	15	38.46%

#### B7: JF journal citation network in Earth and Planetary Sciences

20 Journals that have no less than 4 publications and 70 citations are selected to map the JF journal citation network in Earth and Planetary Sciences. Four parameters are clusters (6), local links (74), link strength (608), and items (20).

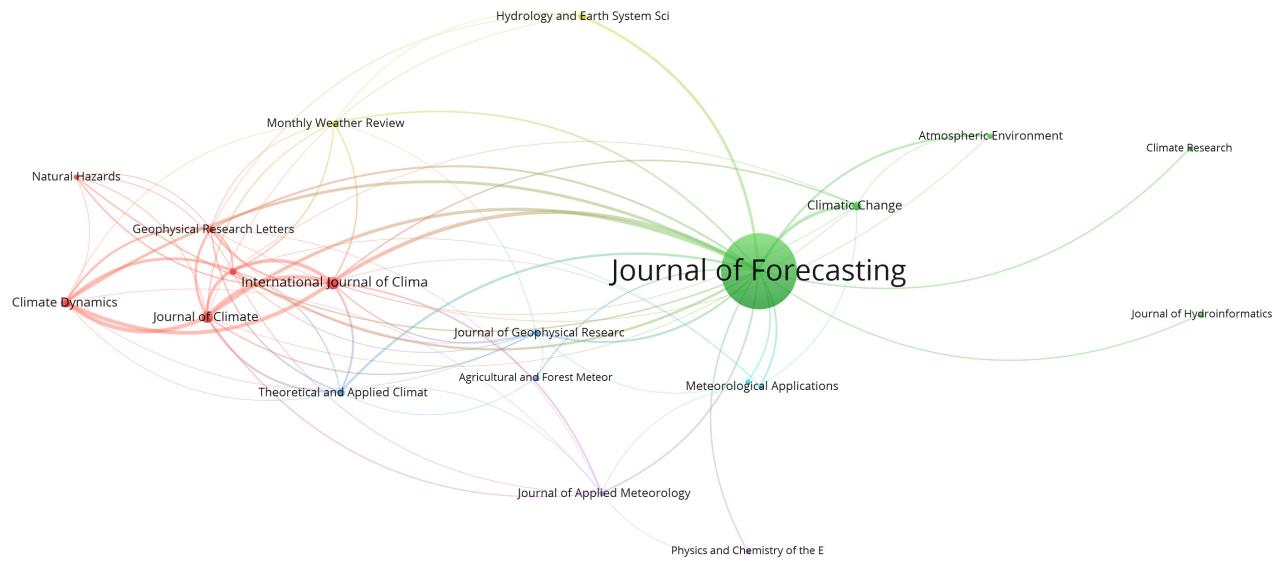


Figure 26: JF journal citation network in Earth and Planetary Sciences

Table 30: Information about the JF journal citation network in Earth and Planetary Sciences

Rank	Journal	Links	Links with IJF	%
1	International Journal of Climatology	198	37	18.69%
2	Journal of Climate	177	27	15.25%
3	Climate Dynamics	142	22	15.49%
4	Quarterly Journal of the Royal Meteorological Society	118	15	12.71%
5	Geophysical Research Letters	70	11	15.71%
6	Theoretical and Applied Climatology	49	14	28.57%
7	Climatic Change	37	26	70.27%
8	Journal of Geophysical Research Atmospheres	28	11	39.29%
9	Journal of Applied Meteorology and Climatology	27	8	29.63%
10	Monthly Weather Review	27	7	25.93%

## References

- Armstrong, J. Scott, and Fred Collopy. 1992. "Error Measures for Generalizing About Forecasting Methods: Empirical Comparisons ." *International Journal of Forecasting* 8 (1): 69–80.
- Booth, Heather. 2006. "Demographic Forecasting: 1980 to 2005 in Review." *International Journal of Forecasting* 22 (3): 547–81.
- Brown, Lawrence D. 1993. "Earnings Forecasting Research: Its Implications for Capital Markets Research." *International Journal of Forecasting* 9 (3): 331–35.
- Calma, Angelito, and Martin Davies. 2016. "Academy of Management Journal, 1958–2014: A Citation Analysis." *Scientometrics* 108 (2): 959–75.
- Clark, Todd E., and Kenneth D. West. 2006. "Approximately Normal Tests for Equal Predictive Accuracy in Nested Models." *Journal of Econometrics* 138 (1): 291–311.
- Clemen, Robert T. 1989. "Combining Forecasts: A Review and Annotated Bibliography." *International*

Journal of Forecasting 5 (4): 559–83.

Conejo, Antonio J., Javier Contreras, Rosa Espínola, and Miguel A. Plazas. 2005. “Forecasting Electricity Prices for a Day-Ahead Pool-Based Electric Energy Market.” International Journal of Forecasting 21 (3): 435–62.

Crone, Sven F., Michèle Hibon, and Konstantinos Nikolopoulos. 2011. “Advances in Forecasting with Neural Networks? Empirical Evidence from the Nn3 Competition on Time Series Prediction.” International Journal of Forecasting 27 (3): 635–60.

Darbellay, Georges A., and Marek Slama. 2000. “Forecasting the Short-Term Demand for Electricity : Do Neural Networks Stand a Better Chance?” International Journal of Forecasting 16 (1): 71–83.

Diebold, Francis X., and Kamil Yilmaz. 2012. “Better to Give Than to Receive: Predictive Directional Measurement of Volatility Spillovers.” International Journal of Forecasting 28 (1): 57–66.

Eck, Nees Jan Van, and Ludo Waltman. 2009. “How to Normalize Cooccurrence Data? An Analysis of Some Well-Known Similarity Measures.” Journal of the American Society for Information Science and Technology 60 (8): 1635–51.

Fildes, Robert. 2006. “The Forecasting Journals and Their Contribution to Forecasting Research: Citation Analysis and Expert Opinion.” International Journal of Forecasting 22 (3): 415–32.

Fildes, Robert, Paul Goodwin, Michael Lawrence, and Konstantinos Nikolopoulos. 2009. “Effective Forecasting and Judgmental Adjustments: An Empirical Evaluation and Strategies for Improvement in Supply-Chain Planning.” International Journal of Forecasting 25 (1): 3–23.

Freeman, Linton C. 1977. “A Set of Measures of Centrality Based on Betweenness.” Sociometry 40 (1): 35–41.

Gardner, Everette S. 2006. “Exponential Smoothing: The State of the Art—Part II.” International Journal of Forecasting 22 (4): 637–66.

Giacomini, Raffaella., and Halbert. White. 2006. “Tests of Conditional Predictive Ability.” Econometrica 74 (6): 1545–78.

Giannone, Domenico, Lucrezia Reichlin, and David Small. 2008. “Nowcasting: The Real-Time Informational Content of Macroeconomic Data.” Journal of Monetary Economics 55 (4): 665–76.

Gooijer, Jan G. De, and Rob J. Hyndman. 2006. “25 Years of Time Series Forecasting.” Monash Econometrics & Business Statistics Working Papers 22 (3): 443–73.

Hansen, Peter R., Asger Lunde, and James M. Nason. 2011. “The Model Confidence Set.” Econometrica 79 (2): 453–97.

Harvey, David, Stephen Leybourne, and Paul Newbold. 1997. “Testing the Equality of Prediction Mean Squared Errors.” International Journal of Forecasting 13 (2): 281–91.

Holt, Charles C. 2004. “Forecasting Seasonals and Trends by Exponentially Weighted Moving Averages.” International Journal of Forecasting 20 (1): 5–10.

Hong, Tao, Pierre Pinson, and Shu Fan. 2014. “Global Energy Forecasting Competition 2012.” International Journal of Forecasting 30 (2): 357–63.

Hong, Tao, Pierre Pinson, Shu Fan, Hamidreza Zareipour, Alberto Troccoli, and Rob J. Hyndman. 2016. “Probabilistic Energy Forecasting: Global Energy Forecasting Competition 2014 and Beyond.” International Journal of Forecasting 32 (3): 896–913.

Hyndman, Rob J., and Anne B. Koehler. 2006. “Another Look at Measures of Forecast Accuracy.” International Journal of Forecasting 22 (4): 679–88.

Hyndman, Rob J., Anne B. Koehler, Ralph D. Snyder, and Simone Grose. 2000. “A State Space Framework for Automatic Forecasting Using Exponential Smoothing Methods.” Monash Econometrics &

Business Statistics Working Papers 18 (3): 439–54.

Kleinberg, J. 2003. “Bursty and Hierarchical Structure in Streams.” *Data Mining and Knowledge Discovery* 7 (4): 373–97.

Lawrence, Michael, Paul Goodwin, Marcus O’Connor, and Dilek ?nkal. 2006. “Judgmental Forecasting: A Review of Progress over the Last 25 Years.” *International Journal of Forecasting* 22 (3): 493–518.

Leydesdorff, Loet, and Robert L. Goldstone. 2014. “Interdisciplinarity at the Journal and Specialty Level: The Changing Knowledge Bases of the Journal Cognitive Science.” *Journal of the Association for Information Science & Technology* 65 (1): 164–77.

Makridakis, Spyros, and Michèle Hibon. 2000. “The M3-Competition: Results, Conclusions and Implications.” *International Journal of Forecasting* 16 (4): 451–76.

Merigó, José M., Alicia Mas-Tur, Norat Roig-Tierno, and Domingo Ribeiro-Soriano. 2015. “A Bibliometric Overview of the Journal of Business Research Between 1973 and 2014.” *Journal of Business Research* 68 (12): 2645–53.

Porter, A. L., and D. E. Chubin. 1985. “An Indicator of Cross-Disciplinary Research.” *Scientometrics* 8 (3-4): 161–76.

Rowe, G., and G. Wright. 1999. “The Delphi Technique as a Forecasting Tool: Issues and Analysis.” *International Journal of Forecasting* 15 (4): 353–75.

Shi, Shunshun, Wenyu Zhang, Shuai Zhang, and Jie Chen. 2018. “Does Prestige Dimension Influence the Interdisciplinary Performance of Scientific Entities in Knowledge Flow? Evidence from the E-Government Field.” *Scientometrics* 117 (2): 1237–64.

Taylor, James W., Lilian M. De Menezes, and Patrick E. Mcsharry. 2006. “A Comparison of Univariate Methods for Forecasting Electricity Demand up to a Day Ahead.” *International Journal of Forecasting* 22 (1): 1–16.

Thomas, Lyn C. 2000. “A Survey of Credit and Behavioural Scoring: Forecasting Financial Risk of Lending to Consumers.” *International Journal of Forecasting* 16 (2): 149–72.

Timmermann, Allan. 2006. “Forecast Combinations.” *Handbook of Economic Forecasting* 1: 135–96.

Weron, Rafał. 2014. “Electricity Price Forecasting: A Review of the State-of-the-Art with a Look into the Future.” *International Journal of Forecasting* 30 (4): 1030–81.

Wichaisri, Sooksiri, and Apichat Sopadang. 2018. “Trends and Future Directions in Sustainable Development.” *Sustainable Development* 26 (1): 1–17.

Witt, Stephen F., and Christine A. Witt. 1995. “Forecasting Tourism Demand: A Review of Empirical Research.” *International Journal of Forecasting* 11 (3): 447–75.

Yu, Dejian. 2015. “A Scientometrics Review on Aggregation Operator Research.” *Scientometrics* 105 (1): 115–33.

Yu, Dejian, and Shunshun Shi. 2015. “Researching the Development of Atanassov Intuitionistic Fuzzy Set: Using a Citation Network Analysis” 32: 189–98.

Yu, Dejian, Zeshui Xu, Witold Pedrycz, and Wanru Wang. 2017. “Information Sciences 1968-2016: A Retrospective Analysis with Text Mining and Bibliometric.” *Information Sciences* 418: 2727–36.

Zhang, B. Eddy Patuwo, and Michael Y. Hu. 1998. “Forecasting with Artificial Neural Networks: The State of the Art.” *International Journal of Forecasting* 14 (1): 35–62.