Current Comments®
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3501 MARKET ST., PHILADELPHIA, PA 19104

Is Japanese Science a Juggernaut?

Number 46 November 16, 1987

The recovery and expansion of the Japanese economy since the end of World War II is one of the most remarkable developments of the twentieth century. In the past decade, in fact, Japan has increasingly become a sort of yardstick against which the US and the industrialized nations of Europe measure their own growth and productivity. In manufacturing and quality assurance, for example, Western nations have not been measuring up to Japan's high standards.

While this realization brought concern and discomfort to political and business leaders in the US and in Europe, there was reassurance for them in the conventional wisdom that technology was largely indigenous to the West. The ability to produce high-quality knockoffs of Western goods—even ones that surpassed the originals—was impressive, but new technologies were more important and would allow the US and European nations to stay a step ahead. Now that assumption is in doubt. To mention only a current example, Japanese scientists have gained their share and more of the recent advances in basic research into superconductivity.[1]

Stephen Kreider Yoder, staff reporter for the *Wall Street Journal*, recently wrote: "Japan feels it has caught up in applied research—where researchers have a commercial product or process in mind—and desperately wants to take a lead in pure science. Dozens of companies, from electronics giants to steelmakers to food companies, are staking millions of dollars to set up basic-research labs. The government, too, has pitched in with showy programs to encourage basic research."[2] The proposed Human Frontiers Science Program—a Japanese-led international biological research program—is one such effort.

Last October, D.C. Smith, P.M.D. Collins, D.M. Hicks, and S. Wyatt, Royal Society/Fellowship of Engineering Science and Engineering Policy Studies Unit, London, UK, published an article entitled "National performance in basic research."[3] The authors drew their data from the US National Science Foundation's (NSF) *Scientific Literature Indicators Data Base*, which is based in part on ISI®'s *Science Citation Index®* (*SCI®*). According to the authors, Japan increased its production of published articles in science during the period 1973 to 1982 by 4.9 percent per year. This surpasses by far the figures given for France (−0.3 percent), the Federal Republic of Germany (FRG) (0.8 percent), the UK (−0.8 percent), and the US (0.5 percent).[3]

In terms of citations, Japan registered a similarly stunning performance: citations to Japanese papers over the period increased at a rate of 6.7 percent annually, while those to papers from France increased 1.3 percent; from the FRG, 2.0 percent; and from the US, 0.6 percent. Citations to UK papers actually declined 2.8 percent. Over this same 10-year period, Japan's share of world publications in science increased by 40 percent.[3] Its share of world citations increased 65 percent, according to the team of J. Irvine, B. Martin, T. Peacock, and R. Turner, Science Policy Research Unit, University of Sussex, UK. Their data, too, were drawn from the *SCI*-based NSF database.[4] Such measures of output and esteem would certainly suggest that Japan has the potential to become a juggernaut in basic research.

Table 1: Top 15 countries, ranked by the number of source items in the 1978 *SCI*®. Data represent 1978-1982 *SCI* citations to the 1978 *SCI* source items.

Country	1978 Items	Percent of 1978 Items	1978-1982 Citations	Percent of 1978-1982 Citations	Five-Year Impact	Cited Items	Percent Cited
US	171,231	44.1	975,632	52.6	5.7	95,541	55.8
UK	34,926	9.0	181,915	9.8	5.2	21,144	60.5
FRG	24,124	6.2	107,375	5.8	4.5	13,942	57.8
USSR	21,158	5.5	31,574	1.7	1.5	8,772	41.5
Japan	20,810	5.4	83,834	4.5	4.0	13,357	64.2
France	17,314	4.5	73,329	4.0	4.2	10,501	60.7
Canada	16,054	4.1	78,324	4.2	4.9	10,163	63.3
India	9,262	2.4	15,066	0.8	1.6	4,846	52.3
Australia	7,538	1.9	33,174	1.8	4.4	4,829	64.1
Italy	6,309	1.6	24,969	1.4	4.0	3,747	59.4
Switzerland	5,572	1.4	34,122	1.8	6.1	3,203	57.5
Sweden	5,464	1.4	38,161	2.1	7.0	3,812	69.8
The Netherlands	5,327	1.4	32,568	1.8	6.1	3,445	64.7
Israel	3,801	1.0	18,767	1.0	4.9	2,380	62.6
Poland	3,402	0.9	8,727	0.5	2.6	1,970	57.9
All Others	35,984	9.3	119,299	6.4	3.3	21,127	58.7
SCI Totals	388,276	100.0	1,856,836	100.0	4.8	222,699	57.4

Japan already excels in its system of support for strategic research, which Irvine and Martin define as "basic research carried out with the expectation that it will produce a broad base of knowledge likely to form the background to the solution of recognized current or future practical problems."[5] Among large industrialized nations Japan is superior at "picking winners" in science, these authors conclude, and this skill can only be expected to leverage the success of that country's future advances in basic or fundamental research.

Scope and Methodology

This essay provides a rough sketch of Japan's output of scientific articles in 1978 and the impact (in terms of citations) these 1978 articles had during the years 1978 to 1982. (Later, perhaps next year, I hope to publish a sequel to this study that will provide data on Japan's scientific output and impact since 1982.) In addition, I have reviewed below which countries cited Japanese articles and which countries were cited by Japanese researchers; the languages of the articles and citations to them; the growth of Japanese articles during the period 1973 to 1982 vis-à-vis other nations; as well as comparative data from other studies.

In this study, an article was identified as Japanese if the primary author listed a Japanese address. This method of identifying the nationality of articles is not foolproof but should serve for this type of study.[6]

Our data derive from the *SCI* and thus represent only articles and references cited in the journals selected by ISI for coverage in the *SCI*—in 1978 some 2,600. These journals are carefully chosen—using both quantitative and qualitative criteria—and, while they obviously do not cover the entire universe of scientific journals, they represent the most important portion.[7] Years ago we determined that a small group of core journals contains the most productive and most-cited papers published worldwide.[8] This pattern has not changed.

Thus, what is offered here is a review, at a highly aggregated level, of Japan's contributions to the most significant scientific journals in 1978 and the impact of these articles during the five years following.

Japan's Output and Impact, 1978-1982

Table 1 shows that Japanese articles indexed in the *SCI* in 1978 numbered about

Table 2: Selected country-by-country and field-by-field breakdowns for 1978-1980 *SCI*® source items. The three citation rates are observed (actual), expected (average for journals), and relative (correlation between observed and expected). Data are derived from the two following years of 1978-1982 *SCI* citations to each source year. (The table is based on articles by T. Braun in *Scientometrics*.[9-11])

Country	Field(s)	1978-1980 Items	Percent Share	Citation Rates Obs.	Exp.	Rel.
US	All	407,726	36.32	3.82	3.70	1.03
	Chemistry	32,302	20.70	4.32	4.15	0.93
	Life Sci.	250,941	40.34	4.06	4.02	1.01
	Physics	58,742	32.55	4.48	4.09	1.10
	Mathematics	11,895	41.06	0.86	0.81	1.06
UK	All	100,051	8.91	2.93	2.85	1.03
	Chemistry	10,909	6.99	3.31	3.19	1.04
	Life Sci.	63,487	10.20	3.03	2.87	1.05
	Physics	12,366	6.05	3.09	3.03	1.02
	Mathematics	2,092	7.22	0.82	0.83	1.00
USSR	All	87,999	7.84	0.62	0.69	0.89
	Chemistry	25,063	16.06	0.58	0.62	0.93
	Life Sci.	23,073	3.71	0.48	0.58	0.82
	Physics	22,805	12.64	1.00	1.10	0.90
	Mathematics	1,480	5.11	0.11	0.11	1.00
Japan	All	70,794	6.31	2.35	2.53	0.93
	Chemistry	16,084	10.31	2.47	2.53	0.97
	Life Sci.	31,557	5.07	2.55	2.83	0.90
	Physics	13,542	7.50	2.52	2.80	0.90
	Mathematics	1,229	4.24	0.56	0.64	0.88
FRG	All	69,542	6.19	2.60	2.41	1.08
	Chemistry	10,283	6.59	3.09	3.04	1.02
	Life Sci.	37,571	6.04	2.50	2.25	1.11
	Physics	11,863	6.57	3.67	3.42	1.07
	Mathematics	2,450	8.46	0.63	0.64	0.98
France	All	58,015	5.17	2.32	2.37	0.98
	Chemistry	8,645	5.54	2.59	2.74	0.94
	Life Sci.	32,417	5.21	2.18	2.22	0.98
	Physics	10,779	5.97	2.97	3.07	0.97
	Mathematics	1,641	5.66	0.71	0.67	1.06
India	All	35,322	3,15	0.80	1.30	0.62
	Chemistry	8,792	5.63	0.98	1.30	0.76
	Life Sci.	13,414	2.16	0.73	1.21	0.60
	Physics	6,592	3.65	0.99	2.00	0.50
	Mathematics	860	2.97	0.28	0.39	0.71

21,000, or approximately 5.4 percent of all items indexed that year. This placed Japan fifth in article output. During 1978 to 1982 these 21,000 articles attracted some 84,000 citations, or an average of 4.0 citations each. While the number of citations to Japanese articles, at 4.5 percent of all citations, is somewhat under the proportion of its contribution in terms of articles, the percentage of Japanese articles actually cited turned out to be quite high—64.2 percent. Only Sweden, with 69.8 percent of its articles cited, surpasses Japan in this regard. This type of comparison can sometimes be deceptive, however, owing to, for example, unusual patterns of self-citation.

Strengths, Field-by-Field

Table 2 offers a comparative but slightly different view. The table was compiled from a series of three articles published this year in the journal *Scientometrics* by Tibor Braun and colleagues, Information Science and Scientometric Research Unit, Library of the Hungarian Academy of Sciences, Budapest.[9-11] The data for Braun's study were based on the articles indexed in the *SCI* over three years—1978 to 1980. Braun divided journals into fields and thus was able to categorize groups of articles into subject disciplines. Based upon the impact factors of each journal in which a given article was

Table 3: Countries that cited or were cited by articles with primary author addresses in Japan and the number of 1978 articles they published with primary author addresses in Japan. Data represent 1978-1982 *SCI*® citations to the 1978 *SCI* source items.

Country	Citations to Japanese Articles	Percent of Total	Citations from Japanese Articles	Percent of Total	1978 Items Published
Japan	37,597	44.9	37,597	39.9	9,923
US	19,515	23.3	33,157	35.2	5,850
UK	5,475	6.5	4,991	5.3	1,695
FRG	3,255	3.9	3,658	3.9	614
France	2,733	3.3	2,330	2.5	67
Canada	2,037	2.4	2,422	2.6	31
USSR	1,757	2.1	584	0.6	48
Italy	1,135	1.4	802	0.9	70
The Netherlands	948	1.1	1,091	1.2	1,510
Australia	803	1.0	853	0.9	25
India	781	0.9	353	0.4	15
Switzerland	780	0.9	1,253	1.3	547
Sweden	754	0.9	1,125	1.2	38
GDR	542	0.7	126	0.1	99
Belgium	538	0.6	456	0.5	18
Czechoslovakia	416	0.5	146	0.2	4
Poland	415	0.5	258	0.3	7
Israel	401	0.5	685	0.7	3
Denmark	362	0.4	501	0.5	159
All Others	3,590	4.3	1,940	2.1	87
Total	83,834	100.0	94,149	100.0	20,810

published, he calculated an expected citation rate. After comparing the actual, or observed, citation rate to the expected rate, he obtained a relative citation rate. Unity (1.00) would signify that a group of articles received exactly the number of expected citations based on the impact factors of the journals in which the articles appeared.

In the study by Braun, Japan ranked fourth in output of scientific articles behind the US, UK, and USSR for the period 1978 to 1980. Japan's greatest contribution was in chemistry: 10.31 percent of all chemistry articles in the 1978-1980 file were identified (by primary author address) as Japanese. The relative citation rate for chemistry articles was also Japan's highest—0.97. Mathematics, on the other hand, seems to be the area in which Japan contributed the least and had the lowest relative impact (0.88).

Notice that in no area did Japanese articles receive the expected number of citations (1.00 or more). In this regard, Japan resembles the USSR, France, and India. Language, prejudice, or other subjective factors may partially explain the relative inattentiveness of the world's researchers to the articles from these nations. Subbiah Arunachalam, editor, *Indian Journal of Technology*, examined some of the reasons for such inattentiveness and underuse in a paper delivered at the annual meeting of the Council of Biology Editors, held in Vancouver, Canada, in May 1987.[12]

Braun and A. Schubert have supplemented their measure of relative citation rates with relational charts, but they have not as yet published a comprehensive country-by-country comparison using these graphic representations. The use of relational charts for this purpose is described in a 1986 article in *Scientometrics*.[13]

Citations, Nation to Nation

As might be expected, Japanese researchers, like those of other countries, cite their colleagues more often than do researchers from any other nation. Table 3 shows that of the approximately 84,000 citations to the 1978 Japanese articles during 1978 to 1982, 44.9 percent were given by Japanese articles. Citations to Japanese articles from US

Table 4: Languages of 1978 *SCI®* source items and the percentage of citations each group received in the 1978-1982 *SCI*.

Language	Percent of Items	Percent of Citations	Five-Year Impact
English	88.5	96.4	5.2
Russian	3.9	1.0	1.2
German	3.8	1.5	1.9
French	2.6	1.0	1.8
Japanese	0.4	0.1	0.7
All Others	0.8	0.1	0.5

Table 5: Languages of 1978 *SCI®* source items that had primary author addresses in Japan.

Language	Items	Items Cited	Percent Cited	1978-1982 Citations	Five-Year Cited Impact	Total Five-Year Impact
English	19,055	12,796	67.2	82,544	6.45	4.33
Japanese	1,689	525	31.1	1,152	2.19	0.68
German	40	25	62.5	80	3.20	2.00
French	20	8	40.0	46	5.75	2.30
Russian	1	0	0.0	0	0.00	0.00
All Others	5	3	60.0	12	4.00	2.40
Total	20,810	13,357	64.2	83,834	6.28	4.03

Table 6: The 1978-1982 *SCI®* citations to 1978 source items in Japanese by citing author address.

Country	Citations	Percent of Total
Japan	720	62.3
US	170	14.7
UK	58	5.0
FRG	25	2.2
Canada	23	2.0
USSR	22	1.9
France	18	1.6
Czechoslovakia	15	1.3
GDR	15	1.3
All Others	89	7.7
Total	1,155	100.0

Table 7: The 1978-1982 *SCI®* citations from items with primary author addresses in Japan to 1978 source items by language of cited articles.

Language	Citations
English	92,518
Japanese	720
German	537
French	278
Russian	78
Polish	5
Czech	2
Spanish	2
All Others	9
Total	94,149

researchers represented 23.3 percent of all citations to Japanese articles.

Citations from Japanese articles, numbering about 94,000 over the period 1978 to 1982, went in the largest part to Japanese articles (39.9 percent), followed by those to US articles (at 35.2 percent).

The column at the far right in Table 3, "1978 Items Published," divides the 20,810 Japanese articles from 1978 by country, based on the place of publication for the journal in which each article appeared. These numbers are provided for comparative purposes.

Table 8: National publication productivity, 1973-1978 and 1978-1982, by primary author address of *SCI*® source items.

Country	1973 Items	1978 Items	Percent of Change, 1973-1978	1982 Items	Percent of Change, 1978-1982
US	151,939	171,231	13	181,450	6
UK	32,728	34,926	7	39,695	14
USSR	24,715	21,158	−14	23,403	11
FRG	20,137	24,124	20	27,900	16
France	17,707	17,314	−2	20,795	20
Japan	15,569	20,810	34	28,657	38
Canada	15,362	16,054	5	17,200	7
India	7,888	9,262	17	10,198	10
Australia	6,985	7,538	7	9,036	20
Italy	6,012	6,309	5	10,122	60
Sweden	4,989	5,464	10	6,867	26
Switzerland	4,483	5,572	24	6,081	9
The Netherlands	4,114	5,327	30	7,111	34
Israel	3,199	3,801	19	4,710	24
Poland	2,918	3,402	17	2,465	−28
All Others	34,503	35,984	4	48,065	34
Total	353,248	388,276	10	443,755	14

Languages: English as the *Lingua Franca* of Science

Table 4 divides all 1978 articles by language. English clearly predominates as a *lingua franca* of the scientific literature, even if one disregards translation journals (about 3 percent of the 88.5 percent listed for English).[14] In terms of citations, English-language articles dominate even more. Japanese-language articles represent a very small portion of the 1978 articles indexed in the *SCI*. Many Japanese journals, especially those that aim to reach an international audience, publish in English, French, or German.

Table 5 lists the 1978 Japanese items by language of publication. Nearly 95 percent of these Japanese articles were written in English. Compared to the Japanese-language articles, the English-language articles by Japanese researchers were cited at roughly twice the level (67.2 versus 31.1) and had three times the impact (6.45 versus 2.19) during 1978 to 1982.

Table 6 shows that the 1,155 citations given during 1978 to 1982 to the 525 cited Japanese-language articles came preponderantly from Japanese researchers. This is expected, given the relative inaccessibility of the Japanese language to nonnatives. Considering the wide availability of abstracting services, especially in chemistry, it is interesting that only 15 percent came from US researchers; however, we found many years ago that Japanese-language items—although listed in *Current Contents*® in English—were rarely requested by readers, even those in industry.

Finally, Table 7 analyzes by language of the cited article the 94,149 citations given out by Japanese articles to 1978 items. Japanese researchers cited, to an enormous extent, English-language articles.

Increasing Output: Japan Leads the Way

From 1973 to 1978, with no change in the number of Japanese journals covered in the *SCI* (77), Japan increased its output of articles by 34 percent, as Table 8 shows. From 1978 to 1982, with only a 20 percent increase in Japanese journals covered in the *SCI* (to 92), Japanese researchers increased their output of articles by some 38 percent. These numbers would seem to foreshadow the emphasis placed on basic research in Japan that began in the early years of this decade.

Table 9: Percent of annual change in productivity for selected countries distributed over the major divisions of science. (Table is based on articles by T. Braun in *Scientometrics.*[9-11])

Country	All	Chemistry	Life Sci.	Physics	Mathematics
US	3.93	5.08	3.55	4.68	0.38
UK	3.95	0.80	4.56	8.46	0.65
USSR	3.79	0.32	5.43	8.02	-2.53
Japan	9.81	7.32	10.34	10.74	4.27
FRG	2.24	5.08	1.22	6.54	0.86
France	1.50	-0.47	-1.08	3.19	-30.52
India	0.64	5.54	0.15	-0.07	24.95

The data in Table 9 are drawn from the study by Braun and provide a field-by-field breakdown and an average annual increase in output for 1978 to 1980. Once again, Japan increased its productivity at more than twice the rate of any other nation across all scientific fields. The largest increases were in the life and physical sciences, followed by chemistry and mathematics.

Conclusion

Clearly, Japanese science made great strides during the late 1970s and early 1980s. In the next installment, we will bring out the data for Japan from 1982 to the present. Preliminary data, I will say here, show continued and impressive growth of the Japanese science enterprise. For example, data published in ISI's *Current Contents Address Directory* reveal that Japan ranked sixth in terms of publishing authors in 1978. In 1982 Japan ranked fifth. And in 1986 it ranked third. (Only primary author addresses are included in this analysis.)

Charles Thomas Owens, who spent four years in NSF's Tokyo office and who is now head of NSF's Division of Information and Analysis, International Programs, in Washington, DC, when commenting on an early draft of this essay, observed: "Japanese researchers have not, heretofore, been greatly motivated by their system of recognition or reward to publish—either promptly or comprehensively. That may be changing now, as researchers begin to strive for international recognition to a greater extent. That recognition requires not only quality but being first and in a 'good' journal. Add to this the general impulse to be 'creative' and to boost investment in basic research and you have a Japan *poised* to become a juggernaut. The tale will be told in the next 15 years or so."[15]

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My thanks to David A. Pendlebury and Janet Robertson for their help in the preparation of this essay.

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