The sleeping dragon wakes up: A scientometric analysis of the growth of science and the usage of journals in China

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An overview of the journals used by scientists in post Cultural Revolution China is presented based on papers published by them in the 2649 journals indexed in Science Citation Index (SCI) for the period 1981–85 as well as in journals covered by three editions of Current Contents (CC) for the second half of 1988. We have also looked at the frequency of citation of the papers indexed in SCI 1981–85, by way of cross-reference in other papers. Clearly, China's share of the world's journal literature and the share of Chinese language papers are increasing rapidly. However, Chinese work is very infrequently cited. For the period 1981–85, for example, China's share was 0.44% of the total world's published journal literature, as seen from SCI, but only 0.08% of the total citations referred to Chinese papers, the majority of which are in the physical sciences. About 70% of China's research papers come from as few as 24 institutions, reflecting the centralized nature of the Chinese scientific enterprise. Laboratories under Chinese Academy of Sciences play a dominant role, and only a few universities seem to be active in scientific research. About 30% of the papers in our CC sample have appeared in Chinese journals and the rest in foreign journals, mostly published in USA. A number of papers, especially in physics, have appeared in well-known letters journals. However, papers by Chinese scientists have rarely appeared in multidisciplinary journals such as Nature and Science. The data in the literature reinforce our conclusion that growth in China's share of the world's journal literature of science has not yet flattened off.

CHINA, like India and Egypt, is the home of a truly ancient and great civilization and has a glorious tradition of scientific and technical achievements. It is China which gave the world technologies such as printing (long before Gutenberg reinvented it), gunpowder and the compass, three inventions of the greatest significance to human history which together 'changed the whole outlook of the world and the situation of matters' as Francis Bacon said in *Novum organum*. The British scientist and historian of science Joseph Needham was so fascinated by the great scientific and technological achievements of China that he decided to devote most of his time to the study of and bringing to light the science and civilization of China.

However, since the early days of the industrial revolution in the West, China lost its status as a leader in scientific innovation. Added to this, the country was ravaged by wars and internal strife, an ambience not conducive to sustained invention and innovation. In particular, the Cultural Revolution (1966–76) proved disastrous to all intellectual activity in China, including scientific and technological research.

Today China is back on the road to greatness in science and technology. Chinese leaders, both of the polity and of science, now realize that the success of China's four modernizations depends on developing science and technology and on cultivating a mighty technical force[1]. In fact, science and technology have figured prominently in the fierce political struggles that have taken place in China since the founding of the People's Republic, much more so than in other societies undergoing rapid social and economic changes[2]. But it is only after the mid-1970s, soon after the arrest of the 'gang of four', that the relationship between science, technology and economic development became a matter

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of much greater concern in China. It was then that the Chinese leadership reaffirmed the general principle of rapid modernization and took steps to put the S&T system on firmer footing than before[2]. An important feature that characterizes the resurgence of China is the willingness of China to throw open the Bamboo Curtain, not only in the realm of trade and economy but also in matters cerebral and scientific. Today China is not only increasingly involved in international technology transfer and becoming more and more a global business partner[3], but she is also inviting many outstanding research scientists from abroad to devote some time in China and to conduct seminars and workshops for Chinese scientists and research students. Further, the UNDP-sponsored TOKTEN programme, under which expatriate Chinese scientists and technologists are invited to visit China for a short period to interact with researchers and technologists working in Chinese laboratories and industries, is gaining momentum. However, despite the dramatic changes that have taken place in the past decade or so, China's contacts with the outside world remain geographically peripheral and it will take some time before China can grow out of her proverbial status of an 'intellectual island'.

According to a *Nature* survey[4], the Government of China claimed in 1985 that there were more than 4000 independent research organizations in China. By the end of 1987, the Chinese government claimed a total of 5568 scientific and technical research and development organizations, staffed by 341,000 scientists and engineers. In addition, there are now (as of 1991) 793 universities and colleges, having 207,000 scientists and engineers[5].

Despite the less-than-conducive environment, science in China did not die down totally even during the worst years of the Cultural Revolution. For example, as early as 1965, China startled the world with the first-ever total synthesis of insulin and followed it up with the chemical synthesis of vasopressin, oxytocin, angiotensin and leutinizing-hormone-releasing hormone and the total synthesis of yeast alanine transfer RNA (in 1981) and the cloning and sequencing of a subtype of hepatitis B virus. At the 1978 National Science Congress, huge programmes were outlined in eight thrust areas, which included, apart from agriculture and energy, high-tech areas such as materials, lasers, computer science, genetic engineering, space and high-energy physics. Some recent achievements in the area of lasers include the development of inertial-confinement fusion systems, a 3 MJ/pulse high-energy laser and excimer lasers, and some excellent work in laser spectroscopy and atomic hyperfine structure. Indeed, despite the early lead India had in optics, Dr D. D. Bhawalkar, one of India's leading laser experts, believes that China's performance in laser research is better than that of India[6]. In medicine, as early as 1979 China had brought out the *Atlas of Cancer Mortality* in China. Today China's achievements in satellite and rocket technology, oil exploration, nuclear technology (atomic bombs, nuclear submarines, power generation), and condensed-matter physics (high-temperature superconductivity) are attracting worldwide attention[5].

In this paper we look at one aspect of the post Cultural Revolution Chinese scientific enterprise, viz. China's contribution to the journal literature of world science, as seen from two important sources, *Current Contents* (*CC*) and *Science Citation Index* (*SCI*).

The databases produced by the Philadelphia-based Institute for Scientific Information (ISI) have been used earlier[7-15] to estimate national contributions of India, Japan, Brazil, and other third-world, ASEAN and Latin American countries to various fields. Bibliometric studies on China, however, are not many It is only in the past four or five years that the Institute of Scientific and Technical Information of China (ISTIC) has started systematic collection of data on China's publication output and citation impact. Wu Yishan of ISTIC presented a detailed account of bibliometric studies in China at the Third International Conference on Informetrics[16]. The ISTIC group had subsequently brought out a few other bibliometric studies based on both ISI data and data collected by ISTIC on publications in about 1230 Chinese journals[17, 18]. One of the early bibliometric studies on Chinese science is now available in English[19].

There have been considerable reservations about the use of ISI databases for estimating the volume of contributions made by developing countries, on the grounds that their coverage of developing countries' journals (as well as East European journals) is scanty[20, 21]. Persson[22] has shown that the numbers one arrives at for the contributions made by a country depend on the database one chooses to work with. For instance, the US contribution to the world literature of optics in 1982 turned out to be 48.57% as seen from the 1973 constant-journal set of *SCI* (Computer Horizons Inc.), 39.56% as seen from the 1981 constant-journal set of *SCI*-CHI, and 25.92% as seen from *Physics Abstracts*. Obviously, this is a reflection of SCI's bias in favour of the journal literature produced in the US.

There are others, such as Spagnolo[23], who believe that the choice of ISI databases is not too bad after all. Garfield[11] claims that 'the journals ISI covers represent the major channels of international scientific communication'. In the view of Frame[24], if one is concerned not with everything that is published but only with the 'significant' part of the literature then ISI databases provide a reasonably good basis. This view is supported by Carpenter and Narin[25].

Beginning with the end of the Cultural Revolution, there has been a tremendous increase in China's scientific activity (see, for instance, ref 26). About six years ago, Frame and Narin[27] attempted a study on the growth of science in China, based on 1973 and 1981

SCI-CHI constant-journal sets publication data, and concluded that the rapid growth had already started flattening around 1984. Our results, however, indicate that the growth is still continuing. In some ways, this paper is an extension of the pioneering paper of Frame and Narin.

Methodology

We have collected two sets of data. The first includes all the papers originating from China and covered in (a) Physical, Chemical and Earth Sciences (PCES), (b) Life Sciences (LS) and (c) Engineering, Technology and Applied Sciences (ETAS) editions of *CC* published during July–December 1988 (except for issue no. 29 of the LS edition and issue No. 47 of the ETAS edition due to non-availability). As done earlier[28], data were collected by scanning the Author Index and Address Directory in each issue of *CC* and locating all the papers with an author address in China; these data do not cover any citation impact measure.

In the second set we collected data on papers published from Chinese institutions and covered by the 2649 journals indexed in *SCI* every year during the five-year period 1981–85. This set of data was compiled from the extensive 'world flash' report published in *Scientometrics* 1989 by Schubert *et al.*[29]. We used this five-year *SCI*-based data set to identify the more than 100 journals in which Chinese scientists published at least 10 papers during the five-year period and to compare China's share of journal articles in different subfields with the shares of several other countries. The same data set was used also to study the citation impact of Chinese work in different subfields.

Results of analysis

The half-year data from CC

Table 1 and Figure 1 show China's share of the world's scientific literature from our analysis of papers covered in *CC*.

Table 2 and Figure 2 give the distribution of Chinese papers into different subdisciplines (as classified in *CC*) and over a large number of journals. Clearly, physics is China's forte and China is much more active in physics and chemistry than in life sciences, mathematics and earth sciences. This trend is also evident from the 5-year data[29] based on *SCI* 1981–85. It is evident from Figure 1 that Chinese scientists did not publish many papers in multidisciplinary journals like *Nature* and *Science*, which were covered by more than one edition of *CC* during that period. In a typically Bradfordian manner, more than one half of the journals wherein Chinese scientists published carried only one paper each from China in the half-year sample considered. Also, 13 of

Table 1. Chinese share of the world's literature in different areas of science and technology as seen from *Current Contents*. July–December 1988

	PCES	LS	ETAS
Total no. of papers (approx.)	75,550	104,200	32,200
Papers from China	1645	348	543
Share of China (%) (approx.)*	2.18	0.33	1.69

*As seen from *SCI* 1981–1985 data[29], 0.44% in all science fields (see Table 7)

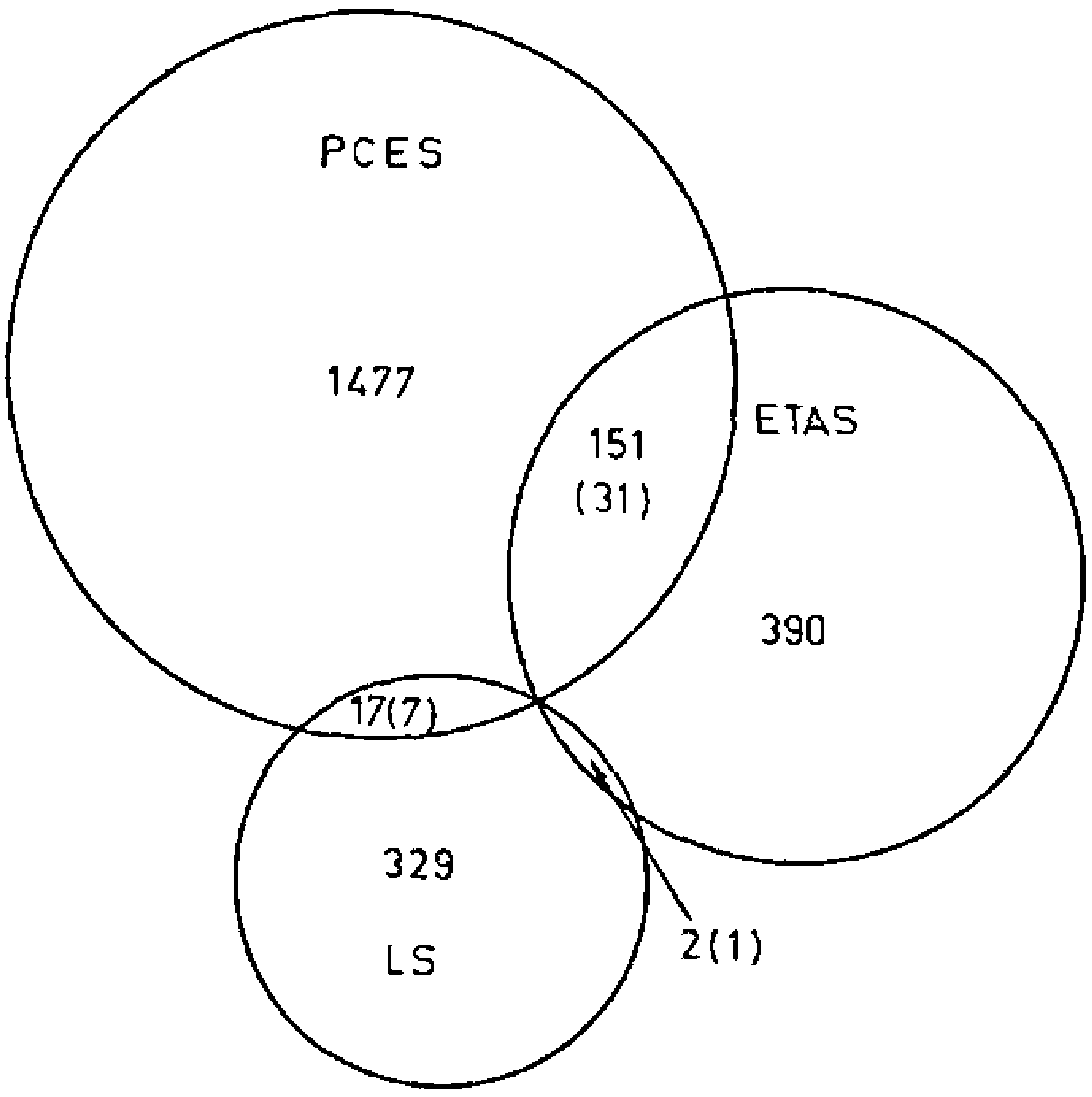

Figure 1. Numbers of papers of Chinese origin in three editions of *Current Contents* in the second half of 1988 (Numbers in parentheses denote the number of journals common to two editions.)

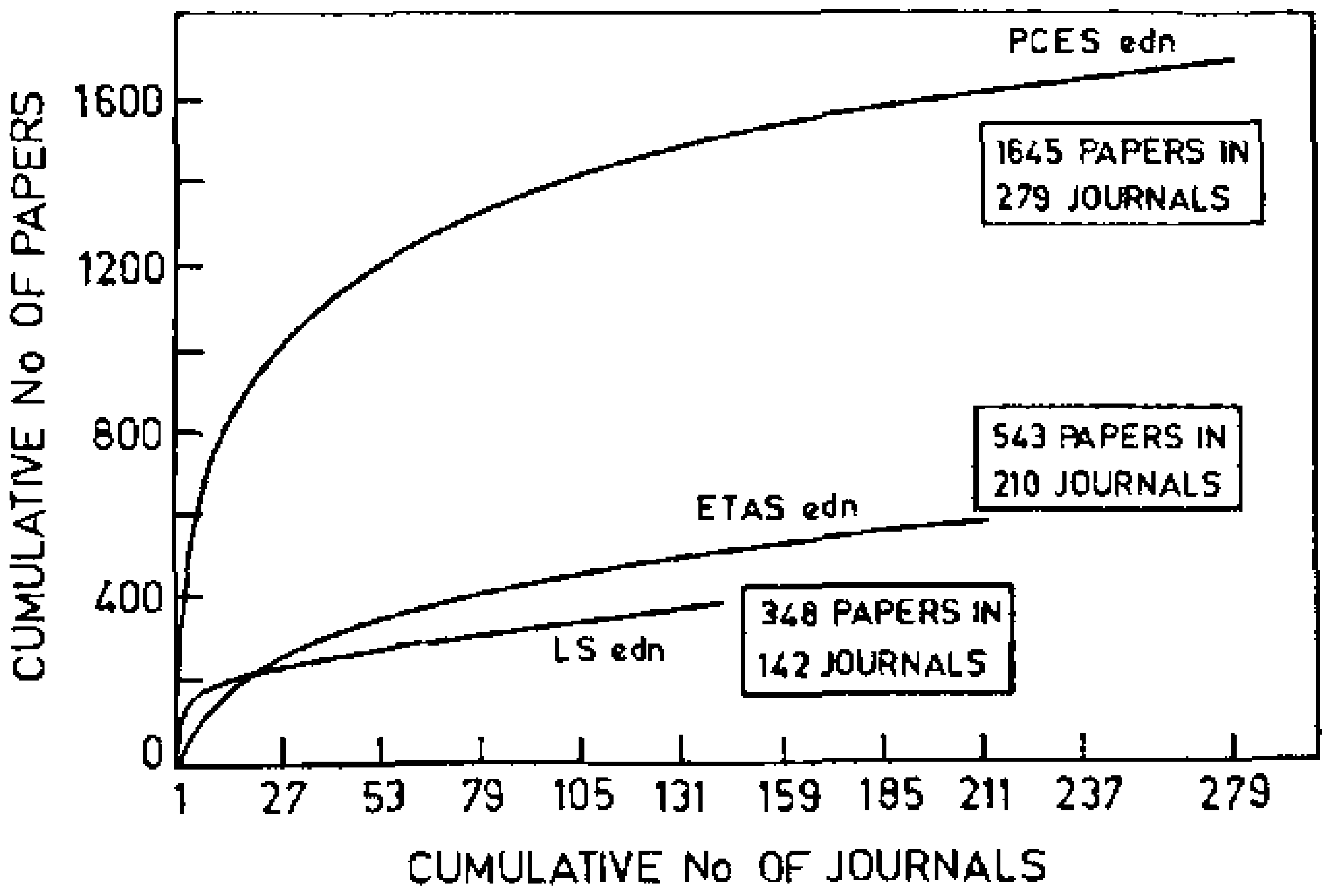

Figure 2. Plots of cumulative numbers of papers vs number of journals as seen from three editions of *Current Contents* in the later half of 1988

Table 2. Distribution of journal of Chinese researchers in different areas of science and technology as seen from three editions of *Current Contents*, July–December 1988

Subject	No of papers
Mathematical, physical, chemical & earth sciences	
Multidisciplinary	255
Physics	384
Applied physics/condensed matter	446
Physical chemistry/chemical physics	78
Analytical, inorganic and nuclear chemistry	112
Chemistry	153
Organic chemistry/polymer science	76
Earth sciences	20
Space sciences	18
Mathematics	103
Total	1645
Life sciences	
Multidisciplinary	66
Chemistry	32
Biochemistry	40
Molecular biology and genetics	5
Microbiology and cell biology	12
Pharmacology	84
Immunology	6
Physiology	1
Experimental biology and medicine	37
Clinical medicine	34
Neurosciences and behaviour	14
Animal and plant science	17
Total	348
Engineering, technology & applied sciences	
General/management	28
Aerospace	14
Chemical	20
Communication/information/EDP	36
Electrical and electronic	37
Environment/civil	30
Geology/petrology/mining	7
Instrumentation/control	48
Materials	92
Mechanics	79
Metallurgy	41
Nuclear	27
Optics and acoustics	84
Total	543

Table 3. Distribution of papers by institutions in three different editions of *Current Contents* (1988)

Institution	No of papers		
	PCES	LS	ETAS
Beijing Normal University, Beijing	25	3	1
Beijing University, Beijing	94	7	16
Chinese Centre for Advancement of Science & Technology, Beijing	30	0	0
Chinese Academy of Medical Sciences, Beijing	4	38	0
Chinese Academy of Sciences, Beijing	505	91	82
Fudan University, Shanghai	83	11	9
Hangzhou University, Hangzhou	16	3	3
Huazhong (Central China) University of Science & Technology, Wuhan	9	0	6
Hunan University, Changsha	11	0	4
Jilin University, Changchung	22	1	4
Lanzhou University, Lanzhou	30	5	5
Nanjing University, Nanjing	77	2	8
Nankai University, Tianjing	42	6	9
Shandong University, Jinan	22	2	2
Shanghai Jiao Tong University, Shanghai	16	0	11
Sichuan Normal University, Chengdu	10	0	2
Tianjin University, Tianjin	7	0	8
Tongji University, Shanghai	8	0	9
Tsinghua University, Beijing	25	0	24
University of Science and Technology of China, Hefei	74	4	11
Wuhan University, Wuhan	23	1	3
Xian Jiaotong University, Xian	2	0	13
Zhejiang University, Hangzhou	15	1	14
Zhongshan (Sun Yat-Sen) University, Guangzhou	15	1	2
Others	480	172	297
Total	1645	348	543

the 279 journals in the PCES edition in which Chinese scientists published carried more than half of their 1645 papers, and seven of the 142 LS edition journals accounted for half of the 348 Chinese papers. More than half of the 543 Chinese articles covered by *CC* (ETAS edition) appeared in 36 journals, whereas the entire number appeared in 210 journals.

The contributions made by different Chinese institutions (Table 3) show that the Chinese Academy of Sciences contributed more than one fourth of the total publications. Considering the vastness of China, one is indeed surprised to see that most of China's scientific publication activity is restricted to as few as 24 institutions. Such centralization is in stark contrast to the wide distribution of scientific research and publication activity in India, the United States, the UK, etc.

In Table 4, we list the journals most often used by Chinese researchers for publishing their work, along with the country of their origin and their impact factor and immediacy index as seen from *Journal Citation Reports* 1987. It can be seen that a very small number (12%) of Chinese papers are published in journals whose impact factor is greater than 2.00. For instance, of the 1248 (out of a total of 1645 papers in the PCES edition in our sample) papers which appeared in journals to which China had contributed at least five papers in the six-month period, only 208 appeared in journals with an impact factor greater than 2.0.

Table 4 shows that a number of articles have been contributed also to letters journals. In some ways, this trend of seeking quick publication through the columns of letter journals may be taken to be an indication of the extent to which Chinese researchers are working in or close to the actively advancing research fronts, at least in physics. However, one cannot make definitive claims in the absence of a content analysis of the actual papers.

Table 4 Journals used by Chinese scientists for publication as seen from *CC*, July–Dec 1988

Title*	No of papers	Impact factor (1987 *JCR*)	Immediacy index (1987 *JCR*)
Mathematical, physical, chemical & earth sciences (PCES)			
Acta Chim Sin (CHN)	120	0.150	0.024
Anal Chim Acta (NLD)	19	1.332	0.140
The Analyst (GB)	8	1.293	0.186
Appl Opt (USA)	9	1.279	0.273
Appl. Phys Lett (USA)	18	3.180	0.768
Appl Surf Sci (NLD)	6	1.094	0.215
Chem Phys Lett (NLD)	12	2.387	0.498
Chin Ann Math B (CHN)	23	0.063	0.022
Chin Phys (CHN)	78	0.092	0.007
Commun Theor Phys (CHN)	53	0.308	0.056
Inorg Chim Acta (SWL)	5	2.439	0.360
J Am Ceram Soc (USA)	5	1.246	0.225
J Appl. Phys (USA)	42	1.726	0.312
J Chem Phys (USA)	9	3.355	0.758
J Chem Soc Chem Commun (GB)	8	2.330	0.457
J Chromatogr (NLD)	5	1.158	0.624
J Mag & Mag Mater (NLD)	7	1.410	0.635
J Mater Sci (GB)	5	0.813	0.169
J Mater Sci Lett (GB)	6	0.491	0.102
J Math Anal Appl (USA)	5	0.346	0.107
J Math Phys (USA)	7	0.942	0.242
J Non-Cryst Solids (NLD)	7	1.411	0.283
J Organomet Chem (SWL)	5	1.488	0.319
J Phys A (GB)	12	2.882	0.580
J Phys C (GB)	21	2.184	0.476
J Phys. D (GB)	7	0.987	0.218
J Phys (Paris) (FRA)	12	1.009	0.263
J Radioanal Nucl Chem (SWL)	5	0.149	0.014
J Vac Sci Technol A (USA)	6	2.126	0.321
Kexue Tongbao (CHN)	280	—	—
Mater Lett (NLD)	8	0.667	0.146
Mater Sci Eng (SWL)	19	1.262	0.244
Mater Sci Eng A (SWL)	5	—	—
Mikrochim Acta (AUT)	15	0.382	0.214
Mod Phys Lett A (SGP)	5	—	—
Nucl Instrum Methods Phys Res A (NLD)	10	0.593	0.193
Nucl Instrum Methods Phys Res B (NLD)	11	1.510	0.527
Nucl Phys A (NLD)	6	2.272	0.751
Opt Commun (NLD)	14	1.252	0.283
Opt Lett (USA)	7	2.634	0.583
Optik (FRG)	8	0.484	0.126
Phosphorus Sulfur Related Elem (GB)	5	0.709	0.088
Phys Lett A (NLD)	32	1.150	0.331
Phys Lett B (NLD)	7	3.755	0.756
Phys Rev A (USA)	16	2.639	0.537
Phys Rev B (USA)	48	2.965	1.083
Phys. Rev C (USA)	7	2.146	0.456
Phys Rev D (USA)	9	2.423	0.689
Phys Status Solidi B (DDR)	10	0.693	0.172
Physica C (NLD)	19	—	—
Polym Bull. (USA)	29	0.837	0.133
Precambrian Res (NLD)	5	0.902	0.471
Proc Am Math Soc (USA)	9	0.271	0.041
Pure Appl Chem (GB)	11	1.699	0.264
Sci Sin A (CHN)	56	0.180	0.026
Scripta Metall (USA)	12	1.008	0.120
Solid State Commun (USA)	30	1.684	0.552
Synth Commun (USA)	7	0.612	0.096
Tetrahedron Lett (USA)	6	2.018	0.371
Z Phys B (FRG)	8	3.579	0.688
219 Other foreign journals	406	—	—
Total	1645		

contd

Table 4 contd.

Life sciences (LS)			
Acta Pharmcol Sin (CHN)	71	0.103	0.000
The Analyst (GB)	8	1.293	0.186
Hemoglobin (USA)	13	0.811	0.000
Phytochemistry (USA)	8	1.178	0.197
Planta Med (FRG)	5	0.968	0.157
Plast Reconstruct Surg (USA)	6	1.103	0.193
Sci Sin B (CHN)	62	0.203	0.036
Tetrahedron Lett (USA)	7	2.018	0.371
134 Other foreign journals	168	—	—
Total	348		
Engineering, technology & applied sciences			
Appl Math Modelling (GB)	5	0.325	0.035
Appl Surf Sci (NLD)	6	1.094	0.215
Appl Opt (USA)	9	1.279	0.273
Commun Appl Numer Methods (GB)	5	—	—
Comput Graph (USA)	9	0.860	0.019
Electron Lett (GB)	10	1.398	0.314
Eng Fract Mech (USA)	18	0.554	0.103
Fuzzy Set Syst (NLD)	11	0.631	0.194
IEE Proc H (GB)	5	0.497	0.184
IEEE Trans Autom Control (USA)	5	1.233	0.186
Int J Control (GB)	10	0.985	0.229
Int J Infr Millim Waves (USA)	11	0.585	0.082
J Am Ceram Soc (USA)	5	1.246	0.225
J Mater Sci (GB)	5	0.813	0.169
J Mater Sci Lett (GB)	6	0.491	0.102
J Vac Sci Technol A (USA)	6	2.126	0.321
Mater Sci Eng (SWL)	22	1.262	0.244
Mater Sci Eng A (SWL)	5	—	—
Microwave Opt Technol Lett (USA)	14	—	—
Nucl Instrum Methods Phys Res A (NLD)	10	0.593	0.193
Nucl Instrum Methods Phys Res B (NLD)	10	1.510	0.527
Opt Commun (NLD)	14	1.252	0.283
Opt Lett (USA)	9	2.634	0.583
Optik (FRG)	9	0.484	0.126
Scripta Metall (USA)	14	1.008	0.120
Text Res J (USA)	5	0.260	0.184
184 Other foreign journals	305	—	—
Total	543		

*Only journals publishing at least five papers from China in the half-year period considered are listed

AUT	Austria
CHN	China
DDR	(Former) German Democratic Republic
FRA	France
GB	Great Britain
NLD	The Netherlands
SGP	Singapore
SWL	Switzerland

An analysis of Tables 2 and 4 reveals that research in life sciences in China is not as voluminous as in physical and chemical sciences, and that within life sciences, much of the action is in pharmacology, biochemistry and medicine. It also shows that China is active in materials sciences (including metallurgy), optics and mechanics.

Table 5 shows that of the 2366 papers published by Chinese scientists in 592 journals in the second half of 1988 (as seen from three editions of *CC*), the maximum number (756) was published in American journals. Slightly less number (744, 31%) appeared in their home-country journals. In contrast, as shown by studies based on *ISI* databases, Israel uses non-Israeli journals to a much larger extent[28], while India and Japan follow the same pattern as China[9].

As the coverage of Chinese scientific publications in *ISI* databases is rather poor, ISTIC has counted the domestic published output by scanning some 1230 Chinese S&T journals. In 1990, there were 88,728 papers[17], in which medicine accounted for 15,677, agriculture 10,762, machinery and instrumentation 6908 and

Table 5. Breakdown of journal articles from China by country of publication

Journal country	No of journals	No of papers	Percentage of total number of papers
United States (USA)	265	756	32.00
China (CHN)[a]	9	744	31.45
United Kingdom (GB)	119	331	14.00
The Netherlands (NLD)	57	274	11.58
Switzerland (SWL)	27	86	3.63
Federal Republic of Germany (FRG)	19	53	2.24
Austria (AUT)	7	21	0.89
Japan (JPN)	15	21	0.89
(Former) German Democratic Republic (DDR)	4	17	0.72
France (FRA)	6	9	0.38
Italy (ITA)	6	9	0.38
Sweden (SWE)	6	9	0.38
Denmark (DNK)	4	8	0.34
Canada (CAN)	3	7	0.30
Others	45	21	0.89
Total	592	2366	100%

[a] According to a press release from ISTIC (February 1992), Chinese scientists had published 88,728 papers in 1990 in 1230 Chinese journals. Unfortunately, many of them were not captured by international abstracting and indexing services.

Table 6. Distribution of papers in different areas of science and technology according to the impact factor of the journals in which they appeared

Impact factor	PCES	LS	ETAS
≤ 1.0	995	209	390
> 1.0 ≤ 2.0	389	82	132
> 2.0 ≤ 3.0	201	32	20
> 3.0 ≤ 4.0	52	15	1
> 4.0 ≤ 5.0	1	6	0
> 5.0 ≤ 6.0	0	1	0
> 6.0 ≤ 7.0	5	0	0
> 7.0 ≤ 8.0	1	2	0
> 9.0 ≤ 10.0	1	0	0
> 13.0 ≤ 14.0	0	1	0
Total	1645	348	543

chemistry 5039. Surprisingly, physics did not appear in the list of the top six fields accounting for a large number of domestic journal papers[17].

Table 6 provides data on the distribution of papers according to the impact factor of the journals in which they were published. It can be seen that only a few (16% in PCES and LS editions and less than 4% in ETAS edition) papers appeared in journals with impact factor greater than 2.0, the number appearing in journals with impact factor greater than 3.0 being less than 4% in PCES and 7.2% in LS. At the other extreme, about 60–72% of the papers appeared in journals with impact factors less than 1.0.

An analysis of the 2536 papers (seen from three editions of *CC*) shows that 26.7% of them were written by two authors, 23.6% by single authors, 21.6% by three authors and 15.2% by four authors.

The five-year data from SCI

Table 7 presents the percentage share and the rank of China in different areas of science and the measure of international impact of China's published work as seen from five years (1981–85) of *Science Citation Index*. Only the constant-journal set of 2649 journals are considered and only those subfields are included in which China had published at least 50 journal articles in the 5-year period. The subfields are assigned not on an article-by-article basis. Instead, whole journals are assigned to a subfield. For a detailed description of the assignment, see the 'World Flash on Basic Science'[29]. To see China's standing in the world, corresponding data are provided for several other countries.

As was seen from our half-year *Current Contents* data, China is more active in physics than in other areas. In the five years 1981–85 China accounted for 0.80% of the world journal literature of physics, holding the 17th rank. China also occupied the 21st rank in engineering (with 0.50% of world share), 22nd position in mathematics (0.63%) and 22nd position in chemistry (0.54%)*. However, in life sciences China was down to the 33rd rank, accounting for only 0.18% of the world's journal literature. Also, unlike India, China did not publish more than 50 papers in the five-year period in several subfields under all major fields, e.g. operations research and statistics & probability under mathematics; acoustics, mathematical physics, microscopy, mineralogy, oceanography, fluids and particles and fields under physical sciences, and applied chemistry, electrochemistry and inorganic and nuclear chemistry under chemistry.

A comparison of data in Tables 1 and 7 reveals that there was a tremendous increase in scientific activity in China between 1981–85 and late 1988. From Table 7, we find that China's share in mathematics, physical sciences and chemistry (the three groups put together form the PCES data in *CC* data set in Table 1) accounts for about 0.69% of the world's literature in the five years 1981–85. In late 1988, this figure had risen to 2.18% – more than three times the earlier value. The percentage share of Chinese authors in engineering journal papers has also risen to more than three times the earlier value. However, growth in life sciences is slow, viz. less than a factor of two. These results are substantiated by those reported earlier[30–35].

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*However, as early as 1983, *CA* covered more than 8000 documents from China and that made China the 10th in the order of number of documents abstracted in *CA*. This discrepancy between *CA* (and other comprehensive abstracting services) based ranks and SCI-based ranks is a constant irritant in bibliometric studies.

Table 7. Percentage share (and rank) of China compared with those of several other countries, and citation impact of Chinese papers as seen from *SCI* 1981–85 (data from *Scientometrics* June 1989)

Subject	No of journals	No of papers		Percentage share of journal articles and (rank)											Citations won		Citation rate			
		World	China	CHN	IND	USA	SU	JAP	GB	FRG	FRA	CAN	AUS	ISR	No	World share (%)	China Exp	China Obs	China Rel	World Obs
All science fields	2649	1,918,188	8347	0.44 (27)	2.64 (8)	36.81 (1)	7.27 (3)	6.99 (4)	8.96 (2)	5.87 (5)	4.67 (6)	4.17 (7)	2.23 (10)	1.06 (14)	4716	0.08	1.24	0.56	0.45	3.11
Mathematics[a]	—	49,264	309	0.63 (22)	3.22 (7)	41.24 (1)	1.98 (9)	5.07 (6)	7.10 (2)	6.54 (3)	6.37 (4)	5.23 (5)	2.01 (8)	1.83 (11)	163	0.37	0.81	0.53	0.65	0.88
Applied mathematics	33	9327	76	0.81 (19)	1.73 (11)	45.37 (1)	0.62 (23)	2.71 (6)	8.00 (2)	5.52 (4)	4.74 (5)	6.04 (3)	2.00 (10)	2.33 (8)	33	0.35	1.01	0.43	0.43	1.01
Physical sciences[a]	—	370,612	2982	0.80 (17)	3.25 (8)	34.88 (1)	11.53 (2)	7.07 (3)	6.83 (4)	6.33 (5)	5.31 (6)	3.88 (7)	1.85 (10)	1.07 (14)	1568	0.12	1.43	0.53	0.37	3.44
Applied physics	28	44,772	226	0.50 (18)	2.10 (8)	34.52 (1)	13.98 (3)	16.80 (2)	5.96 (4)	4.51 (6)	5.06 (5)	2.38 (7)	1.09 (11)	1.04 (12)	155	0.12	2.82	0.69	0.24	2.92
Astronomy & astrophysics	25	22,800	59	0.26 (29)	3.80 (8)	38.54 (1)	8.11 (4)	2.75 (9)	9.03 (2)	8.95 (3)	4.69 (5)	3.96 (6)	1.94 (11)	0.46 (22)	53	0.05	2.79	0.90	0.32	4.53
Atomic, molecular & chemical physics	13	32,489	51	0.16 (32)	2.52 (9)	37.00 (1)	2.58 (8)	5.70 (5)	9.14 (2)	8.58 (3)	5.84 (4)	5.02 (6)	1.83 (12)	1.94 (11)	47	0.03	3.77	0.92	0.24	4.54
Crystallography	12	13,228	55	0.42 (25)	5.41 (7)	16.43 (1)	12.71 (2)	8.13 (4)	7.82 (6)	7.85 (5)	9.17 (3)	2.58 (11)	1.75 (13)	0.97 (19)	55	0.21	2.63	1.00	0.38	2.02
Geology	32	10,507	448	4.26 (6)	4.49 (5)	44.80 (1)	— (—)	1.81 (10)	9.16 (2)	2.43 (9)	3.02 (8)	6.79 (3)	5.77 (4)	0.79 (18)	73	0.30	0.37	0.16	0.44	2.30
Geosciences	58	26,912	361	1.34 (10)	2.43 (9)	42.42 (1)	12.33 (2)	3.20 (8)	7.75 (4)	3.29 (7)	3.30 (6)	7.87 (3)	3.32 (5)	0.92 (14)	92	0.11	0.79	0.25	0.32	3.11
Instruments & instrumentation	14	18,017	91	0.51 (20)	2.01 (9)	38.77 (1)	10.09 (2)	6.99 (4)	7.12 (3)	6.11 (5)	3.32 (7)	5.68 (6)	1.58 (11)	1.07 (15)	87	0.34	1.46	0.96	0.66	1.42
Mechanics	26	10,535	96	0.91 (15)	4.68 (7)	37.19 (1)	9.47 (3)	5.31 (4)	10.61 (2)	4.77 (5)	4.71 (6)	4.17 (8)	2.66 (9)	1.58 (11)	66	0.46	1.07	0.69	0.64	1.35
Meteorology & atmospheric sciences	23	15,519	53	0.34 (22)	3.26 (5)	59.83 (1)	6.26 (2)	2.00 (9)	5.43 (3)	3.66 (4)	2.19 (8)	3.24 (6)	2.81 (7)	0.68 (13)	84	0.15	2.63	1.58	0.60	3.61
Nuclear physics	7	17,443	84	0.48 (25)	2.35 (10)	26.31 (1)	13.05 (3)	5.34 (5)	5.07 (6)	14.15 (2)	5.65 (4)	3.57 (7)	1.67 (13)	1.09 (17)	120	0.22	3.34	1.43	0.43	3.07
Optics	13	10,538	115	1.09 (16)	2.50 (9)	36.66 (1)	3.00 (8)	7.73 (4)	8.08 (3)	8.36 (2)	7.12 (5)	3.28 (6)	2.30 (10)	1.72 (12)	62	0.27	1.82	0.54	0.30	2.18
Paleontology	8	1910	196	10.26 (2)	— (—)	49.42 (1)	— (—)	— (—)	6.91 (3)	— (—)	3.25 (6)	4.92 (5)	6.75 (4)	— (—)	36	1.06	0.25	0.18	0.73	1.78
Condensed matter physics	19	39,927	156	0.39 (26)	4.31 (7)	21.98 (2)	22.60 (1)	5.47 (5)	5.26 (6)	8.61 (3)	5.89 (4)	2.32 (10)	0.61 (20)	1.11 (15)	142	0.11	3.05	0.91	0.30	3.24
Spectroscopy	20	17,810	68	0.38 (27)	2.34 (8)	48.33 (1)	1.51 (10)	4.45 (5)	7.77 (2)	5.79 (4)	6.57 (3)	4.33 (6)	1.17 (12)	0.61 (17)	13	0.04	1.23	0.19	0.15	1.71
Chemistry[a]	—	255,140	139	0.54 (22)	5.18 (6)	22.36 (1)	14.77 (2)	11.37 (3)	6.43 (5)	7.26 (4)	— (—)	3.19 (8)	1.57 (13)	0.67 (21)	703	0.11	1.12	0.51	0.45	2.59

Analytical	31	35,731	178	0.50 (26)	4.32 (8)	26.01 (1)	5.54 (5)	10.42 (2)	5.74 (4)	6.16 (3)	— (—)	3.12 (10)	1.82 (14)	0.59 (24)	159	0.17	2.35	0.89	0.38	2.67
Organic	28	50,734	106	0.21 (31)	5.80 (7)	21.04 (1)	14.37 (2)	12.17 (3)	7.86 (5)	8.23 (4)	— (—)	2.29 (10)	1.09 (12)	0.69 (17)	137	0.10	2.83	1.29	0.46	2.59
Physical	46	42,941	177	0.41 (25)	2.28 (10)	25.61 (1)	17.02 (2)	7.38 (4)	7.03 (5)	7.42 (3)	— (—)	3.12 (7)	1.35 (15)	1.01 (16)	104	0.09	2.29	0.59	0.26	2.84
Polymer science	25	21,804	79	0.36 (23)	5.78 (4)	22.94 (1)	15.90 (3)	17.27 (2)	5.60 (6)	5.75 (5)	— (—)	2.73 (8)	0.86 (14)	0.65 (18)	102	0.23	2.18	1.29	0.59	2.01
Life sciences	—	1,065,030	1927	0.18 (33)	1.58 (12)	40.76 (1)	3.04 (7)	5.89 (3)	10.62 (2)	5.49 (4)	4.35 (6)	4.58 (5)	2.66 (8)	1.18 (14)	1274	0.04	1.43	0.66	0.46	3.39
Biochemistry & molecular biology	97	115,804	87	0.08 (39)	1.65 (11)	39.73 (1)	4.07 (6)	10.56 (2)	7.42 (3)	5.69 (5)	5.84 (4)	3.80 (7)	1.60 (12)	1.19 (15)	157	0.02	4.03	1.80	0.45	6.22
Botany	77	39,420	55	0.14 (39)	4.86 (6)	31.99 (1)	3.33 (9)	4.89 (5)	10.08 (2)	7.16 (4)	4.03 (8)	7.68 (3)	4.59 (7)	1.72 (11)	39	0.04	2.43	0.71	0.29	2.35
General & internal medicine	60	97,865	735	0.75 (19)	1.68 (11)	31.68 (1)	3.95 (6)	0.85 (18)	22.52 (2)	5.92 (3)	5.20 (4)	3.10 (8)	4.02 (5)	1.42 (12)	280	0.11	0.38	0.38	1.00	2.56
Neurosciences	89	63,040	58	0.09 (35)	0.42 (23)	46.03 (1)	2.17 (9)	5.99 (3)	8.25 (2)	5.59 (5)	4.49 (6)	5.98 (4)	1.98 (10)	1.14 (14)	95	0.04	3.81	1.64	0.43	4.09
Pharmacology & pharmacy	107	80,849	69	0.09 (41)	1.16 (16)	32.22 (1)	4.29 (7)	13.14 (2)	8.98 (3)	5.75 (4)	4.76 (5)	4.07 (8)	1.81 (11)	0.61 (20)	99	0.04	2.92	1.43	0.49	2.99
Surgery	49	42,314	110	0.26 (21)	0.53 (18)	52.68 (1)	— (—)	3.43 (6)	10.82 (2)	5.09 (3)	3.85 (5)	5.01 (4)	1.43 (10)	1.33 (11)	102	0.11	1.59	0.93	0.58	2.25
Zoology	68	23,508	273	1.16 (15)	1.58 (9)	37.34 (1)	5.79 (4)	4.50 (6)	8.49 (3)	3.39 (8)	5.33 (5)	9.52 (2)	4.16 (7)	0.63 (21)	27	0.07	0.14	0.10	0.71	1.70
Engineering	—	197,424	988	0.50 (21)	3.18 (8)	39.28 (1)	6.52 (4)	9.29 (2)	7.40 (3)	6.32 (5)	3.27 (7)	4.42 (6)	1.76 (9)	1.04 (15)	599	0.21	1.42	0.61	0.43	1.44
Chemical	33	20,461	80	0.39 (22)	3.42 (7)	42.46 (1)	0.35 (25)	10.59 (2)	5.26 (4)	7.45 (3)	2.26 (9)	4.75 (5)	2.09 (10)	1.02 (13)	23	0.08	1.36	0.29	0.21	1.47
Computer applications & cybernetics	45	18,266	98	0.54 (21)	1.66 (10)	48.52 (1)	0.55 (20)	5.79 (3)	8.62 (2)	4.28 (5)	2.81 (6)	4.49 (4)	2.05 (9)	1.60 (11)	104	0.36	1.47	1.06	0.72	1.58
Electrical & electronics	54	40,204	260	0.65 (16)	3.17 (7)	44.72 (1)	5.81 (4)	11.43 (2)	7.70 (3)	3.97 (6)	2.82 (8)	4.50 (5)	1.29 (11)	0.78 (15)	166	0.24	1.68	0.64	0.38	1.75
Energy & fuels	19	7833	59	0.75 (16)	7.24 (3)	46.39 (1)	— (—)	4.72 (4)	8.25 (2)	2.85 (7)	2.63 (8)	4.71 (5)	4.35 (6)	1.31 (10)	34	0.36	1.35	0.58	0.43	1.19
Materials science	25	16,867	76	0.45 (23)	5.86 (6)	26.37 (1)	13.14 (2)	8.95 (4)	9.52 (3)	4.87 (7)	6.65 (5)	1.99 (11)	2.42 (10)	1.19 (13)	45	0.19	1.69	0.59	0.35	1.43
Mechanical	17	7822	66	0.84 (12)	2.20 (7)	37.69 (1)	6.64 (4)	25.02 (2)	6.66 (3)	1.99 (8)	1.10 (10)	3.41 (6)	1.42 (9)	0.84 (11)	13	0.23	0.56	0.20	0.35	0.71
Metallurgy & mining	35	22,539	123	0.55 (17)	2.05 (8)	21.91 (2)	27.75 (1)	11.93 (3)	4.78 (5)	10.69 (4)	4.29 (6)	2.81 (7)	1.37 (9)	0.54 (18)	106	0.34	1.86	0.86	0.46	1.39
Nuclear science & technology	28	25,638	141	0.55 (24)	3.33 (6)	35.19 (1)	2.80 (9)	10.47 (2)	6.33 (4)	10.31 (3)	3.50 (5)	2.96 (8)	1.01 (18)	0.91 (19)	79	0.21	1.57	0.56	0.36	1.45

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[a] China accounted for less than 50 papers in the following subfields operations research and management science, statistics & probability accoustics, mathematical physics microscopy, mineralogy, oceanography physics of fluids & plasmas physics of particles & fields, applied chemistry, electrochemistry and inorganic & nuclear chemistry Hence, these are not included in this table

SU Former Soviet Union

Exp Expected, Obs Observed, Rel Relative

The dramatic increase in China's share of the world's literature of science has been attributed by Jacques Gaillard[36] to three interdependent phenomena: increased contact with western science (after the end of the Cultural Revolution), a sharp rise in the number of scientific journals published in China, and ISI's stated decision to correct the under- or non-representation of China in ISI databases such as *CC* and *SCI*.

According to Chemical Abstracts Service[26], who have developed a system for identification and acquisition of Chinese publications, the dramatic increase in the number of Chinese documents abstracted in *CA* reflects

(i) the damage done to education and science by the Cultural Revolution, when most of the universities and research institutions were closed and China lost a whole generation of scientists, engineers and educators;
(ii) the gradual resumption of research activities in the late 1970s;
(iii) the opening of communication by China to the outside world;
(iv) the recent shift of emphasis by the Chinese leadership from 'ideological purity' towards communism to technical advance.

The importance of the decision of database producers in the West to correct the under- or non-representation of China cannot be underestimated, says Gretchen Whitney (personal communication). Whitney's own data 'dramatically supports the interpretation of increased coverage by the secondary services, rather than increased production, that accounts for the trends found. Political events, such as the opening of Chinese relations under (US President) Nixon not only provided increased access to the country but to her literatures as well. Admittedly, her increasing capabilities for STI (scientific and technical information) and rising role internationally also sparked increased interest in China's work. It is a combination of access and interest.'

While China's rank (based on *SCI* coverage in 1981–85) varies between 17th in physical sciences and 33rd in life sciences, India holds 6th to 8th ranks in most areas and 12th in life sciences. Among the subfields in which China is having a relatively high share of the world's significant journal literature are palaeontology (with 10.26%, China is second only to the United States!), geology (6th rank), geosciences (10th rank) and mechanical engineering (12th rank).

The undoubted supremacy of USA in every major field comes out clearly from Table 7, although her relative superiority in chemistry is not as pronounced as in other areas. Except in physics of condensed matter and metallurgy and mining, where the former Soviet Union was the world leader with 22.60% and 27.75% respectively of the journal literature, in every other subfield listed in Table 7 USA held the first rank.

It can further be seen from Table 7 that China's work is rather poorly cited, the average for that period being 0.56 citations per paper compared to the world average of 3.11.

Table 8 lists the more than 100 *SCI*-covered journals in which Chinese researchers had published at least 10 papers in the five-year period. Only seven of these 105 journals are home-country journals, but they accounted for 2914 papers out of a total of 4859 published in the 105 often-used journals. Apart from Chinese journals, Chinese scientists often use journals published from USA (802 papers in 41 journals in our 5-year *SCI*-based sample), the Netherlands (572 papers in 25 journals), UK (272 papers in 16 journals), FRG (114 articles in six journals), and France (65 papers in two journals).

Of the more than 4850 papers analysed in Table 8 nineteen were published in *Lancet*, which had a 1984 impact factor of greater than 9.0. More than 80 papers were published in journals having a 1984 impact factor of greater than 3.0: *Physics Letters* B (49) *Physical Review* B (15), *Analytical Chemistry* (10) and *Surface Science* (10).

Concluding remarks

Science in China is growing rapidly. Contrary to Frame and Narin's surmise that the rapid growth began to flatten around 1983–84 (ref. 27), clear evidence exists that the growth is continuing. The numbers of papers of Chinese origin that are included in ISI databases such as *CC* and *SCI* and comprehensive secondary services such as *CA*, GeoRef, *Biological Abstracts* and Medline clearly show that China's output of research publications is increasing. This conclusion is reinforced by reports from Gretchen Whitney[34], Chemical Abstracts Service[26, 35] and Chinese analysts themselves[16–19].

Indeed, the growth in Chinese output of scientific publications since the end of the Cultural Revolution has been phenomenal and no other country has recorded such fast growth at any time since the turn of the century.

How does one explain this rapid growth? Is it largely because the western database producers woke up to developments in China in the late 1970s and started covering the Chinese literature which they had ignored earlier? Or has there been truly an increase in the production of research papers in China in recent years? We believe that much of the increase is genuine, i.e there has actually been an increase in scientific research in China since the late 1970s.

The growth is, however, not uniformly rapid across the fields. Unlike in most Third World countries, where much of the activity is in biology and biomedical research[37], in China the emphasis seems to be on physical sciences. In certain areas, e.g. lasers, chemistry, palaeontology and geology, China has overtaken India and accounts for a higher world share of papers. But in many other areas China is not active. Also, growth rate in biology is low.

Table 8. Journals publishing at least 10 papers from China during 1981–85 as seen from *SCI* (data from *Scientometrics*, June 1989)

Journal	No of articles from China	Impact factor (*JCR* 1984)	Total no of articles from 1981 to 1985 (World)
AAPG Bull (USA)	10	1.528	626
Acta Chim Sin (CHN)	799	0.091	811
Acta Geol Sin (CHN)	113	0.096	113
Acta Geophys Sin (CHN)	240	0.031	245
Acta Zool Sin (CHN)	264	0.025	265
Am J Pub Health (USA)	23	1.889	1153
Anal Chem (USA)	10	3.020	3689
Anal Chim Acta (NLD)	12	1.229	2134
The Analyst (GB)	11	1.217	1266
Appl Opt (USA)	23	1.434	4010
Appl Phys (USA)*	13	1.717	1061
Astron Astrophys (FRG)	15	1.930	3785
Astrophys Space Sci (NLD)	26	0.696	1629
Biochim Biophys Acta (NLD)	10	2.536	10446
Brain Res (NLD)	12	2.818	6569
Bull Mineral (FRA)	11	0.901	391
Chem Phys Lett (NLD)	17	2.185	5720
Chinese Med J (CHN)	702	0.085	724
Chinese Phys (CHN)	624	0.037	627
Clin Plast Surg (USA)	21	0.285	313
Comput Methods Appl Mech Eng (NLD)	15	0.670	511
Desalination (NLD)	26	0.182	582
Discrete Math (NLD)	12	0.285	785
Electron Lett (GB)	18	1.327	3623
Eng Fract Mech (USA)	55	0.609	680
Ferroelectrics (USA)	21	0.443	1169
Fuel (GB)	10	1.562	1417
Geol Magn (GB)	13	1.079	290
Hadronic J (USA)	10	1.056	316
Hemoglobin (USA)	21	0.846	295
Hydrobiologia (NLD)	34	0.579	1625
IEEE J Quantum Electron (USA)	15	2.645	1423
IEEE Trans Magn (USA)	41	0.779	3039
IEEE Trans Nucl Sci (USA)	23	0.642	3619
IEEE Trans Power Appar. Syst (USA)	24	0.390	2522
Int J Control (GB)	12	0.717	911
Int J Electron (GB)	21	0.375	830
Int J Fract (NLD)	21	0.567	475
Int J Infrared Millim Waves (USA)	12	0.815	429
Int J Numer Methods Eng (GB)	10	0.678	698
Int J Quantum Chem (USA)	24	1.019	1264
Int J Radiat Oncol Biol Phys (USA)	12	2.208	1496
J Chromatogr (NLD)	13	1.826	7403
J Cryst Growth (NLD)	12	1.282	2095
J Diff Equations (USA)	10	0.659	483
J. Energy Resour Technol – Trans ASME (USA)	13	0.046	345
J Geophys Res (USA)	10	2.393	5469
J Hydraul Eng – ASCE (USA)	10	0.791	520
J Less Common Met (SWL)	19	1.281	1561
J Liq Chromatogr (USA)	13	1.310	965
J Lumin (NLD)	21	0.541	802
J Mag Mag Mater (NLD)	27	0.998	2206
J. Mater Sci. (GB)	12	0.989	2306
J Math Anal. Appl (USA)	39	0.395	1378
J Math Phys (USA)	10	1.159	2167
J Mech Des-Trans ASME (USA)	10	0.174	666
J Non-Cryst Solids (NLD)	56	1.182	1777
J Organomet Chem (SWL)	40	1.917	4274
J Phys A (GB)	36	2.381	2408
J Phys C (GB)	17	2.293	3823
J Phys – Paris (FRA)	54	1.119	4016
J. Radioanal Nucl Chem (SWL)	14		1929

contd ...

(Table 8 contd.)

J Vac Sci Technol (USA)	20	2 469	2838
Lancet (GB)	19	9 444	11906
Macromol Chem Phys Macromol Chem (SWL)	25	–	2168
Mater Sci Eng (SWL)	10	0 765	904
Metall Trans A (USA)	19	1 153	1314
Mikrochim Acta (AUS)	11	0 425	531
Mol Cryst Liq Cryst (GB)	19	1 278	2208
Nonlinear Anal – Theor Methods Appl (USA)	20	0 443	529
Nucl Instrum Methods (NLD)	45	1 160	6266
Nucl Phys A (NLD)	24	2 522	3022
Opt Acta (GB)	10	0 667	666
Opt Commun (NLD)	18	1 474	1910
Optik (FRG)	13	0 625	437
Philos Mag A (GB)	10	1 610	796
Phys Fluids (USA)	10	1 527	2175
Phys Lett A (NLD)	33	1 217	4335
Phys Lett B (NLD)	49	4 470	6788
Phys Rev A (USA)	12	2 442	4673
Phys Rev B (USA)	15	3 126	10035
Phys Rev C (USA)	11	2 143	3275
Phys Rev D (USA)	11	2 598	4132
Phys Status Solidi A (DDR)	16	0 698	3757
Phys Status Solidi B (DDR)	15	0 770	3492
Physica B & C (NLD)	22	1 231	2611
Planta Med (FRG)	28	0 997	982
Plast Reconstruct Surg (USA)	11	1 151	1387
Precambrian Res (NLD)	27	1 032	304
Proc Am Math Soc (USA)	23	0 262	2108
Proc Soc Photo-Opt Instrum Eng (USA)	44	0 418	8143
Radiat Phys Chem (USA)	35	0 809	868
Scripta Metall (USA)	23	0 834	1502
Soil Sci (USA)	16	0 804	568
Solid State Commun (USA)	39	1 761	5044
Solid State Ionics (NLD)	11	0 789	1012
Surf Sci (NLD)	10	3 277	3589
Synthesis – Stuttgart (FRG)	23	1 358	1872
Talanta (GB)	44	1 080	1074
Tectonophysics (NLD)	19	1 334	1047
Tetrahedron Lett (USA)	20	1 993	7928
Theor Appl Genet (FRG)	20	1 602	894
Vacuum (GB)	10	0 687	568
Vertebbrata Palasiatica (CHN)	172	0 060	173
Z Phys B (FRG)	15	1 952	1057
Total	4859		236,137

*Impact factor of *Appl Phys A*

At this point, we would like to add a note of caution. While the results presented in this paper may reflect to a high degree of accuracy the publications of Chinese scientists in the world's significant non-Chinese journals, they do not at all reflect well those in Chinese journals, for the simple reason that very few Chinese journals were included in ISI databases in the 1980s. ISTIC is collecting and analysing data on papers published in Chinese journals since 1987 (refs. 16, 17) In 1990, for example, 88,728 papers were published in 1230 Chinese journals, with medicine and agricultural sciences topping the list with 15,677 and 10,762 papers respectively and physics not even finding a place in the top six fields[17]! This is in stark contrast to the distribution of China's publications in international journals, in which physics clearly dominates, followed by medicine. It is probable that China has different priorities for domestic and international consumption.

A study on the coverage of Chinese journals in international abstracting, indexing and current awareness services, similar to the study on the coverage of Indian Journals by Manorama and Bhutiani[18], will indeed be useful. There appears to be a vast difference between what is being published by Chinese scientists and what is actually being covered by the secondary services. Also of interest would be an assessment of the trends in the number of papers originating from China and then covered in different 'comprehensive' and 'international' secondary (abstracting and indexing) services such as *Biological Abstracts*, *Chemical Abstracts*, *Engineering Index*, *Excerpta Medica*, *Index Medicus*, *Mathematical Reviews*, and INSPEC databases.

Another striking feature is that China is rapidly coming out of its self-imposed isolation as reflected by the rapid increase in English language publications in

China (nearly a quarter of China's contribution to the literature of chemistry as seen from *CA* 1990 was in English[1]), and the increasing interest in international collaboration For instance, of the 88,728 papers published in 1990 in domestic journals, 998 (1.8%) were written by Chinese scientists in collaboration with foreign scientists[17]. A study by Arunachalam[40] has shown that in 1991 China had published more collaborative papers than India, with authors from every advanced country (G7, EC, OECD) except the United Kingdom, as seen from *SCI*, even though China published less than two-third the number of papers published by India. The West also perceives China as an important factor in policy formulation. In a testimony before the House Foreign Affairs Subcommittee, for instance, George Keyworth, scientific advisor to President Reagen, observed: 'It is in our fundamental interest to advance US relations with China – and co-operation in science and technology is essential to that relationship'[26]. Chinese scientists are also keen to keep track of developments elsewhere, even though their resources are limited. More than ten years ago, the US National Technical Information Service (NTIS) reported that China became 'one of the largest user nations in the world by ordering two microfiche copies of *everything* NTIS publishes'[26].

Frame and Narin[27], in their paper, posed the interesting question 'Who is publishing the papers in China – the older scientists who came back to their laboratories after the Cultural Revolution or the new recruits to science?' Unfortunately, the data we have collected provide no clues. However, according to ISTIC[17], 35.7% of the authors in a sample of 3988 papers published in 1990 are below 35 years, and more than 47% are between 35 and 55 years of age. The average age is 43 years. Thus, middle-aged researchers seem to be the mainstay of China's scientific enterprise.

Science in China has come a long way from the immediate post-1976 period, when the S&T scene was one of chaos, intellectual paralysis and professional lethargy[2], although Chinese leaders are somewhat concerned about the degree to which their efforts in science and technology are having an impact on their economy. Ever since Deng Xiaoping took command, pragmatism took precedence over ideology in matters relating to S&T policy, and since then several reforms have been introduced. As far as quantitative indicators are concerned, the results of the S&T reforms are promising, observes Conroy[2]: overall funding is increasing; there is greater economic and managerial autonomy at the grass-roots level and many more R&D projects are completed and awarded prizes. The economic impact of completed research is growing rapidly, links between research and production sectors are developing in breadth and depth and some personnel mobility is emerging. Although the trend towards more effective utilization of S&T resources for direct economic development is clear, this is not being achieved without many problems and the advances are uneven.

The most important problems seem to be the hostile climate of anti-intellectual leftism and the wage structure, under which scientists get paid very little for their work[2, 41]. For example, according to a 1985 survey of 5000 workers in Beijing, the average monthly income of an intellectual worker was 79 yuan as against 89 yuan for manual workers[42]. Then certain policies calculated to enhance the performance of S&T system have had unexpected negative consequences. For example, the policy to entice Chinese scientists and research students working abroad to return to China with special benefits has disenchanted the local scientists[41].

Notwithstanding such problems, the future of science in China looks bright. Even visiting scientists who spend a few weeks to a few months in Chinese laboratories and at best meet 10–100 scientists return to their home countries with a positive view of science in China. For instance, Baskaran[39] of Matscience, Madras, known for his contribution to resonance valence bond theory of high-temperature superconductors and quantum Hall effect, felt that Chinese students who attended a workshop on condensed matter physics he and five American scientists conducted at Beijing on an invitation from Prof. T. D. Lee were both better prepared and better motivated than most students he had met in India, and that they seemed to be working on interesting and significant problems. Such anecdotal evidence, if collected systematically, can give valuable clues to the status and direction of science in China.

In a recent article in an Indian newspaper, Swaminathan[43], the eminent agricultural scientist and champion of sustainable development, drew attention to the fact that China had not only achieved the world's highest rates of industrial and agricultural sector growth in recent years (economic growth rate of 12.8% during 1992, average annual GDP growth rate of 8.9%), but had also taken the lead in environmental issues and ecologically sustainable development. The ample data presented here show that China is also poised to catch up with the advanced countries in science. The seriousness with which the Chinese leaders and scientists approach this goal and the Chinese national ethos of speaking less and doing more[43], we guess, will enable China to reach its goal of attaining a place of prominence in the world of science sooner than later.

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