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The authorship and internationality of Industrial Engineering journals

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This paper surveys 32 renowned Industrial Engineering (IE) journals with regard to authorship for the period of 1996-2005. The findings show that the USA was the top contributing country, accounting for approximately one-third of the total number of articles. The 80/20 rule and the entropy measure consistently identify *Issues in Science and Technology* (*IST*), *Industrial Engineer* (*IE*), and *R&D Magazine* (*RDM*) as journals of high country concentration, or journals of low internationality. Conversely, *Journal of Materials Processing Technology* (*JMPT*), *Production Planning & Control* (*PPC*), and *Technovation* (*TNV*) have the highest degree of country diversity, or internationality. The quality of a journal, as expressed by impact factors, its internationality, and its number of articles published, are found to be independent of each other.

Introduction

Industrial Engineering (IE) is concerned with the design, improvement, and installation of integrated systems of people, materials, equipment, and energy. It draws upon specialized knowledge and skill in the mechanical, physical, and social sciences together with the principles and methods of engineering analysis and design to specify, predict, and evaluate the results to be obtained from such systems [SAUNDERS, 1982]. The main goal to be achieved is productivity improvement. Unlike other traditional fields of engineering, such as electrical, mechanical, and chemical, which have clearer domains and specific industries of application, IE is multidisciplinary, it can be applied to all kinds of industry, including service industries. Many people attribute the economic progress in manufacturing over the past two centuries to IE. In this regard, it will be interesting to investigate which countries are devoting more effort to research in IE as there might exist specific relationships between the economic development of a country and its research performance in this field.

Research results are expressed in different forms, such as unpublished technical reports, patents, conference proceedings, books, and academic journals. Of these, academic journals are the most common media for researchers and practitioners to present their research and to share their experiences. They are also easier and less costly

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to acquire. Following the custom of academia and taking into account accessibility, this study only investigates research works published in international journals. The questions to be probed include country contributions to IE research, country concentration and internationality of IE journals, and characteristics of journal citations.

In the literature, the authorship of the field of Operations Research (OR) has been studied [ETO, 2000, 2002; KAO, 2009]. OR is a tool for IE researchers and practitioners in optimization. As a matter of fact, some OR journals are also considered as IE journals. It is worthwhile to see the difference between the authorship of IE and OR.

Academic journals have the major goal of disseminating knowledge. A journal of higher internationality achieves this goal better. BUELA-CASAL & AL. [2006], UZUN [2004], and ZITT & BASSECOULARD [1998] discussed the measurement of internationality for academic journals, while this paper will also conduct a simple measurement of the degree of internationality of IE journals. Following the discussion of internationality, this paper will examine the correlation between the internationality and quality of IE journals as many people believe that more internationalized journals tend to be disseminated wider and consequently cited more often.

In the next section, the method used for investigating the authorship and internationality of IE journals will be described. After that, the results, including country contribution, country concentration, internationality, and impact factors, obtained from the investigation are presented and discussed. Finally, some conclusions are drawn from the discussion.

Methods

The main goals of this paper are to explore the country contribution to IE studies, and country concentration and internationality of IE journals. In this regard, the journals to be included for investigation have an influential effect to the result. There are at least two difficulties in determining the journals to be investigated. One concerns the scope and the other the visibility and accessibility. Since IE involves social sciences in addition to the traditional mathematical and physical sciences, it is difficult to specify the journals which can be regarded as IE journals. One factor which makes this difficulty even more complicated is that while a journal, in general, may be considered as an IE journal from its name and scope, it may contain a few articles which are far from the general consensus of IE studies. Conversely, there are also journals which are not related to IE, yet contain articles which are typical IE studies.

Regarding visibility and accessibility, there are countries which are very active in IE. For example, in Taiwan, international conferences are held, scientific journals are published, and professional certificates are accredited. The *Journal of the Chinese Institute of Industrial Engineers* is evaluated by the National Science Council of the Republic of China (Taiwan) as one of the top journals published in Taiwan [KAO & AL., 2008). Regretfully, however, this journal is not well known to international scholars and practitioners, and is accessible only through subscription.

For the second difficulty, a custom widely accepted in academia is that the journal must, at least, have authors and readers from all over the world [BUELA-CASAL & AL., 2006]. In other words, a journal must be cited frequently enough abroad. The Institute of Scientific Information (ISI) has been compiling the number of citations for many journals. Those which appear in their Journal Citation Report (JCR) must have a large number of citations, and are accessible online (ISI Web of Knowledge).

For the first difficulty, the JCR has classified journals into different categories according to their domain. A journal can be classified into several categories as the boundary of a category usually is not clear. In JCR Science Edition (ISI Web of Knowledge) there is a category of IE. Hence, the IE journals reported by the ISI are the subject of this study. Since new journals are emerging and the scope of a journal may change with time, the journals classified as IE by ISI are not the same from year to year. This study adopts the 2005 classification to determine the journals to investigate.

Regarding country concentration, three measures are used, each looks at different depth. The first is single-country contribution, which measures the share of the largest contributing country. In counting the country contribution for articles written by several authors from different countries, the conventional way is to count by one for each country that has appeared. Suppose an article is written by five authors from three countries. Then each of the three countries will have a contribution of one article. Authors of the same country will be counted only once.

Looking at only the largest contributing country to draw a conclusion may be misleading. The result will be more reliable if more countries are being examined. The second measure calculates the share of the top 20% countries. The idea is based on the 80/20 rule [TRUESWELL, 1967], which suggests that more than 80% of the articles should be contributed by the top 20% countries.

The top-country contribution only looks at one country, which tells the contrast of the top country to all other countries. The 80/20 rule examines 20% countries. The result is a contrast of the top 20% countries with the remaining countries. However, these two measures only tell part of the story, and KAO [2009] used the concept of entropy to measure the concentration of all countries.

The application of the concept of entropy to the field of scientometrics can be traced back to the study of GRUPP [1990] which measures the institutional involvement of the location of research and development. In measuring the concentration, the idea is as follows. Let p_i, i=1,…, n, be the share of the ith country. The Shannon measure of entropy, E, is defined as [ZIMMERMANN, 1976]:

$$E = \sum_{i=1}^{n} p_i \ln p_i \qquad (1)$$

The largest value of this measure occurs when all n countries contribute the same proportion of $1/n$ articles. The corresponding entropy value is $E_{max} = \ln n$. In contrast, the smallest value is 0, which occurs when one p_i is equal to 1 and all others are equal to 0. Mathematically, cases of larger n have larger entropy values. Therefore, the entropy value is usually divided by E_{max}, the largest value which can occur, to obtain a standardized value lying between 0 and 1 so that cases of different n are comparable.

The three measures for country concentration do not have threshold values for classifying a journal as low or high concentration. However, when they are used together, a general consensus can be obtained.

The term "internationality", although widely used, does not have a clear definition. In the context of academic publishing, BUELA-CASAL & AL. [2006] identified four criteria for measuring the internationality of journals after an extensive analysis of existing measures. These are: international co-authorship, distribution of editorial board members, distribution of associate editors, and distribution of authors. Of these, the distribution of authors is considered by BUELA-CASAL & AL. [2006] as the most important measure for journal internationality.

In order to create an image of internationalization and prestige, many journals invite famous scholars from all over the world to serve as editorial board members. Their names are listed in the journal, although they often have no responsibilities, nor duties, regarding journal publishing. The distribution of editorial board members in such cases merely distorts the real degree of internationality. The number of associate editors is only the policy of a journal, and the task of publishing can be done by the editor-in-chief with many assistants or distributed among many associate editors. Thus, using the distribution of associate editors as a criterion may not be appropriate. Regarding international co-authorship, a common measure for this criterion is the share of internationally co-authored papers. In investigating the contribution of different countries to IE journals, each country of the institute that an author is affiliated with is counted. In this way, the level of international co-authorship is reflected in the distribution of authors. Hence, to investigate internationality, it suffices to investigate the distribution of authors.

BUELA-CASAL & AL. [2006] used the Gini coefficient to measure the degree of internationality. The Gini coefficient is a measure of concentration. To view from the opposite side, it is also a measure of diversity, which has the same effect as the entropy used by KAO [2009] to measure the degree of country spread. Since the entropy values of the journals have already been calculated, we will use them to discuss the degree of internationality.

This paper investigates the journals classified as IE by the ISI in the 2005 version of the JCR Science Edition for a period of ten years, 1996–2005, to obtain results regarding country contribution, country concentration, and internationality. The next section shows the results.

Results

There are 32 IE journals (ISI Web of Knowledge). Each journal publishes a different number of issues each year and each issue contains a different number of articles. The first column of Table 1 shows the names of those journals, with abbreviations in parentheses for easy representation. Note that *Industrial Engineer* (No. 23) was named *IIE Solutions* before 2003. In this study, they are treated as one journal with the name of *Industrial Engineer*.

Table 1. IE journals, their base countries, and the number of articles in 1996–2005

Journal	Country/ territory	Total articles
1. *Journal of Materials Processing Technology* (*JMPT*)	Switzerland	6730
2. *International Journal of Production Research* (*IJPR*)	England	2354
3. *Computers & Industrial Engineering* (*CIE*)	England	1473
4. *Journal of Scientific & Industrial Research* (*JSIR*)	India	1333
5. *Ergonomics* (*ERG*)	England	1221
6. *Computers & Operations Research* (*COR*)	England	1180
7. *Reliability Engineering & System Safety* (*RESS*)	England	1179
8. *IIE Transactions* (*IIET*)	England	972
9. *Journal of Management in Engineering* (*JME*)	USA	963
10. *International Journal of Industrial Ergonomics* (*IERG*)	Netherlands	890
11. *R&D Magazine* (*RDM*)	USA	867
12. *Issues in Science and Technology* (*IST*)	USA	839
13. *Journal of Construction Engineering and Management-ASCE* (*JCEM*)	USA	830
14. *Production Planning & Control* (*PPC*)	England	818
15. *Research-Technology Management* (*RTM*)	USA	722
16. *Technovation* (*TNV*)	Netherlands	721
17. *CIRP Annals-Manufacturing Technology* (*MT*)	Switzerland	688
18. *Applied Ergonomics* (*AE*)	England	643
19. *Industrial Management & Data Systems* (*IMDS*)	England	627
20. *Safety Science* (*SS*)	Netherlands	520
21. *IEEE Transactions on Engineering Management* (*EM*)	USA	458
22. *Journal of Quality Technology* (*JQT*)	USA	451
23. *Industrial Engineer* (*IE*)	USA	446
24. *Industrial Robot-An International Journal* (*IR*)	England	385
25. *IEEE Industry Applications Magazine* (*IAM*)	USA	377
26. *Int. J. of Industrial Engineering-Theory Applications and Practice* (*IJIE*)	USA	366
27. *Probability in the Engineering and Informational Sciences* (*PEIS*)	USA	346
28. *Journal of Manufacturing Systems* (*JMS*)	USA	310
29. *Journal of Product Innovation Management* (*JPIM*)	USA	291
30. *Travail Humain* (*TH*)	France	210
31. *Journal of Engineering and Technology Management* (*JETM*)	Netherlands	186
32. *Research in Engineering Design* (*RED*)	England	155
Total		29551
Average		923

Most of the journals have also been classified into other categories, such as Operations Research/Management Science (ten journals), Manufacturing Engineering (eight), Multidisciplinary Sciences (five), Computer Science (three), Psychology (two), Statistics & Probabilities (two), etc. Only six journals, *Applied Ergonomics*, *IEEE Transactions on Engineering Management*, *Industrial Engineer*, *International Journal* *of Industrial Engineering*, *Journal of Engineering & Technology Management*, and *Journal of Production Innovation Management*, belong only to the category of Industrial Engineering. From the categories that the IE journals have been classified, one can see that IE is a multidisciplinary field. However, the major focus of the discipline is system optimization, with applications to manufacturing.

The second column of Table 1 is the base country/territory of the journal. Of the 32 journals, the US and the UK publish 13 and 11 journals, accounting for 40.6% and 34.4% of the journals, respectively. For the remaining eight journals, the Netherlands publishes four (12.5%), Switzerland two (6.3%), and France and India publish one journal (3.1%) each. The publication language is English for all 32 journals. Compared to the 56 OR journals [KAO, 2009], the three countries which publish the largest number of journals are the same. However, the order and the associated percentage are somewhat different: 19 journals (32.9%) for the UK, 18 journals (32.1%) for the US, and 11 journals (19.6%) for the Netherlands. The US has a higher percentage while the Netherlands has a lower percentage and the UK has a similar percentage for IE journals.

The total number of articles appearing in each journal in 1996–2005 is shown in the last column of Table 1. On average, each journal has 923 articles in ten years, or 92.3 articles each year. The *Journal of Materials Processing Technology* (*JMPT*) has a huge number of articles, 6,730. This number is far ahead of the next journal, the *International Journal of Production Research*, which has 2,354. The *JMPT* is not a typical IE journal. According to ISI, it is also classified as a Manufacturing Engineering journal and a Multidisciplinary Materials Science journal. The top 20% journals, i.e., the top six journals, in terms of the number of articles, have an average of 2,382 articles in ten years, while the bottom 20% journals have an average of 250 articles, a difference of approximately ten times.

Country contribution

One of the major objectives of this study is to investigate the contribution of different countries to the international repertoire of research in IE. As shown at the bottom of Table 1, there are 29,551 articles published in the 32 journals from 1996 to 2005. As mentioned in the preceding section, in investigating the country contribution, for articles written by authors from different countries, each country will be counted by one. Since many articles have authors from more than one country, this type of counting results in a total number of articles greater than 29,551.

Table 2 shows the number of articles contributed by the top 30 countries for the 32 IE journals. The top 30 countries are concentrated in Europe and Asia, in that 16 are in Europe, nine in Asia, two in North America, two in Oceania, and one in South America. Note that the total number of articles contributed by the top 30 countries is 30,067, which has already exceeded the total number of articles contained in the 32 journals, 29,551. This is because an article contributed by authors from two or more countries will be counted several times. The US contributed the largest number of articles, 9,909. The second largest contributing country is the UK, although its number of 2,235 is less than one quarter that of the US. The following eight countries are China (1,788 articles), India (1,545), South Korea (1,516), Taiwan (1,378), Canada (1,245), Japan (1,232), Hong Kong (875), and Germany (869). The numbers in parentheses in Table 2 are percentages of the corresponding numbers of articles of the top 30 countries. Approximately one-third of the articles are contributed by the US.

Table 2. Thirty countries which have contributed the most to IE journals

Country	Articles	(%)	Country	Articles	(%)
1. USA	9909	(32.96)	16. Singapore	571	(1.90)
2. UK	2235	(7.43)	17. Sweden	481	(1.60)
3. China	1788	(5.95)	18. Spain	407	(1.35)
4. India	1545	(5.14)	19. Turkey	391	(1.30)
5. South Korea	1516	(5.04)	20. Israel	329	(1.09)
6. Taiwan	1378	(4.58)	21. Ireland	295	(0.98)
7. Canada	1245	(4.14)	22. Brazil	268	(0.89)
8. Japan	1232	(4.10)	23. Denmark	217	(0.72)
9. Hong Kong	875	(2.91)	24. Finland	213	(0.71)
10. Germany	869	(2.89)	25. Belgium	202	(0.67)
11. France	790	(2.63)	26. Greece	195	(0.65)
12. Australia	684	(2.27)	27. Portugal	187	(0.62)
13. Netherlands	634	(2.11)	28. Norway	173	(0.58)
14. Poland	581	(1.93)	29. Switzerland	144	(0.48)
15. Italy	574	(1.91)	30. New Zealand	139	(0.46)
Total				30067	(100)

The general impression to most people is that economic giants such as the G7 countries, Canada, France, Germany, Italy, Japan, the UK, and the US, and several Western European countries spend relatively larger amount of money and manpower on research. Therefore, these countries will contribute most of the articles. The results in Table 2 follow this impression, in that the G7 countries are ranked among the top 15, and 11 Western European countries, not including the G7, are among the top 30. It is somewhat surprising to find six Asian countries/territories being ranked among the top 10. They are China, India, South Korea, Taiwan, Japan, and Hong Kong. Of these countries, Japan is a G7 country. South Korea, Taiwan, and Hong Kong are of the so-called Four Dragons of Asia, and the other dragon, Singapore, is ranked sixteenth. China and India are the BRIC countries (i.e., Brazil, Russia, India, and China), rising stars with great potential for economic development. The recent report (2007–2008) on the global competitiveness of 131 countries by the World Economic Forum (WEF Website) shows that the top 10 countries in IE journal publications have ranks of 1, 9, 34, 48, 11, 14, 13, 8, 12, and 5, respectively. Only China and India have relatively lower ranks of competitiveness, 34 and 48, respectively. The other eight are ranked among the top 14. Although it is not clear whether IE research is the cause, effect, or neither, of economic development, the correlation between IE research and economic development is evident.

Compared to the OR journals [KAO, 2009], the largest contributing country is also the US, with a similar percentage of 32.32%. Recall that the percentage of the US for IE journals is 32.96%. The top ten contributing countries are the US, UK, Canada, China, Germany, Taiwan, France, Netherlands, Japan, and Italy. Seven are among the top ten of IE journals, a very high overlapping.

Country concentration

An international journal must have a high diversity of authors in terms of country spread in addition to a high number of citations. If a journal is contributed by authors from a limited number of countries, then it is only a local journal, not international.

The second column of Table 3 shows the country which is the largest contributor to each journal, and the names in this table are in abbreviation. The number, in parenthesis, following each abbreviation is the number of the journal with the full name in Table 1 for reference. Column 3 shows the percentage of articles contributed by the associated country. For example, the largest contributing country for the first journal, the *Journal of Materials Processing Technology* (*JMPT*), is China, with a share of 14.38% among the 30 countries. The US is the largest contributor for 23 journals, accounting for 72% of the journals. The UK is the largest contributor to five journals. The remaining four journals have their largest contributors from China, Germany, France, and India, respectively. There are 15 journals whose largest contributor has a share greater than 50%. Five journals, *Research-Technology Management* (*RTM*), the *Journal of Scientific & Industrial Research* (*JSIR*), *Issues in Science and Technology* (*IST*), *Industrial Engineer* (*IE*), and *R&D Magazine* (*RDM*), have a share greater than 80%.

The journal with the largest percentage of single-country contribution is *RDM*, a percentage as high as 96.7%. A high percentage of single-country contribution gives people the impression that the journal is monopolized by that country, and scholars and experts of other countries will be reluctant to submit their research to this journal. Hence, this journal would be considered as a local, rather than an international, journal. According to the numbers in Table 2, the largest contributing country to IE journals is the US, with a percentage of 32.96%. Theoretically, if the authors are evenly distributed in 32 journals, then each journal should have the US as the largest contributor, with a share of 32.96%. Certainly, this is not the case. Suppose we allow a 100% variation. Then each journal could have a top-country share of 65.92% (=32.96%×2). Under this standard, a journal with a top-country percentage greater than 70% will be considered as a high concentration journal. There are seven, or 21.88%, of the 32 journals which pass this threshold. These journals are those five journals with a top-country contribution greater than 80% plus *Travail Humain* (*TH*) and the *Journal of Management in Engineering* (*JME*). Compared with OR/MS journals, where only five out of 56 journals, or 8.93%, have a top-country contribution greater than 70% [KAO, 2009], the IE journals are 3.5 times higher.

Table 3. Country concentration and spread of 32 IE journals

Journal	Top country	(%)	Top second to sixth countries	(top six %)	Entropy	Impact factor
1. *JMPT* (1)	China	(14.38)	UK, Korea, Japan, Poland, USA	(54.01)	0.8691	0.578
2. *PPC* (14)	USA	(19.49)	UK, Taiwan, India, Italy, China	(54.36)	0.8645	1.504
3. *TNV* (16)	UK	(18.59)	USA, Japan, Australia, Italy, Canada	(55.79)	0.8555	0.889
4. *RESS* (7)	USA	(26.31)	UK, Italy, France, Korea, Netherlands	(55.96)	0.8353	0.551
5. *SS* (20)	UK	(17.07)	USA, Netherlands, Australia, Sweden, France	(62.48)	0.8227	0.593
6. *COR* (6)	USA	(30.44)	Taiwan, Canada, Korea, China, Hong Kong	(64.60)	0.7853	0.562
7. *ERG* (5)	UK	(25.61)	USA, Canada, Netherlands, Sweden, Japan	(66.69)	0.7672	0.741
8. *IJPR* (2)	USA	(32.70)	Taiwan, UK, China, Canada, Korea	(63.82)	0.7669	0.558
9. *AE* (18)	UK	(20.56)	USA, Sweden, Netherlands, Canada, Australia	(70.70)	0.7590	0.889
10. *IERG* (10)	USA	(30.61)	Sweden, Taiwan, Canada, Korea, Australia	(68.31)	0.7557	0.711
11. *MT* (17)	Germany	(22.22)	Japan, USA, Italy, UK, Canada	(71.50)	0.7502	0.973
12. *PEIS* (27)	USA	(36.91)	Netherlands, Israel, Japan, China, Canada	(68.09)	0.7112	0.523
13. *IR* (24)	UK	(32.50)	USA, Italy, Germany, Australia, Japan	(74.16)	0.6892	0.741
14. *CIE* (3)	USA	(38.02)	Korea, Japan, China, Taiwan, Canada	(75.53)	0.6843	0.632
15. *IJIE* (26)	USA	(38.22)	Taiwan, Korea, India, Hong Kong, Japan	(81.42)	0.6206	0.632
16. *IMDS* (19)	USA	(49.21)	UK, Taiwan, Hong Kong, China, Australia	(82.19)	0.5882	1.504
17. *JCEM* (13)	USA	(48.94)	Canada, China, Hong Kong, Singapore, UK	(83.69)	0.5644	1.315
18. *IIET* (8)	USA	(55.23)	Hong Kong, Canada, China, Israel, Taiwan	(82.00)	0.5516	0.503
19. *RED* (32)	USA	(52.05)	UK, Germany, Sweden, Canada, Netherlands	(81.87)	0.5479	1.114
20. *JPIM* (29)	USA	(58.60)	Netherlands, Canada, UK, Sweden, Italy	(82.80)	0.5277	0.885
21. *JMS* (28)	USA	(60.06)	Korea, Taiwan, Canada, China, Hong Kong	(85.71)	0.5001	0.973
22. *EM* (21)	USA	(64.66)	Canada, China, Hong Kong, UK, Singapore	(83.08)	0.4938	0.573
23. *JETM* (31)	USA	(64.04)	Canada, UK, Germany, Netherlands, Japan	(82.76)	0.4824	1.114
24. *IAM* (25)	USA	(65.23)	Korea, Canada, Germany, Japan, France	(86.21)	0.4648	0.391
25. *JQT* (22)	USA	(68.46)	Canada, Korea, Taiwan, Singapore, UK	(86.13)	0.4382	1.315
26. *TH* (30)	France	(71.98)	Canada, Belgium, UK, Germany, USA	(92.86)	0.3608	0.593
27. *JME* (9)	USA	(79.76)	UK, Hong Kong, China, Australia, Canada	(95.09)	0.2829	0.711
28. *RTM* (15)	USA	(82.09)	Canada, UK, Netherlands, Germany, Japan	(93.44)	0.2751	0.677
29. *JSIR* (4)	India	(87.99)	USA, Turkey, UK, Japan, Korea	(94.79)	0.2018	0.885
30. *IST* (12)	USA	(95.10)	Canada, UK, France, Switzerland, Japan	(98.72)	0.0905	0.531
31. *IE* (23)	USA	(94.68)	UK, Canada, China, Israel, Japan	(99.12)	0.0893	0.326
32. *RDM* (11)	USA	(96.70)	Germany, UK, Switzerland, Korea, Australia	(99.34)	0.0605	0.578
Aggregate	USA	(32.96)	UK, China, India, Korea, Taiwan	(61.10)	0.7926	

A further step to explore country concentration is to apply the 80/20 rule by counting the total contribution of the top 20% countries. For 30 countries, 20% is six. We examined the top second to top sixth contributing countries for each journal, and the results are shown in the central part of Table 3. The US is among the top six countries for all 32 journals, and the UK appears for 24 journals. The following four countries are

Canada, Japan, China, and South Korea, each has appeared in 23, 14, 13, and 12 journals, respectively. Numbers in the third-to-last column are the total share of the top six countries. Surprisingly, 18 journals, or 56.25 %, have a total share greater than 80%. There are seven, or 21.88% of the 32 journals, which have a total share even greater than 90%. Consistently, the journals with a six-country share greater than 90% are the same as those with a top-country contributing percentage greater than 70%. Again, whether this phenomenon is common to other categories of journals is not clear. However, at least for OR journals, there are only 11 out of 56 journals, or 19.64%, which have a total share greater than 80% and only three journals, or 5.36%, with a total share greater than 90%. These numbers indicate that IE journals have a higher extent of country concentration.

The third step is to examine all thirty countries (n=30) by calculating the entropy value. Using the data of all IE journals the entropy value calculated from (1) after standardization is 0.7926. The second-to-last column of Table 3 shows the standardized entropy values of the 32 journals in descending order. Of these, *Journal of Materials Processing Technology* (*JMPT*) has the largest value of 0.8691, indicating that this journal has the most even spread of those 30 countries. The following four journals are *Production Planning & Control* (*PPC*), *Technovation* (*TNV*), *Reliability Engineering & System Safety* (*RESS*), and *Safety Science* (*SS*), with entropy values of 0.8645, 0.8555, 0.8353, and 0.8227, respectively. Only these five journals have entropy values greater than that calculated from the aggregated data, 0.7926.

The entropy is a relative measure. It only indicates which journals have a relatively even spread of countries, and there is no threshold value to distinguish between even spread and narrow concentration. However, one can derive one from the concept of the 80/20 rule. According to the 80/20 rule, 20% of the leading countries should contribute 80% of the articles. Let $p_{(i)}$ be the share of the ith country rearranged in descending order, that is, $p_{(i)} \geq p_{(i+1)}$. The largest entropy measure under the 80/20 rule, i.e., $p_{(1)}+p_{(2)}+p_{(3)}+p_{(4)}+p_{(5)}+p_{(6)}= 80$, is 0.7554 which occurs at $p_{(i)}= 0.8/6$, i=1,…,6, and $p_{(i)}= 0.2/24$, i=7,…,30, and the smallest entropy value is 0.4018 which occurs at $p_{(1)}= 91/120$ and $p_{(i)}= 1/120$, i=2,…,30. Therefore, 0.4018 can be considered as a threshold value. Journals with an entropy value smaller than 0.4018 are thus considered journals of high concentration.

In general, the order of entropy values of the 30 countries is consistent with that of the single-country shares and top six-country percentages. For the bottom seven journals in Table 3, the results are exactly the same, in that journals with a single-country share greater than 70% have a top six-country percentage greater than 94% and an entropy value smaller than 0.4. They are thus journals of high concentration. The last three journals in Table 3, *Issues in Science and Technology* (*IST*), *Industrial Engineer* (*IE*), and *R&D Magazine* (*RDM*), have single-country shares greater than 90%, top six-country percentages greater than 98%, and entropy values smaller than 0.1, a sign of very high concentration. Moreover, their second top countries have shares of only 1.16%, 1.27%, and 2.07%, respectively, which are far below their top-country shares.

To grasp more clearly the idea of the entropy value, consider cases of 70% of the single-country share and 90% of the top six-country percentage. The largest entropy value for cases of 70% single-country share is 0.4766, which occurs at $p_{(1)}$= 0.7 and $p_{(i)}$= 0.3/29, i=2,…, 30, and the smallest value is 0.1796, which occurs at $p_{(1)}$= 0.7, $p_{(2)}$= 0.3, and $p_{(i)}$= 0, i=3,…, 30. For cases with a 90% top six-country percentage, the largest entropy value is 0.6631, occurring at $p_{(i)}$= 0.9/6, i=1,…,6 and $p_{(i)}$= 0.1/24, i=7,…, 30, and the smallest value is 0.2280, occurring at $p_{(1)}$= 211/240 and $p_{(i)}$= 1/240, i=2,…, 30.

For OR journals [KAO, 2009], the aggregate entropy value for all 56 journals is 0.8039, which is quite similar to that of IE journals, 0.7926. However, there are only three out of 56 journals, or 5.4%, which have an entropy value smaller than 0.4 as opposed to seven out of 32 journals, or 21.8%, for IE journals. On the contrary, there are 15 out of 56 journals, or 26.8%, which have an entropy value greater than 0.8 as opposed to five out of 32 journals, or 15.6%, for IE journals. The country concentration is relatively uneven for IE journals.

Internationality

Before the discussion, it must be noted that internationality should not be equated with quality. It is quite possible that a non-international journal publishes very advanced and innovative research. Journals with wider national representation merely increase the diversity of ideas and criticism and accelerate the advancement of knowledge. In this regard, the five journals at the top of Table 3 with entropy values greater than 0.8, namely, *Journal of Materials Processing Technology* (*JMPT*), *Production Planning & Control* (*PPC*), *Technovation* (*TNV*), *Reliability Engineering & System Safety* (*RESS*), and *Safety Science* (*SS*), have played a good role in knowledge exploration and dissemination. Conversely, the seven journals at the bottom of Table 3, with entropy values smaller than 0.4, have failed in playing this role. The last three journals, *Issues in Science and Technology* (*IST*), *Industrial Engineer* (*IE*), and *R&D Magazine* (*RDM*), even have an entropy value of smaller than 0.1, and the top-country share almost greater than 95%. Unless they have wide group of readers from many countries, they can hardly be considered as international journals. It is worthwhile to note that, for OR journals [KAO, 2009], there is not a single journal whose entropy value is smaller than 0.2, nor any journal with a top-country share greater than 90%.

A quick method for checking whether a journal is an international journal is to look at the top-country share. If it is greater than 80%, then this journal should probably not be considered as an international journal. A better way is to look at the top six-country percentage, and journals with a top six-country percentage greater than 90 should probably not be considered international. Certainly, the most reliable way is to calculate the entropy, and journals with an entropy value of smaller than 0.4 should not be considered international.

Intuitively, a journal with larger number of articles should have a higher country spread, and consequently a higher degree of internationality. The point is that more countries would appear when the number of articles is large. To investigate whether the number of articles published is correlated with the internationality of IE journals, the correlation coefficient between the number of articles and the entropy is calculated. The value is 0.228, and so no significant correlation is detected. This indicates that although the number of countries increases as the number of articles increases, it is not high enough to result in significantly higher entropy values.

Impact factor

For a long time, academics have endeavoured to find a measure which reflects the quality of journals, and much effort has been devoted to this task [BONNEVIE-NEBELONG, 2006; BUTLER, 2002; DUL & AL., 2005; KAO & AL., 2008; NISONGER, 1999; TURBAN & AL., 2004]. Despite its multicriteria nature and subjectivity, most studies agree that cross-citation, that is, the number of times that a journal is being cited by other journals, is the most appropriate indicator. If a journal's articles are cited more often than those contained in another journal then the former is considered to have larger impact, or better quality, than the latter in a loose sense. Several institutes have been compiling this type of data. The impact factor of the ISI for a journal in Year Y is to count the number of times that the articles published in this journal in the last two years, $Y-1$ and $Y-2$, are cited by articles published in a list of journals in Year Y divided by the total number of articles this journal published in Years $Y-1$ and $Y-2$. A larger value of impact factor indicates that this journal is being referred to more often, and is thus regarded as a better journal.

There are two different hypotheses regarding the value of impact factor. One is journals of higher country diversity have higher impact factor. The reason is that higher country diversity implies wider readership, and consequently greater influence. The other is the opposite, which believes that journals of higher concentration have higher impact factor, because higher concentration indicates a smaller group of researchers, and they are inclined to cite each other. The last column of Table 3 shows the impact factor of each journal for 2005 compiled by the ISI. The correlation coefficient between the entropy value and the impact factor of the 32 journals is 0.1718. This value is close to 0, indicating that the correlation between the impact factor and country diversity, or degree of internationality, is slightly positive, yet is not significant. In other words, neither of the two hypotheses holds.

Some people believe that journals with more articles tend to have a lower impact factor, because more articles will dilute it. To test this hypothesis, we calculated the correlation coefficient between the number of articles and the impact factor for the 32 journals, and obtained a value of –0.1825. The negative value seems to support the hypothesis that more articles tend to dilute the impact factor. However, the value is close to 0, indicating that the relationship is rather weak.

Conclusions

Based on the data from 1996 to 2005 compiled by the ISI, *Journal of Materials Processing Technology* (*JMPT*), *International Journal of Production Research* (*IJPR*), and *Computers & Industrial Engineering* (*CIE*) publish the largest number of articles in the category of IE. The top three countries in contributing articles to IE journals are the USA, UK, and China. Notably, six Asian countries are among the top ten.

Several journals are dominated by a few countries. Prominently, authors from the USA contributed approximately 95% of the articles in *Issues in Science and Technology* (*IST*), *Industrial Engineer* (*IE*), and *R&D Magazine* (*RDM*). The top-country share, the 80/20 rule, and the entropy measure consistently identify *Travail Humain* (*TH*), the *Journal of Management in Engineering* (*JME*), *Research-Technology Management* (*RTM*), and the *Journal of Scientific & Industrial Research* (*JSIR*), in addition to the three previously mentioned journals, to be journals of high country concentration, or low internationality. Conversely, the *Journal of Materials Processing Technology* (*JMPT*), *Production Planning & Control* (*PPC*), *Technovation* (*TNV*), *Reliability Engineering & System Safety* (*RESS*), and *Safety Science* (*SS*) are journals of high country diversity and have a high degree of internationality. Although there is no threshold value for distinguishing whether a journal is of high country concentration, the results from OR journals indicate that IE journals have relatively higher country concentration.

A simple calculation of the correlation coefficient indicates that the number of articles of a journal is independent of its internationality and the quality, as expressed by the impact factor. The journal's internationality is also independent of its quality. The comparison of country contributions, quality, and internationality for journals of the same category is relatively simple due to their homogeneity in many aspects. How to compare journals of different categories will thus be a topic for future research.

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