Bibliometrics of Vietnam Publications in the Science Citation Index: general trends and comparison with other tropical countries

Nguyễn Thị Nha Trang[1], Julián Monge-Nájera[2] & Yuh-Shan Ho[3]*

1. Department of Biotechnology, College of Health Science, Asia University, No. 500 Lioufeng Road, Wufeng, Taichung 41354, Taiwan; nhatrangnguyen113@gmail.com
2. Laboratorio de Ecología Urbana, Vicerrectoría de Investigación, Universidad Estatal a Distancia, 2050 San José, Costa Rica; julianmonge@gmail.com
3. Trend Research Centre, Asia University, No. 500 Lioufeng Road, Wufeng, Taichung 41354, Taiwan; ysho@asia.edu.tw
    * Correspondence

Abstract. Introduction: The economy of Vietnam, a highly populated tropical country with a per capita gross domestic product of $ 8 000, is growing rapidly, but there are few recent studies of general scope about its scientific productivity and how it compares with other tropical countries. **Objective:** To identify trends in Vietnamese science and compare them with trends in other tropical countries. **Methods:** We extracted data about scientific papers, in all disciplines that had Vietnam as country in the Science Citation Index Expanded for the period 1991 to 2018, focusing on type of publication, language, subject, authorship, collaboration, and citations. **Results:** Vietnam publishes more document types than other tropical countries, and those in this particular database are mostly in English, albeit most Vietnamese science is published in Vietnamese and not covered by the index. The primary categories were multidisciplinary materials science, mathematics, and applied mathematics. Most collaboration was done with the USA, Japan, South Korea, and France. A large number of articles were published by the Vietnam Academy of Science and Technology, and the most frequent foreign collaboration was with the University of Oxford. **Conclusion:** the tropical countries of Latin America, Africa, and Asia studied in our project have some similarities but also crucial differences. Science is developing rapidly in Vietnam and the production of articles in Vietnamese, which represent the vast majority of research in the country but is not included in this database, should also be studied.

Key words: scientific productivity; scientific collaboration; Asia region; tropical science.

In the last decade, publication performances in tropical countries has received much attention. A series studies were presented for Latin America including Costa Rica (Monge-Nájera & Ho, 2012), Panama (Monge-Nájera & Ho, 2015), Nicaragua (Monge-Nájera & Ho, 2017a), Honduras (Monge-Nájera & Ho, 2017b), El Salvador (Monge-Nájera & Ho, 2017c), Guatemala (Monge-Nájera & Ho, 2018), and Ecuador (Calahorrano, Monge-Nájera, Wang, & Ho, 2020). Similar investigations were also done in Africa, including Gambia (Bah, Fu, & Ho, 2019), Cameroon (Tchuifon Tchuifon, Fu, & Ho, 2017) and Ghana (Boamah & Ho, 2018). A compared bibliometric study of Brunei (an Asian country) and Neotropical countries was also recently published (Ho et al., 2018). Other approaches

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have been used to evaluate country publication performance, for example, six publication indicators such as total, independent, collaboration, first-author, corresponding-author, and single-author publications (Ho & Kahn, 2014); and citation indicators, for instance, total citations from Web of Science Core Collection since publication to the end of the most recent year (Wang, Fu, & Ho, 2011; Chuang, Wang, & Ho, 2011), citations in the most recent year only (Ho, 2012), and citations per publication (Fu, Wang, & Ho, 2012; Ho, 2018).

Located in Southeast Asia, Vietnam is the 15th most populous country in the world, with a mean yearly per capita gross domestic product of $ 8 000 and a medium human development index of 0.69; despite widespread poverty, the country's economy has grown significantly in recent years (Fforde, 2019). The Vietnam State Science Committee was established in 1959 with social, applied and basic science branches. In the early 1970s, scientific research facilities were also established in Nghia Do to cover Mathematics, Physics, and Marine Studies (vast.ac.vn). The 1980s were marked by close work with the Soviet Union, followed in 1993 by an emphasis on using high technological research for socio-economic development and more recently by the formal establishment of the Vietnam Academy of Science and Technology (vast.ac.vn, chinhphu.vn).

A study done a decade ago found that Vietnamese researchers were active in fields of pure and applied mathematics, theoretical and applied physics, public health and infectious diseases (Nguyen & Pham, 2011). A recent study reported that most Vietnam papers in the SCI are attributable to international collaboration, and that Vietnam is building up research capacity (Nguyen, Ho-Le, & Le, 2017). The country also has a growing academic interest in eco-compensation (Yu et al., 2020) and has good citation rates for Mekong River research (Sui, Chen, Lu, & Chen, 2015) and dengue research (Dwivedi, 2017), as well as patents for the printing industry, which show capacity for innovation (Kwon, Li, & Sohn, 2019).

The aim of this study was to analyze publications by Vietnamese researchers, in all fields of science covered by the Science Citation Index Expanded (SCI-EXPANDED) from 1991 to 2018, and to compare Vietnam with other tropical countries.

MATERIALS AND METHODS

The data refer not only to tropical biology, but to all areas of science covered by the Science Citation Index Expanded (last updated October 03, 2019). We searched for "Vietnam" in the country field, 1991 to 2018. The impact factors (IF_{2018}), used to compare the impact of different document types, and of locally-lead versus foreign-lead projects, were extracted from the 2018 Journal Citation Reports (JCR).

The database uses the term "reprint author", but here we use "corresponding-author". Single authors are considered both first- and corresponding- authors in this study. In documents with several "corresponding-authors" we used the last "corresponding-author". We used three citation indicators. The first was the number of citations from the Web of Science Core Collection *in a particular year*, for instance, C_{2018} means the number of citations in 2018 (for a justification, see Ho, 2012). The second was *total citations* from the Web of Science Core Collection since publication to the end of 2018 was recorded as TC_{2018}. The third was *mean citations* per publication ($CPP_{2018} = TC_{2018}/TP$).

RESULTS

Results are presented below according to type of publication, language, impact, subject and collaboration. Note: Figures 4-7, and Tables 3-9, appear as supplementary files in Digital Appendix 1 (figures) and Digital Appendix 2 (tables).

Document type and language of publication: The index records 17 document types and 34 790 publications from Vietnam for the

period 1991-2018. The majority were articles (90 % of 34 790 publications), followed distantly by meeting abstracts (5.4 %), proceedings papers (3.8 %), and reviews (2.5 %) (Table 1).

The maximal citations per publication value (CPP_{2018}) was in reviews with 34, which was 2.6 times the citation rate of common articles (Table 1). The mean number of authors per publication (APP) was 93 in data papers, 16 in articles and 9.2 in reviews (Table 1). Web of Science can classify a document in more than one type, for example, 1 332 proceedings papers were also classified as articles, and thus the sum of percentages can be higher than 100 %. We chose only journal articles (31 216 articles) for further analysis because they represented the majority of document types, as well as whole research ideas and results (Ho, Satoh, & Lin, 2010).

Language of publication is one of the basic concerns in bibliometric studies of big data analysis (Wang & Ho, 2011). Vietnam research was published in a total of 12 languages (Table 8 in Appendix 1), but 99 % were in English (31 017 articles), followed distantly by French (94; 0.30 %), Russian (64; 0.21 %), and German (19; 0.061 %). Other languages were Chinese (8; 0.026 %), Japanese (5; 0.016 %), Czech (2; 0.0064 %), and Dutch (2; 0.0064 %). One article was bilingual (English and French). Articles not in English had fewer citations, with CPP_{2018} of 2.7, versus a CPP_{2018} of 13 for English.

Publication output and citation impact: The CPP_{2018} increased more rapidly in the first year after publication. The initial value for citations per publication was 0.63 and reached a peak with CPP_{2018} of 3.0 in the 2nd year (Fig. 1, Table 9 in Appendix 1).

The annual publication output and mean CPP_{2018} for the years 1991-2018 appear in Fig. 2; they have increased steadily from 119 articles in 1991 to 4 992 articles in 2018; while the highest CPP_{2018} was found in 2001 and 2004 with CPP_{2018} of 31 for isolated articles produced by large international research projects.
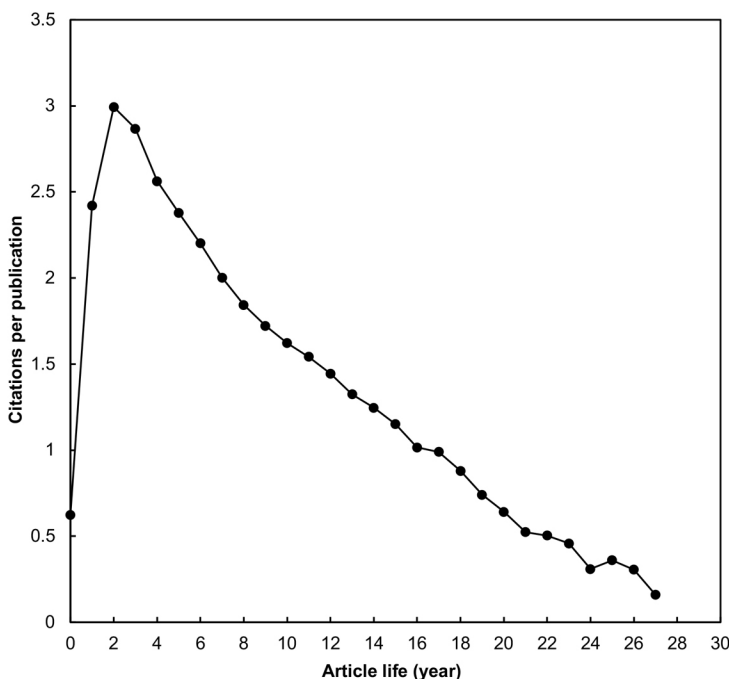

Fig. 1. Citation life span for Vietnam articles.

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TABLE 1

Characteristics of document type (percentage from a total of 34 790 publications)

Document type	%	AU	APP	TC_{2018}	CPP_{2018}
Article	90	511 277	16	402 929	13
Meeting abstract	5.4	11 659	6.2	198	0.11
Proceedings paper	3.8	6 845	5.1	14 221	11
Review	2.5	7 932	9.2	28 998	34
Editorial material	0.83	1 579	5.5	3 366	12
Letter	0.78	1 813	6.7	1 620	6.0
Correction	0.54	8 698	46	155	0.82
Note	0.15	191	3.7	772	15
Book chapter	0.11	196	5.0	336	8.6
News item	0.069	94	3.9	58	2.4
Retracted publication	0.011	13	3.3	11	2.8
Biographical-item	0.0086	4	1.3	9	3.0
Book review	0.0086	3	1.0	1	0.33
Data paper	0.0086	279	93	20	6.7
Reprint	0.0086	23	7.7	7	2.3
Retraction	0.0086	12	4.0	0	0
Addition correction	0.0029	1	1.0	5	5.0

TP: number of publications; AU: number of authors; APP: number of authors per publication; TC_{2018}: the total number of citations from Web of Science Core Collection since publication to the end of 2018; CPP_{2018}: number of citations (TC_{2018}) per publication (TP).
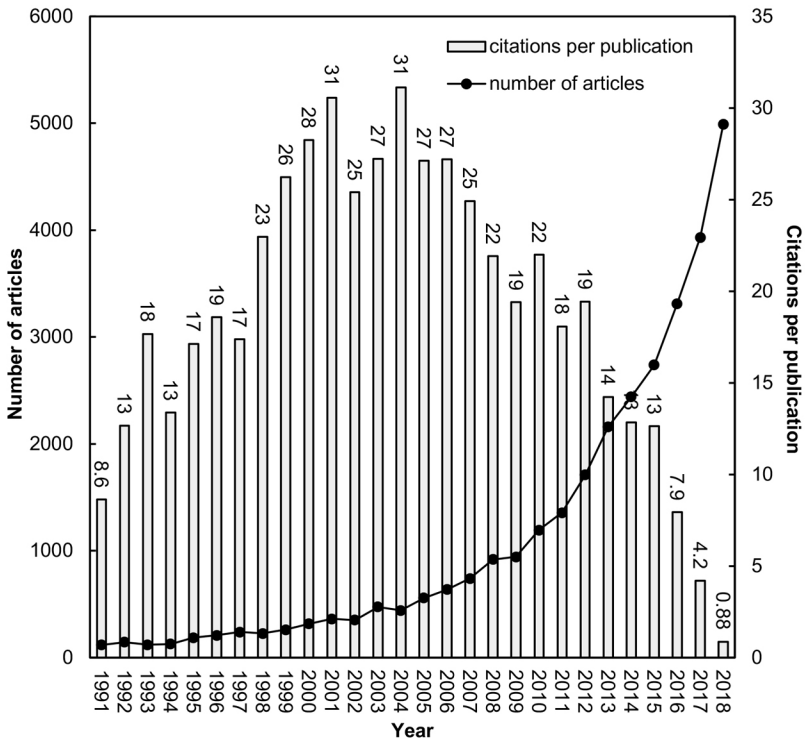

Fig. 2. Number of articles and citations per publication by year.

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Web of Science categories and journals: To assess development among research fields and their interactions, we used a relationship between the number of articles in each category and publication year (Ho, Satoh, & Lin, 2010) (Fig. 4 in Appendix 2). The Vietnamese articles were published in 4 783 journals among all 178 SCI-EXPANDED categories. The top ten productive Web of Science categories are listed in Table 2, and Fig. 5 in Appendix 2.

A total of 3 129 articles (10 % of articles) were published in materials science-related categories including multidisciplinary materials science (8.2 %), composites materials science (0.75 %), coatings and films materials science (0.46 %), ceramics materials science (0.31 %), biomaterials materials science (0.29 %), characterization and testing materials science (0.18 %), paper and wood materials science (0.10 %), and textiles materials science (0.048 %). Similarly, a total of 2 625 articles (8.4 % of articles) were published in mathematics-related categories including mathematics (7.5 %), applied mathematics (7.5 %), and interdisciplinary applications mathematics (10 %).

The top 10 most productive journals are listed in Table 3 in Appendix 1 (Fig. 6 in Appendix 2). *PLoS One* (IF_{2018} = 2.776) in the category of multidisciplinary sciences, published the most articles with 393 (1.3 % of articles). Articles published in *Physical Review B* and *Journal of High Energy Physics* had higher CPP_{2018} of 18 and 17 respectively. In addition, articles published in *Nature* (IF_{2018} = 43.070) had a CPP_{2018} of 1 112. These tend to be journals that publish well financed research from large international projects, often in the fields of physics and medicine articles (Long, Huang, & Ho, 2014) with TC_{2018} of 1 000 or more Koboldt et al. (2012) with TC_{2018} of 4 577; Bhatt et al. (2013) with TC_{2018} of 2 742; Altshuler et al. (2015) with TC_{2018} of 2 385; Hammerman et al. (2012) with TC_{2018} of 1 725; and Weinstein et al. (2014) with TC_{2018} of 1 121. The large size of these projects is reflected in the number of authors, which range from 18 to 774. The journal with the highest IF_{2018} (5.833) was the *Journal of High Energy Physics* with 155 articles, followed by *Physical Review B* (IF_{2018} = 3.736) with 148 articles, and *PLoS One* (IF_{2018} = 2.776) with 393 articles. Journals with the lower impact factors but still high in the rank included *Zootaxa* with an IF_{2018} of 0.990, and the *Journal of the Korean Physical Society* with an IF_{2018} of 0.63.

Collaborative countries and institutes: There were 24 214 (78 % of 31 216) internationally collaborative articles and 7 002 (22 % of 31 216) Vietnam independent articles; of these 3 104 (9.9 % of 31 216 articles) nationally collaborative articles and 3 898 (12 %) institutional independent articles. Overall, the internationally collaborative articles had a higher CPP_{2018} of 15, while Vietnam independent articles had a CPP_{2018} of 5.6 (Fig. 3).

TABLE 2

Top 11 Web of Science categories with TP > 1 000 (Percentage from a total of 17 720 articles)

| Web of Science categories	%	No. Journals
Multidisciplinary Materials Science	8.2	293
Mathematics	7.5	313
Applied Mathematics	7.5	254
Applied Physics	5.8	148
Environmental Sciences	4.8	250
Electrical and Electronic Engineering	4.4	265
Condensed Matter Physics	4.2	68
Physical Chemistry	3.6	148
Infectious Diseases	3.6	89
Plant Sciences	3.6	228
Public, Environmental and Occupational Health	3.6	185
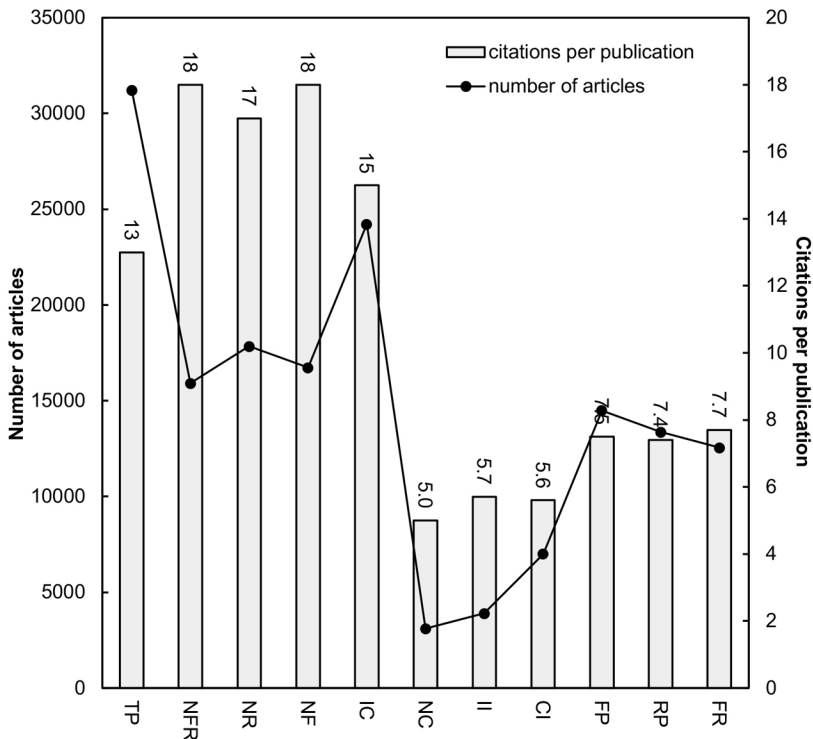
Fig. 3. Characteristics of publication type and their citations per publication. *TP*: total articles, *NFR*: both first and corresponding-authors are not from Vietnam, *NR*: corresponding-author is not from Vietnam, *NF*: first-author is not from Vietnam, *IC*: internationally collaborative articles, *NC*: nationally collaborative articles, *II*: institutional independent articles, *CI*: Vietnam independent articles, *FP*: first-author is from Vietnam, *RP*: corresponding-author is from Vietnam, *FR*: both first and corresponding-authors are from Vietnam.

Articles published with Vietnamese researchers as first- or corresponding-authors had lower CPP_{2018} of 7.5 and 7.4, respectively (Fig. 3). Neither the first nor the corresponding-authors of the most cited articles are Vietnamese, with a mean of 18 citations per publication (Fig. 3).

The top ten most collaborative countries are listed in Table 4 in Appendix 1 (Fig. 7 in Appendix 2). Vietnamese researchers collaborated the most with the USA including 3 949 internationally collaborative articles (13 % of articles). Nevertheless, Japan had the most first- and corresponding-author articles (7.1 and 7.6 %, respectively). Articles with Italy, the UK, and the Netherlands had higher citations per publication values (lower with South Korea and Japan).

A total of 3 898 (12 %) articles were single institution articles (*IP*) and 88 % were inter-institutionally collaborative articles (*CP*). Table 5 in Appendix 1 presents the 10 most productive institutions in Vietnam. The Vietnam Academy of Science and Technology ranked top in the all six publication indicators with *TP* of 5 673 articles (18 % of articles), *IP* of 835 articles (21 % of 3 898 institute independent articles), a *CP* of 4 838 articles (18 % of 27 318 inter-institutionally collaborative articles), a *FP* of 2 496 articles (8.0 % of 31 216 first-author articles), a *RP* of 2 343 articles (7.6 % of 30 911 corresponding-author articles), and an *SP* of 395 articles (20 % of 1 951 single-author articles). The Oxford University Clinical Research Unit published 782 articles, therein three single-institute articles and two single-author articles had a CPP_{2018} of 58, the highest value.

Table 6 in Appendix 1 presents the top 10 oversea institutions that collaborated with Vietnam in research publications with three publication indicators TP, FP, and RP, and citation indicator CPP_{2018}. Vietnam collaborated the most articles with University of Oxford in the UK, at 1 151 articles. The Russian Academy of Sciences had 692 collaborative articles with Vietnam including 280 first-authors articles and 286 corresponding-author articles. Collaborative articles with Heidelberg University in Germany had the highest CPP_{2018} (63), followed by University of Oxford in the UK with a CPP_{2018} of 52 and the University of Edinburgh, also in the UK, with a CPP_{2018} of 50.

Citation life cycles of the most frequently cited articles: A total of 446 articles had a TC_{2018} of 100, 52 % with a first-author from the USA (17 %), the UK (12 %), France (6.3 %), Japan (6.1 %), Switzerland (5.8 %), and Netherlands (4.5 %), while 50 % were published by a corresponding-author from the USA (19%), the UK (13 %), France (7.2 %), Switzerland (5.8 %), and Japan (5.6 %). Table 7 in Appendix 1 shows the ten classic articles with a TC_{2018} of 1 000 or more (Long et al., 2014). Nine had first- and corresponding-authors from the USA, in the tenth, they were from the UK. Eight articles were published by a big group with 357 to 774 authors. Furthermore, the Vietnam independent article with the highest TC_{2018} (238 total citations) was "Expanding applications of metal-organic frameworks: Zeolite imidazolate framework ZIF-8 as an efficient heterogeneous catalyst for the Knoevenagel reaction" (Tran, Le & Phan, 2011) by U.P.N. Tran, K.K.A. Le, and N.T.S. Phan from the Department of Chemical Engineering at the HCMC University of Technology.

DISCUSSION

Vietnam published 17 document types, above other tropical countries, for example, 11 in Brunei (Ho et al., 2018), 12 in Gambia (Bah et al., 2019), 13 in Honduras (Monge-Nájera & Ho, 2017b), and 15 in Panama (Monge-Nájera & Ho, 2015).

Vietnam was colonized by France and for many years French was a second language in the country, but its publications in this database are 99 % in English, closer to countries like Gambia (Bah et al., 2019), Ghana (Boamah & Ho, 2018), and Brunei (Ho et al., 2018) which were colonized by the British. A probable reason is that journals covered by this particular index publish mostly in English. Other trends may occur in journals that publish in French or Vietnamese, but these are not covered by the index, even if they are important for the local development of research in Vietnam. In fact, the Science Citation Index Expanded is far from giving a representative view of science in Vietnam, because 95 % of all articles are published in Vietnamese and not covered by the index (Hien, 2010).

The increase in the number of publications, in all fields of science, is a general trend of tropical countries in the last decade, the same trend has been found in Asia (Ho et al., 2018), Africa (Boamah & Ho, 2018; Bah et al., 2019), and Latin America (Monge-Nájera & Ho, 2018; Calahorrano et al., 2020).

Vietnamese research published in collaboration with other countries was more cited in this database (CPP_{2018}) than local articles. Similarly, articles published by first-authors or corresponding-authors from Vietnam also had lower CPP_{2018} values. For the 446 highly cited articles (TC_{2018} 100), 53 % had a first-author from the USA, the UK, France, Japan, Switzerland, or the Netherlands, while 50% were published by a corresponding-author from the USA, the UK, France, Switzerland, or Japan. International collaboration with developed countries produced higher citation rates. The USA contributed the most citations to Vietnam publications. The USA, Japan, South Korea, and France were the most frequent research partners. Collaborative articles with Italy, the UK, and Netherlands had higher citations. These patterns can be also found in other tropical countries (Monge-Nájera & Ho, 2017a; 2017b; 2017c; Tchuifon Tchuifon et al., 2017;

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Ho et al., 2018; Boamah & Ho, 2018; Bah et al., 2019; Calahorrano et al., 2020).

Vietnam published more articles than other tropical countries. However, its independent articles had lower citation rates (CPP_{2018} 5.6) than tropical countries in Latin America such as Guatemala with a CPP_{2018} of 13 (Monge-Nájera & Ho, 2018), Ecuador (8.5) (Calahorrano et al., 2020), Honduras (7.5) (Monge-Nájera & Ho, 2017b), Nicaragua (6.4) (Monge-Nájera & Ho, 2017a), El Salvador (5.9) (Monge-Nájera & Ho, 2017c), and Ghana (6.4) in Africa (Boamah & Ho, 2018) and Brunei (7.9) in Asia (Ho et al., 2018).

Vietnam publications were dominated by materials science, which is different from other tropical countries, for example, ecology in Brunei (Ho et al., 2018), Ecuador (Calahorrano et al., 2020), and Panama (Monge-Nájera & Ho, 2015); public, environmental and occupational health in Cameroon (Tchuifon et al., 2017), El Salvador, Gambia (Bah, Fu, & Ho, 2019), Ghana (Boamah & Ho, 2018), Guatemala (Monge-Nájera & Ho, 2018), Honduras (Monge-Nájera & Ho, 2017b), and Nicaragua (Monge-Nájera & Ho, 2017a).

Tropical medicine, plant sciences, immunology, infectious diseases, and nutrition and dietetics also dominated research in tropical countries (Tchuifon et al., 2017; Bah et al., 2019; Boamah & Ho, 2018; Monge-Nájera & Ho, 2018; Monge-Nájera & Ho, 2017b). However, Costa Rica published the most articles in biology (Monge-Nájera & Ho, 2012).

The reason for the importance of materials science research in Vietnam is that the subject was included as a priority by the government (Zink, 2009).

In conclusion, the tropical countries of Latin America, Africa, and Asia studied have some similarities in the importance of applied research subjects, and their dependence on foreign initiatives, but there are also crucial differences. Although science in Vietnam is developing and shows a positive trend in number of papers and citations, most of the impact found in this study results from minor participation of Vietnamese authors in large international projects. This important conclusion that we obtain from our data sadly matches the findings and call made over a decade ago by Hien, who stated that Vietnam depended too much on foreign authors, and called for more multidisciplinary work and internationally-recognized standards (Hien, 2010). For a more robust development of local science, the country should significantly enhance collaboration among Vietnamese institutes in order to lessen its dependence on overseas projects, even if at the beginning this causes a fall in the impact of their work as measured by this particular database.

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RESUMEN

Bibliometría de las publicaciones de Vietnam en el *Science Citation Index*: tendencias generales y comparación con otros países tropicales. Introducción: La economía de Vietnam, un país tropical muy poblado con un producto interno bruto per cápita de $ 8000, está creciendo rápidamente, pero hay pocos estudios recientes y de enfoque general sobre su productividad científica y cómo se compara con la de otros países tropicales. **Objetivo:** identificar tendencias en la ciencia vietnamita y compararlas con las tendencias en otros países tropicales. **Métodos:** extrajimos datos sobre artículos científicos, en todas las disciplinas que tenían a Vietnam como "país" en el *Science Citation Index Expanded* para el período 1991 a 2018, centrándonos en el tipo de publicación, idioma, tema, autoría, colaboración y citas. **Resultados:** Vietnam publica más tipos de documentos que otros países tropicales,

y los de esta base de datos en particular están principalmente en inglés, aunque la mayoría de la ciencia vietnamita se publica en vietnamita y no está cubierta por el índice. Las categorías principales fueron ciencia de materiales (estudios multidisciplinarios), matemáticas y matemáticas aplicadas. La mayor parte de la colaboración se realizó con EE. UU., Japón, Corea del Sur y Francia. La Academia de Ciencia y Tecnología de Vietnam publicó una proporción importante de estos artículos, y la colaboración extranjera más frecuente fue con la Universidad de Oxford. **Conclusión:** los países tropicales de América Latina, África y Asia estudiados en nuestro proyecto tienen tanto similitudes como diferencias importantes con Vietnam. La ciencia en Vietnam está en una etapa de crecimiento y convendría estudiar los artículos que se publican en vietnamita, los cuales representan la amplia mayoría de la ciencia del país, pero no se incluyen en esta base de datos.

Palabras clave: productividad científica; colaboración científica; Asia; ciencia tropical.

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Article
Bibliometrics of Vietnam Publications in the Science Citation Index: general trends and comparison with other tropical countries

Authors
Nguyễn Thị Nha Trang[1], Julián Monge-Nájera[2] & Yuh-Shan Ho[3]*
1. Department of Biotechnology, College of Health Science, Asia University, No. 500 Lioufeng Road, Wufeng, Taichung 41354, Taiwan; nhatrangnguyen113@gmail.com
2. Laboratorio de Ecología Urbana, Vicerrectoría de Investigación, Universidad Estatal a Distancia, 2050 San José, Costa Rica; julianmonge@gmail.com
3. Trend Research Centre, Asia University, No. 500 Lioufeng Road, Wufeng, Taichung 41354, Taiwan; ysho@asia.edu.tw
*Correspondence

Digital Appendix 1
Nomenclature and Additional Tables

Countries with changing status or names

Articles from England, Scotland, Northern Ireland, and Wales were marked as United Kingdom. Affiliations in Hong Kong prior to 1997 were included under China. Affiliations in the Union of Soviet Socialist Republics were marked as Russia or Belarus depending on their origin. Affiliations in Czechoslovakia were checked and re-categorized as in Czech Republic. Affiliations in the Neth Antilles (Netherlands Antilles) were marked as being from the Netherlands. Affiliations in Fr Polynesia (French Polynesia), French Guiana, New Caledonia, and Reunion were re-categorized as France. Affiliations in Rep Congo were marked as Congo (Republic of the Congo. Affiliations in Zaire were re-categorized as Dem Rep Congo (The Democratic Republic of the Congo). Affiliations in Greenland were marked as Denmark. Affiliations in Puerto Rico were marked as USA. Affiliations in United Ara and United Arab were re-categorized as U Arab Emirates (United Arab Emirates).v Acad Sci USSR and USSR Acad Sci (USSR Academy of Sciences) were marked as Russian Acad Sci (Russian Academy of Sciences).

TABLE 3
Top ten most productive journals

Journals	TP (%)	IF_{2018}	Web of Science category	TC_{2018}	CPP_{2018}
PLoS One	393 (1.3)	2.776	Multidisciplinary sciences	5 054	13
Zootaxa	265 (0.85)	0.990	Zoology	1 798	6.8
Journal of Magnetism and Magnetic	202	2.68	Multidisciplinary materials science	2 320	11

Journal	TP (%)	IF2018	Category	TC2018	CPP2018
Materials	(0.65)	3	Condensed matter physics		
Journal of Electronic Materials	194 (0.62)	1.676	Electrical and electronic engineering	346	1.8
			Multidisciplinary materials science		
			Applied physics		
Advances in Natural Sciences-Nanoscience and Nanotechnology	172 (0.55)	N/A	Nanoscience and nanotechnology	796	4.6
			Multidisciplinary materials science		
			Applied physics		
Journal of Mathematical Analysis and Applications	164 (0.53)	1.188	Applied mathematics	1 381	8.4
			Mathematics		
Journal of the Korean Physical Society	163 (0.52)	0.630	Multidisciplinary physics	692	4.2
Journal of Optimization Theory and Applications	158 (0.51)	1.600	Operations research and management science	1 824	12
			Applied mathematics		
Journal of High Energy Physics	155 (0.5)	5.833	Particles and fields physics	2 661	17
Physical Review B	148 (0.47)	3.736	Multidisciplinary materials science	2 679	18
			Applied physics		
			Condensed matter physics		

TP (%): rank and the percentage of number of articles; *IF*2018: journal impact factor in 2018; *TC*2018: the total number of citations from Web of Science Core Collection since publication to the end of 2018; *CPP*2018: number of citations (*TC*2018) per publication (*TP*).

TABLE 4
14 most frequently collaborative countries with TP > 1 000

Country	TP	TP R (%)	FP R (%)	RP R (%)	CPP_{2018}
USA	3 949	1 (13)	4 (4.6)	4 (5.0)	30
Japan	3 866	2 (12)	1 (7.1)	1 (7.6)	18
South Korea	3 431	3 (11)	2 (5.8)	2 (7.0)	17
France	3 343	4 (11)	3 (4.8)	3 (5.1)	23
United Kingdom	2 565	5 (8.2)	10 (1.9)	10 (2.2)	39
Germany	2 543	6 (8.1)	6 (3.0)	6 (3.1)	27
Australia	2 430	7 (7.8)	5 (3.3)	5 (3.6)	25
China	2 342	8 (7.5)	7 (2.8)	7 (2.5)	30
Netherlands	1 503	9 (4.8)	11 (1.9)	11 (1.9)	37
Russia	1 457	10 (4.7)	12 (1.7)	12 (1.8)	28
Thailand	1 308	11 (4.2)	14 (1.2)	14 (1.2)	32
Taiwan	1 296	12 (4.2)	8 (2.2)	8 (2.4)	25
Belgium	1 253	13 (4.0)	9 (1.9)	9 (2.2)	23
Italy	1 155	14 (3.7)	16 (0.67)	16 (0.77)	40

TP R (%): total number of articles and rank; *FP R* (%): total number of first-author articles and rank; *RP R* (%): total number of corresponding-author articles and rank; *CPP*2018: citations per publication (*CPP*2018 = *TC*2018/*TP*).

TABLE 5
Top ten productive institutes

Institute	TP	TP R (%)	IP R (%)	CP R (%)	FP R (%)	RP R (%)	SP R (%)	CPP_{2018}
Vietnam Academy of Science and	5 673	1 (18)	1 (21)	1 (18)	1 (8)	1 (7.6)	1 (20)	8.3

Technology

Institute	TP	TP R (%)	IP R (%)	CP R (%)	FP R (%)	RP R (%)	SP R (%)	CPP2018
Vietnam National University	3 933	2 (13)	2 (14)	2 (12)	2 (4.9)	2 (4.7)	2 (7.7)	12
Hanoi University of Science and Technology	2 092	3 (6.7)	4 (8.1)	4 (6.5)	5 (3.0)	5 (2.9)	6 (3.7)	8.6
Ton Duc Thang University	2 023	4 (6.5)	6 (3.1)	3 (7.0)	4 (3.1)	3 (3.9)	5 (4.3)	4.9
Vietnam National University Ho Chi Minh City	1 999	5 (6.4)	3 (11)	5 (5.7)	3 (3.3)	4 (3.3)	3 (6.9)	8.5
Duy Tan University	1 038	6 (3.3)	10 (1.1)	6 (3.6)	8 (0.95)	8 (0.88)	8 (1.7)	9.9
Hanoi National University of Education	960	7 (3.1)	5 (5.5)	10 (2.7)	6 (1.7)	6 (1.6)	4 (4.7)	5.7
Can Tho University	869	8 (2.8)	11 (1.0)	7 (3.0)	10 (0.78)	10 (0.58)	12 (1.3)	11
Hue University	824	9 (2.6)	7 (1.9)	9 (2.7)	9 (0.91)	9 (0.77)	7 (2.3)	6.6
Oxford University Clinical Research Unit	782	10 (2.5)	81 (0.077)	8 (2.9)	7 (1.0)	7 (0.92)	87 (0.10)	58

TP: total number of articles; *TP R* (%): rank of total number of articles and percentage; *IP R* (%): rank of institute independent articles and percentage; *CP R* (%): rank of inter institutionally collaborative articles and percentage; *FP R* (%): rank of first-author articles and percentage; *RP R* (%): rank of corresponding-author articles and percentage; *SP R* (%): rank of single author articles and percentage; *CPP*2018: citations per publication (*CPP*2018 = *TC*2018/*TP*).

TABLE 6
Top ten collaborative institutions overseas

Institute	TP	TP R (%)	FP R (%)	RP R (%)	CPP2018
University of Oxford UK	1 151	1 (3.7)	24 (0.24)	16 (0.30)	52
Russian Academy of Sciences Russia	692	2 (2.2)	1 (0.90)	1 (0.93)	28
University of Liverpool UK	516	3 (1.7)	120 (0.080)	115 (0.091)	44

	TP	TP R (%)	FP R (%)	RP R (%)	CPP2018
Polish Academy of Sciences Poland	515	4 (1.6)	67 (0.12)	44 (0.16)	25
University of Cambridge UK	504	5 (1.6)	206 (0.051)	103 (0.094)	46
University of Edinburgh UK	478	6 (1.5)	299 (0.035)	239 (0.049)	50
Heidelberg University Germany	461	7 (1.5)	831 (0.010)	381 (0.029)	63
University of Bristol UK	453	8 (1.5)	155 (0.064)	151 (0.071)	44
University of Genoa Italy	449	9 (1.4)	299 (0.035)	326 (0.036)	30
University of Glasgow UK	442	10 (1.4)	274 (0.038)	269 (0.042)	31

TP: total number of articles; *TP R* (%): rank of total number of articles and percentage; *FP R*(%): rank of first-author articles and percentage; *RP R* (%): rank of corresponding-author articles and percentage; *CPP*2018: citations per publication (*CPP*2018 = *TC*2018/*TP*).

TABLE 7
The ten classic articles with TC2018 more then 1 000

Rank (TC_{2018})	Rank (C_{2018})	Article titles	references
1 (4 577)	2 (777)	Comprehensive molecular portraits of human breast tumors	Koboldt et al. (2012)
2 (2 742)	7 (628)	The global distribution and burden of dengue	Bhatt et al. (2013)
3 (2 719)	3 (754)	Global regional and national age-sex specific all-cause and cause-specific mortality for 240 causes of death 1990-2013: a systematic analysis for the Global Burden of Disease Study 2013	Naghavi et al. (2015)
4 (2 385)	1 (1 116)	A global reference for human genetic variation	Altshuler et al. (2015)
5 (1 934)	6 (632)	Global regional and national incidence prevalence and years lived with disability for 301 acute and chronic diseases and injuries in 188 countries 1990-2013: a systematic analysis for the Global Burden of Disease Study 2013	Vos et al. (2015)

6 (1 788)	119 (38)	A novel coronavirus associated with severe acute respiratory syndrome	Ksiazek et al. (2003)
7 (1 725)	15 (275)	Comprehensive genomic characterization of squamous cell lung cancers	Hammerman et al. (2012)
8 (1 174)	4 (734)	Global regional and national life expectancy all-cause mortality and cause-specific mortality for 249 causes of death 1980-2015: a systematic analysis for the Global Burden of Disease Study 2015	Wang et al. (2016)
9 (1 121)	17 (260)	Comprehensive molecular characterization of urothelial bladder carcinoma	Weinstein et al. (2014)
10 (1 011)	5 (700)	Global regional and national incidence prevalence and years lived with disability for 310 diseases and injuries 1990-2015: a systematic analysis for the Global Burden of Disease Study 2015	Vos et al. (2016)

$TC$2018: the total number of citations from Web of Science Core Collection since publication to the end of 2018; $C$2018: number of citations in 2018.b

TABLE 8
Characteristics of language

Language	TP	%	AU	APP	TC_{2018}	CPP_{2018}
English	31017	99	510506	16	402392	13
French	94	0.30	363	3.9	261	2.8
Russian	64	0.21	218	3.4	170	2.7
German	19	0.061	87	4.6	58	3.1
Chinese	8	0.026	47	5.9	26	3.3
Japanese	5	0.016	31	6.2	4	0.80
Czech	2	0.0064	2	1.0	0	0
Dutch	2	0.0064	7	3.5	0	0
Portuguese	1	0.0032	5	5.0	4	4.0

Korean	1	0.0032	5	5.0	3		3.0
Slovak	1	0.0032	2	2.0	3		3.0
Slovene	1	0.0032	2	2.0	1		1.0
English French	1	0.0032	2	2.0	2		2.0

TP: number of publications; *AU*: number of authors; *APP*: number of authors per publication; *TC*2018: the total number of citations from Web of Science Core Collection since publication to the end of 2018; *CPP*2018: number of citations (*TC*2018) per publication (*TP*).

TABLE 9
Yearly distribution of articles authors pages and references for Vietnam

Year	TP	AU	AU/TP*	NR	NR/TP	PG	PG/TP
1991	119	326	2.7	1 718	14	1 224	10
1992	146	454	3.1	2 373	16	1 366	9.4
1993	121	384	3.2	2 098	17	1 091	9.0
1994	127	429	3.4	2 143	17	1 199	9.4
1995	186	625	3.4	3 506	19	1 930	10
1996	208	788	3.8	3 846	18	1 582	7.6
1997	240	985	4.1	4 723	20	2 163	9.0
1998	226	1 025	4.5	4 637	21	1 967	8.7
1999	262	1 218	4.6	5 542	21	2 269	8.7
2000	316	1 382	4.4	7 228	23	3 058	10
2001	362	1 720	4.8	9 027	25	3 260	9.0
2002	351	1 778	5.1	8 388	24	3 390	10

Year	TP	TP*		NR		PG	
2003	476	2 374	5.0	10 625	22	4 228	8.9
2004	441	2 721	6.2	11 033	25	4 514	10
2005	558	2 955	5.3	13 877	25	5 258	9.4
2006	637	3 542	5.6	16 201	25	5 861	9.2
2007	741	5 348	7.2	20 014	27	6 900	9.3
2008	920	6 560	7.1	24 421	27	8 466	9.2
2009	943	6 583	7.0	26 270	28	9 018	10
2010	1 194	9 688	8.1	36 128	30	11 742	10
2011	1 357	12 553	9.3	42 237	31	13 554	10
2012	1 711	35 293	21	54 373	32	17 371	10
2013	2 160	54 738	25	69 715	32	21 925	10
2014	2 439	60 020	25	82 847	34	26 507	11
2015	2 739	66 030	24	95 652	35	30 756	11
2016	3 312	63 967	19	124 386	38	38 115	12
2017	3 932	82 173	21	152 841	39	47 149	12
2018	4 992	85 618	17	203 165	41	60 534	12
Total	31 216	511 277		1 039 014		336 397	
Average			16		33		11

TP: number of articles; *TP**: number of articles with author information; *AU*: number of authors; *NR*: number of cited reference; *PG*: page counts.

Article

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Authors
Nguyễn Thị Nha Trang[1], Julián Monge-Nájera[2] & Yuh-Shan Ho[3]*
1. Department of Biotechnology, College of Health Science, Asia University, No. 500 Lioufeng Road, Wufeng, Taichung 41354, Taiwan; nhatrangnguyen113@gmail.com
2. Laboratorio de Ecología Urbana, Vicerrectoría de Investigación, Universidad Estatal a Distancia, 2050 San José, Costa Rica; julianmonge@gmail.com
3. Trend Research Centre, Asia University, No. 500 Lioufeng Road, Wufeng, Taichung 41354, Taiwan; ysho@asia.edu.tw
*Correspondence
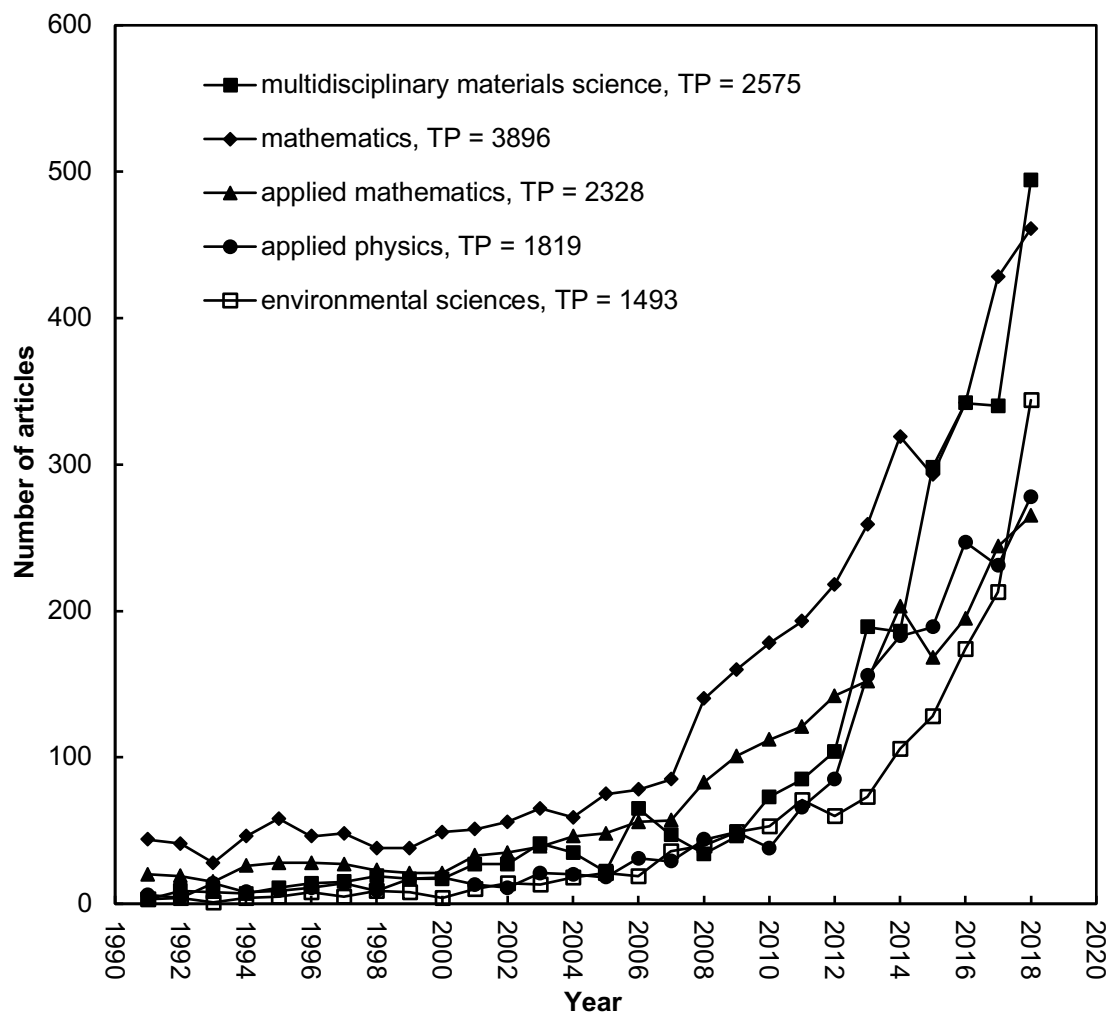
Digital Appendix 2
Additional Figures

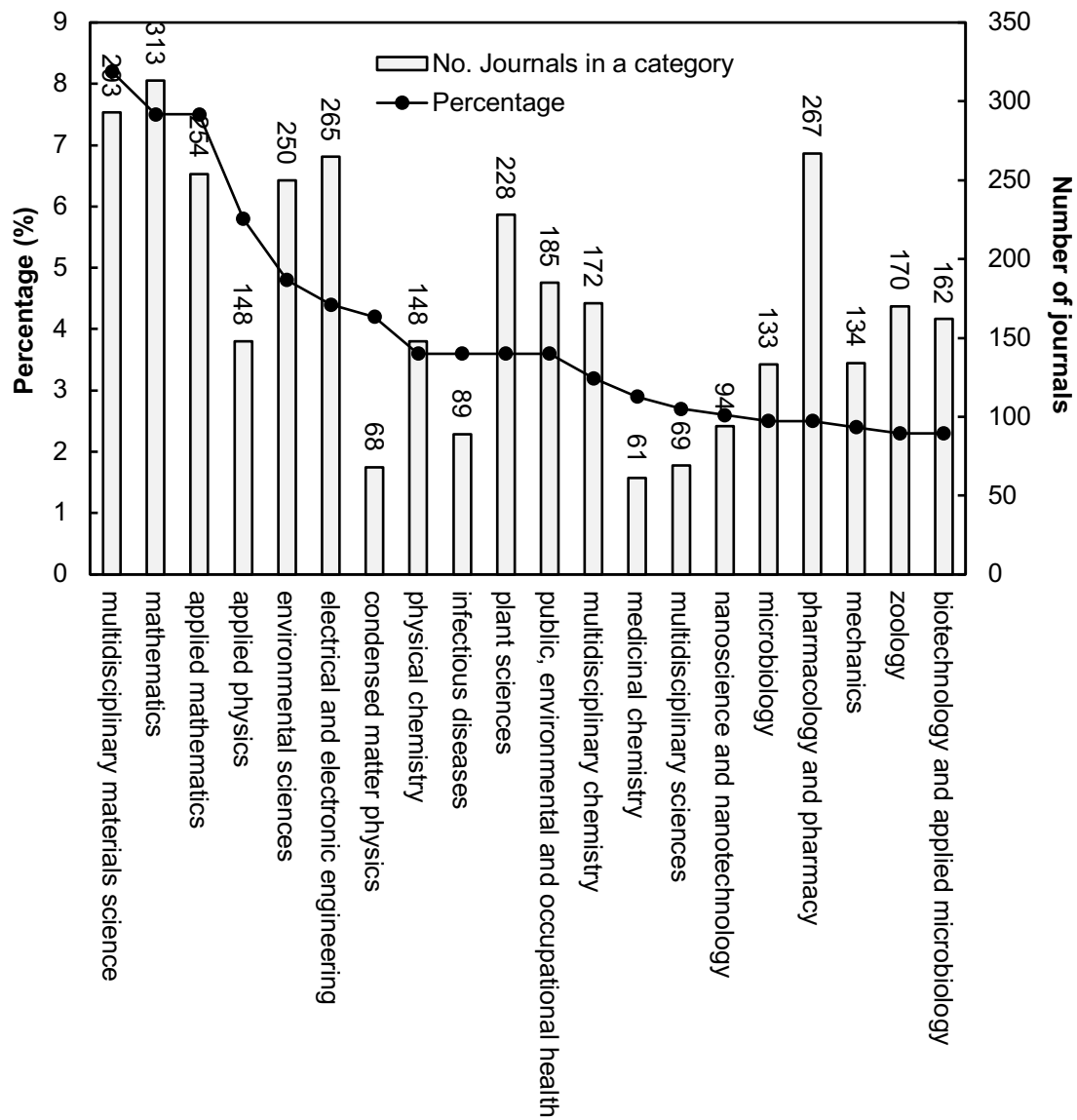**Fig. 4.** Development of the top five Web of Science categories.

Fig. 5. Distribution of the top 20 productive Web of Science categories in the Science Citation Index Expanded.
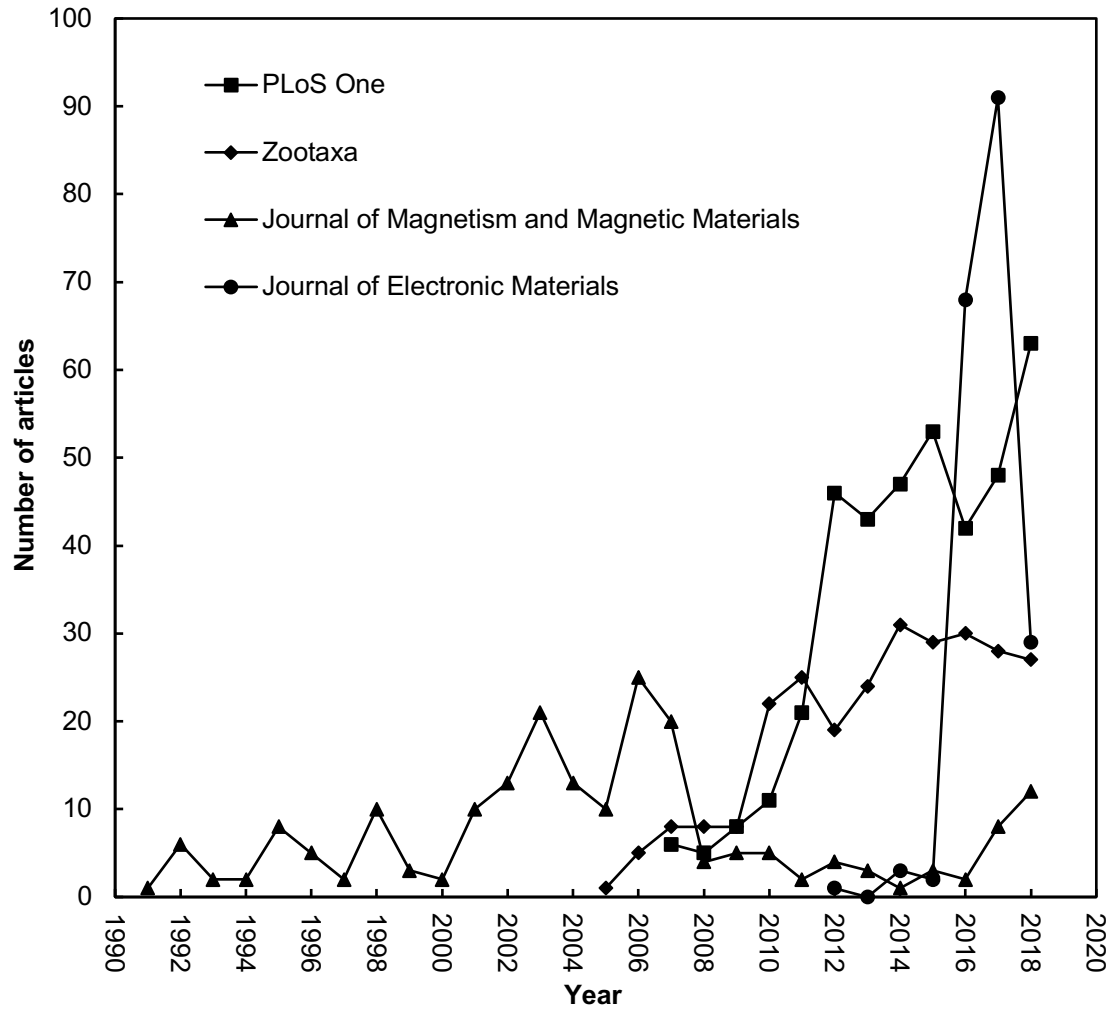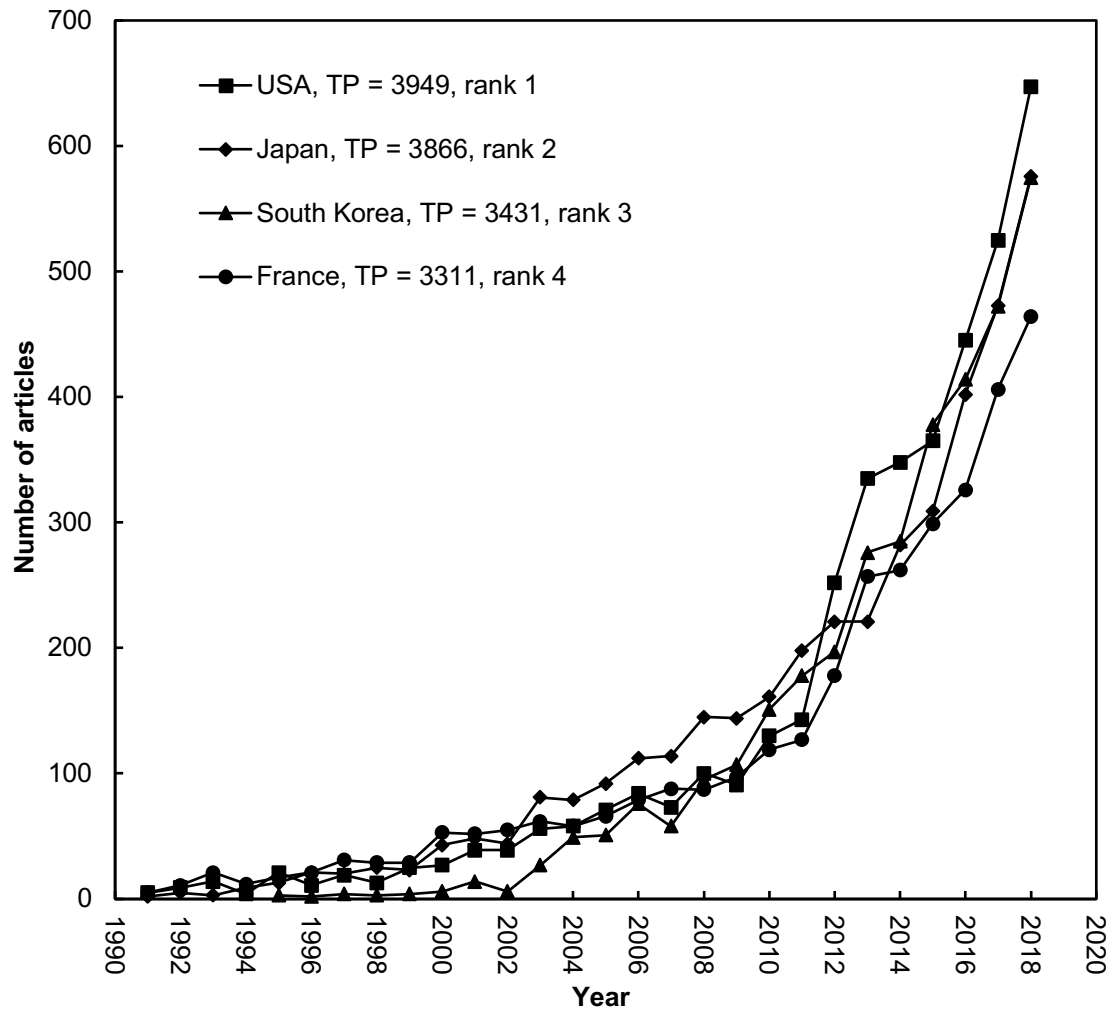
Fig. 6. The top four productive journals.

Fig. 7. Collaborated trends of the top four countries