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A Multi-Level Analysis of World Scientific Output in Pharmacology

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1. Introduction

Over the last few decades and particularly in the present economic context, the distribution of economic resources has been a concern addressed by governmental and corporate scientific policy, which has either benefitted only part of the scientific and technological community or furthered certain lines of research. The pharmaceutical industry in particular has had to confront not only this situation, but also ongoing internationalisation, supported by the relentless advances in communication technologies.

Until the nineteen eighties, industry internationalisation, in terms of R&D, was a marginal matter, not only for economics theory and business in general, but also for governments and the other organisations involved. Globalisation began to acquire importance after the mid nineteen nineties, although not all manufacturing industries have experienced the same degree of R&D internationalisation. The pharmaceutical industry, for one, pioneered this more universal approach to research and development (Noisi, 1999).

Contrary to the widely held opinion according to which R&D internatianlisation is the fruit of domestic innovation in many industries, pharmaceutical constitutes an exception. Indeed, international innovation intensifies the industry's R&D (Patel and Pavitt, 2000), whereas in other lines of business domestic innovation is the driver. In addition to internationalising its R&D, the pharmaceuticals industry has increased its research spending exponentially in recent years (Congressional Budget Office, 2006).

A number of earlier papers studied the bibilometric characteristics of the pharmacological publications generated as a result of the R&D effort in places such as the United States (Narin and Rozek, 1988), India (Kaur and Gupta, 2009; Gupta and Kaur, 2009) or the Middle East (Biglu and Omidi, 2010). Others stressed the contribution of pharmaceutical firms to scientific knowledge (Koening, 1983; McMillan and Hamilton, 2000; Rafols, et al. 2010; Perianes-Rodríguez, et al. 2011). The assessment of the international impact of scientific papers is a present, but not a new concern: it has been a frequent object of study since the nineteen eighties. The use of scientific indicators for several decades to characterise research by subject area, country or institution has confirmed that, although they have their limitations, they are the only suitable tool for scientific assessment (Braun T et al., 1985).

The purpose of this chapter is to analyse international research in "pharmacology, toxicology and pharmaceutics" (hereafter pharmacology) on the basis of the scientific papers listed in the Scopus multidisciplinary database. This primary objective is reached by answering the following questions (in the section on results). What weight does the subject area "pharmacology, toxicology and pharmaceutics" carry in world-wide science? What is the percentage contribution made by the various regions of the world to the subject area "pharmacology, toxicology and pharmaceutics"? Can certain regions be identified as leaders on that basis, as in other scientific contexts? Are emerging countries present in the field? Do the most productive countries also publish the largest number of journals? What features characterise the scientific output of companies that publish pharmacological papers?

2. Methodology

2.1 Database

The possible sources of information for scientometric research include multi-disciplinary databases such as Thomson Reuters' Web of Science, Elsevier's Scopus and resources such as Google Scholar, as well as specialised services such as Medline. These sources analyse research results in the form of scientific papers published in international journals and their subsequent citation by the rest of the scientific community.

Scopus, the Elsevier database created in 2004, lists over 18 000 journals edited by over 5 000 publishers[1]. When it first appeared, it was analysed by many authors and compared to other resources in a whole stream of papers (Fingerman, 2005; LaGuardia, 2005). It was chosen for the present study because of its broad subject area and linguistic coverage; in the understanding that world-wide scientific production is more fully represented in Scopus than in other databases (Sciverse Scopus, 2011). In addition, as a resource suitable for research conducted after 1996, it is particularly apt for a subject area such as pharmacology (Gorraiz and Schloegl, 2008).

Scopus' strong points as a source of information are reinforced by an open access, on-line tool known as SCImago Journal and Country Rank (SJR, 2007). As its name infers, this system of scientific information, drawing from Scopus contents from 1996 to 2010, ranks journals and countries using data intended for world-wide scientific assessment. The tool provides open access to both data and indicators by region or country, with international coverage. It proved to be particularly useful for the aims pursued in the present study.

2.2 Indicators

Two sets of bibliometric indicators were used in this study: one to determine the quantitative characteristics of scientific output and the other to analyse its quality, i.e., the qualitative characteristics of citations and journals (Rehn, 2007). The indicators included in each group are described below.

This study calculated the number of scientific papers published by the units analysed (world, region, country or industry) over the time span defined. All of the various possible types of papers (such as articles, reviews and notes to the editor,) were included in the *output* indicator.

[1] Available from http://www.info.sciverse.com/scopus/scopus-in-detail/facts/. 20/08/2011

When papers were co-authored by researchers from institutions in different countries, a complete computational approach was adopted. The growth rate, when provided, indicates the rise or decline in world-wide output in 2009 with respect to the baseline year, 1996.

A number of indicators were used to obtain an approximate view of the quality of world scientific output in the field of pharmacology. The number of *citations* received refers to the total number of times papers published by the unit analysed were cited during the period studied. This indicator provides an overview of the scientific impact of the articles published by the unit in question. The number of *citations per paper* was calculated as the mean number of citations received by all the papers published by the unit analysed in the period studied.

The *domestic citations* were separated from the total to determine the proportion of the output that was used as a reference in the same geographic area (region or country) and consequently, by simple subtraction, the proportion involving knowledge transfer to other areas. The results are shown as the percentage of the citations used for research conducted in the same geographic area. The *normalised citation* indicator is the relative number of times papers produced by a specific unit were cited, compared to the world-wide mean for papers of the same type, age and subject area.

While citations denote the subsequent use of papers once published, the *references* list the literature cited in papers published by a journal at any given time. The number of *references per paper* was found by dividing the total number of references by the number of papers published by the unit.

A country's *H-index*, in turn, specifies the number of papers (h) produced in that country and receiving at least h citation. It relates a country's scientific productivity (output) to its scientific impact (citations). The *international collaboration* indicator is the percentage of papers with author affiliations in more than one country. This indicator measures institutions' international networking capacity. In this chapter a journal's *% output in Q1* is the percentage of scientific papers published by an institution in what are classified as the most influential journals in the respective category, i.e., the periodicals in the first quartile or Q1, the upper 25 %, based on their SJR value.

Another qualitative indicator used, homonymous with the aforementioned scientific information system (SCImago Journal and Country Rank), was the *Scimago Journal Rank (SJR)*, used as an alternative to the traditional impact factor (I.F.). This indicator, which measures the visibility of the journals in the Scopus® database, is established by the SCImago[2] research team on the grounds of the well-known Google PageRank™ algorithm. It differs from the I.F. in two ways: citations are computed over 3 rather than 2 years; and article citations are weighted, with citations in more visible or prominent journals carrying greater weight than citations in lower-ranking journals (González-Pereira et al., 2009).

3. Results

3.1 World-wide science and pharmacology

World-wide scientific output, as listed in the Scopus database for the period running from 1996 to 2009, came to 21 100 138 papers. The total citations received by those papers during the

[2] http://www.scimago.es/. 20.08.2011

same period amounted to 217 388 448, for a mean of 10.03 citations per paper. The absolute numbers for pharmacology, as one of the 27 subject areas established by Scopus, were logically much smaller. The totals were 564 914 papers and 6 266 408 citations. The mean number of citations in pharmacology was therefore higher than the world average, at 11.09. The growth rate for this subject area was 4.76 %, reflecting the growth in its scientific output.

Figure 1 shows the percentage contribution of the Scopus subject areas to world-wide scientific output during the period studied. Medicine played a predominant role in the international scientific scenario, with a mean yearly contribution of over 20 %. Decision science and dentistry stood at the other extreme, with a mean yearly output of 0.35 %, shown on the figure as very thin lines. The mean yearly contribution of pharmacology to international scientific output in the period was 2.7 %, shown in red on the right half of the graph. When pooled, all the subject areas with relative outputs of under 4 %, which include pharmacology, earth and planet sciences, immunology and microbiology, accounted for 34.83 % of the scientific papers published world-wide.

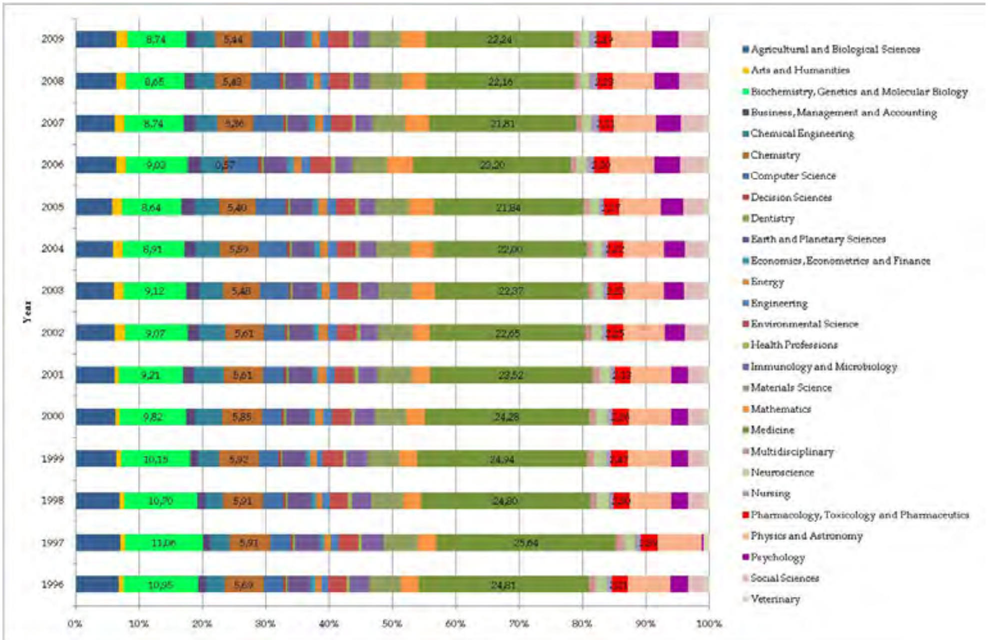

Fig. 1. World output by subject areas (%) (Scopus, 1996-2009)

3.2 Pharmacology by region

While scientific output by region is an important indicator to determine regional contributions to pharmacology, quantitative information alone is incomplete and must be supplemented with data on the impact of these papers on the scientific community. Table 1 gives the vales of some of the indicators described earlier for a number of regions, along with colour bar graphs for readier interpretation.

Region	Output	Citations	Domestic citations	%Domestic citations	Citations per paper
North America	155373	2714951	2209503	81.38	17.47
Western Europe	159512	2383236	1671534	70.14	14.94
Asia	113741	1095409	626665	57.21	9.63
Eastern Europe	21951	178157	57830	32.46	8.12
Latin America	18122	164264	78623	47.86	9.06
Pacific Region	11802	161126	45651	28.33	13.65
Middle East	10256	105817	27329	25.83	10.32
Southern Africa	2167	23987	7406	30.88	11.07
Central Africa	2035	11101	4650	41.89	5.46
Northen Africa	827	7559	1808	23.92	9.14

Table 1. Pharmacological scientific output, citations and domestic citations by region (Scopus, 1996-2009)

The behaviour of the domestic citations indicator merits comment. In North America, these citations accounted for over 80 % percent of the total. The number of domestic citations was likewise very high in Western Europe; in both regions most of the citations were found in articles published in the same country as the paper cited. Consequently, in these two regions, the large number of domestic citations led to an inordinately large number of total citations.

The regions with smaller numbers of citations also had a smaller proportion of domestic citations. In other words, their output was acknowledged primarily by other regions, while domestic citations were less frequent. The region that best illustrates this observation is Northern Africa, where only 23.92 % of the citations received were domestic.

The number of citations per paper was also highest in North America and Western Europe, with the Pacific Region ranking a close third. Central Africa's low scientific output in pharmacology was only scantly acknowledged, with only 5.46 citations per paper on average. Asia, Eastern Europe, Latin America and Northern Africa had similar citations per paper values, which ranged from 8 to 9.

The pharmacological output by regions over the period 1996 to 2009 is shown in Figure 2. The three most productive regions in that period were Western Europe (red), North America (blue) and Asia (green). Asia had a higher growth rate in the latter years of the period and was the most productive region in 2009. This rise may have been the result of greater participation in the pharmacology, particularly in countries that in those years began to adopt a very active role in the field.

3.3 Countries and pharmacology

The basic unit for the regions listed above was defined as the individual country. A total of 194 countries published pharmacological research in the period studied. The analysis conducted of their output provided greater insight into the values found for the regional indicators.

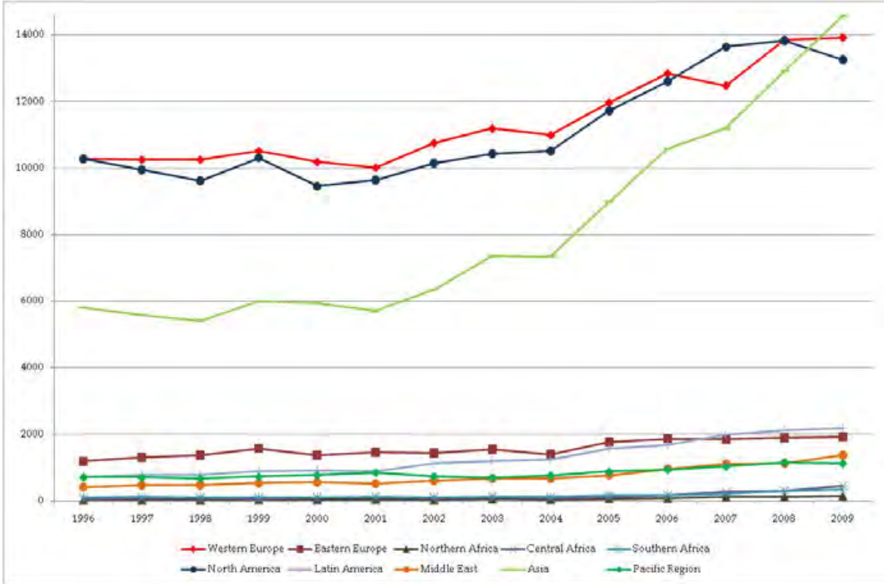

Fig. 2. Pharmacological scientific output by region (Scopus, 1996-2009)

The ten most productive countries accounted for around 71 % of world-wide pharmacological output in the period studied. These ten countries are listed in Table 2, which shows their total output in the period, the number of total and domestic citations received, the citations per paper and the H index. The list is headed by the United States, which had the largest output and number of citations, although the number per paper should be interpreted bearing in mind the impact of the large number of domestic citations identified. At 293, its H index was likewise high, indicating that 293 papers were cited in 293 other articles.

Table 3 ranks the countries whose overall data for the entire period are given in Table 2, year by year across the period. Grey shading indicates that the country changed its position from the preceding year and maroon shading that the country joined the top ten in the year in question.

The regional study showed the enormous progress in Asia in the latter years of the period. That growth was the result of greater participation in the subject area by Asian countries. Although until 2005 Japan was the second largest producer in pharmacology, from 2006 onward it was overtaken by an emerging neighbour: China. In the three earliest years China ranked tenth; in the intermediate years it gradually climbed to higher positions and finally reached second place in 2006. While still among the most productive countries, Japan's position slid, denoting its tendency to contribute less and less to pharmacological output. In the last year of the series, 2009, four of the ten most productive countries were Asian (China, India, Japan and South Korea).

The United States maintained its lead throughout the period. That leadership and Canada's contribution, from lower but still productive positions, made North America the sole region with an output comparable to Asia's in the latter years. All the other most productive countries in pharmacology were from Western Europe: United Kingdom, Germany, Italy and France, and the Netherlands and Spain in some years. Only one Latin American country was among the most productive during the period: Brazil, in 2007.

Country	Output	Citations	Domestic citations	Citations per paper	H Index
United States	154941	2516137	1221126	17.38	293
Japan	47322	543692	164265	11.38	139
United Kingdom	40531	644728	143933	16.9	195
China	36079	178269	80870	6.34	84
Germany	34443	442517	106046	13.49	157
India	23323	144862	59885	9.22	91
Italy	22593	304775	75527	14.88	128
France	21925	320578	64831	15.28	148
Canada	18667	297798	61608	17.18	143
Spain	14232	165910	41389	12.66	101

Table 2. Pharmacological scientific output, domestic citations, citations per document and H index for the 10 most productive countries (Scopus, 1996-2009)

1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
USA	USA	USA	USA	USA	USA	USA	USA	USA	USA	USA	USA	USA	USA
Japan	Japan	Japan	Japan	Japan	Japan	Japan	Japan	Japan	Japan	China	China	China	China
U.K.	U.K.	U.K.	U.K.	U.K.	U.K.	U.K.	U.K.	U.K.	China	Japan	Japan	U.K.	India
Germany	Germany	Germany	Germany	Germany	Germany	Germany	Germany	Germany	U.K.	U.K.	U.K.	Japan	U.K.
France	France	France	France	France	France	Italy	China	China	Germany	Germany	Germany	India	Japan
Italy	Italy	Italy	Italy	Italy	Italy	France	France	Italy	Italy	India	India	Germany	Germany
Canada	Canada	Canada	Canada	China	China	China	Italy	France	India	Italy	Italy	Italy	Italy
Spain	Spain	Netherlands	China	Canada	Canada	Canada	Canada	Canada	France	France	France	France	France
Netherlands	Netherlands	Spain	Netherlands	Spain	Netherlands	India	India	India	Canada	Canada	Canada	Canada	Canada
China	China	China	Spain	India	Spain	Netherlands	Spain	Netherlands	Spain	Spain	Brazil	South Korea	South Korea

Table 3. Country position by output (Scopus, 1996-2009)

Figures 3 and 4 show the relationship between international collaboration and citations per paper in countries publishing at least 1 000 papers. The position occupied by the countries in each region is shown in both figures, but only Western European and North American countries are depicted in Figure 3. All the Asian, Eastern European and Latin American countries are shown in Figure 4, although only the BRIC countries (Brazil, Russia, India, China) are labelled.

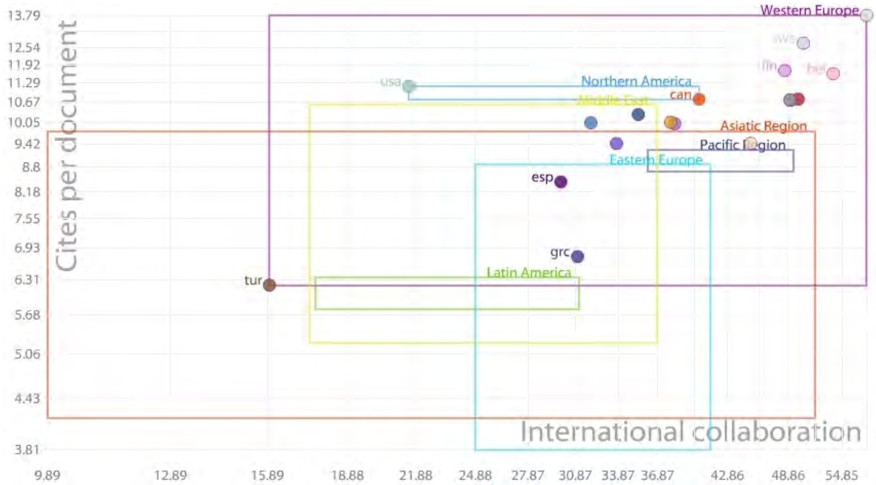

Fig. 3. International collaboration and citations per paper in North American and Western European countries (www.scimagoir.com), 2003-2009.

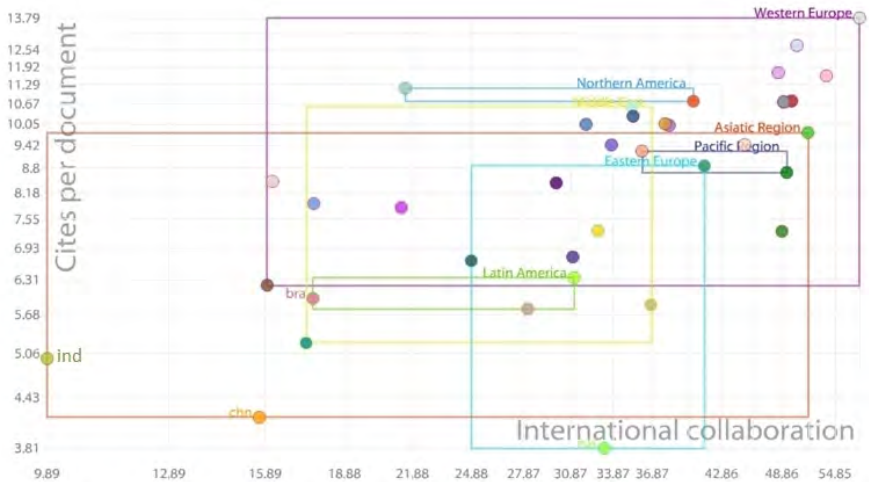

Fig. 4. International collaboration and citations per paper in BRIC countries (www.scimagoir.com), 2003-2009.

The country in Figure 3 with the smallest number of citations per paper and least intense international collaboration was Turkey. With 6.18 citations per paper and an international co-authorship percentage of 16.12, it stood at the low end of its region, Western Europe, and had lower citation values than Latin America or Eastern Europe. In Western Europe, Sweden and Belgium were the two countries both in that region and the world with the highest international collaboration indices and a mean of 12 citations per paper. Both, as well as other countries, also had higher values than the USA (in terms of international collaboration) and Canada.

Measuring their scientific status in terms of citations per paper and international collaboration values, the BRIC countries still have room for improvement. Three of those four countries were positioned very close to the origin on the graph. Of the four, only Brazil showed values close to the results recorded for Turkey.

3.4 Pharmacology in journals

The analysis of the journals that published pharmacological papers included the data for the periodicals that published at least one such paper in 2009. Under that criterion, a total of 482 journals were identified, 61 of which had been recently added to the database and consequently lacked the data needed to calculate their SJR.

Of the remaining 421 (that had published more than one paper and had an SJR index), 110 were edited in the United States, although a fair number were also published in other countries: Netherlands (87), United Kingdom (75), Germany (25), China (12), India (12), Japan (11), Spain (11), France (8), Switzerland (7) and New Zealand (6).

The remaining journals were published in a total of 33 countries, each with less than six journals.

10 top journals by SJR value	SJR	Ouput (2009)	Citations (3years)	Citations per paper (2years)	Refs	Ref per doc	Country
Annual Review of Pharmacology and Toxicology	3.56	19	1429	22.94	2367	124.58	United States
Pharmacological Reviews	3.3	19	1433	17.16	6531	343.74	United States
Nature Reviews Drug Discovery	2.68	202	5827	15.67	7865	38.94	United Kingdom
Trends in Pharmacological Sciences	1.64	84	2588	9.56	5718	68.07	Netherlands
Drug Resistance Updates	1.52	16	530	11.79	1836	114.75	United States
DNA Repair	1.44	169	2237	4.15	10528	62.3	Netherlands
Pharmacology and Therapeutics	1.22	104	3367	9.23	20152	193.77	United States
Current Opinion in Pharmacology	1.14	117	2138	7.57	6206	53.04	Netherlands
Advanced Drug Delivery Reviews	1.1	143	4030	12.34	15219	106.43	Netherlands
10 top journals by total documents in 2009	**SJR**	**Ouput (2009)**	**Citations (3years)**	**Citations per paper (2years)**	**Refs**	**Ref per doc**	**Country**
Bioorganic and Medicinal Chemistry Letters	0.21	1546	10591	2.72	39742	25.71	Netherlands
Pharmaceutical Journal	0.03	1058	124	0.1	972	0.92	United Kingdom
Deutsche Apotheker Zeitung	0.02	967	11	0.02	1440	1.49	Germany
Bioorganic and Medicinal Chemistry	0.2	910	7859	2.88	34194	37.58	Netherlands
Chemosphere	0.15	905	11704	3.41	32003	35.36	Netherlands
European Journal of Pharmacology	0.27	619	6875	2.76	26762	43.23	Netherlands
British Journal of Pharmacology	0.6	616	6819	5.29	28480	46.23	United Kingdom
Medical Hypotheses	0.12	612	1835	1.55	16902	27.62	United States
Japanese Journal of Cancer and Chemotherapy	0.03	611	163	0.09	889	1.45	Japan
International Journal of Pharmaceutics	0.19	528	5930	3.33	17075	32.34	Netherlands

Table 4. Pharmacology journals: SJR, output, citations, citations per paper, references, references per paper and country of publication (Scopus), 2009

The large and unwieldy original table was abbreviated to build Table 4, which gives the values for only the journals with the 10 highest SJR and the 10 scientific journals that published the largest number of pharmacological articles in the last year of the series. Note that none of these journals appears on both lists.

Of the scientific journals with the highest SJR, two were published in the US, *Annual Review of Pharmacology and Toxicology* and *Pharmacological Review*, and one in the United Kingdom, *Nature Reviews and Drug Discovery*. These three journals had SJR scores of 3.56, 3.3 and 2.68, respectively. That means that they received large numbers of citations, but also that since they are weighted by journal prestige to calculate the indicator, those citations appeared in other high quality journals. Neither of the US journals was very productive, with only 19 papers each in 2009, compared to a much larger output by the English periodical, which published a total of 202 articles.

The scientific journals with the highest output in pharmacology were The Netherlands' *Bioorganic and Medicinal Chemistry Letters*, with 1 546 papers, followed by the UK's *Pharmaceutical Journal*, with 1 058 and Germany's *Deutsche Apotheker Zeitung*, with 967. Their SJR indices were lower than for the journals mentioned in the preceding paragraph, however, with scores of 0.21, 0.03 and 0.02, respectively. In other words, in the period calculated for the SJR index (three years), either the absolute number of citations received by this group of more productive journals was very low or the citations were published in lower quality journals.

Each country's contribution to pharmacological scientific output can be analysed from two perspectives: as specified earlier, by the contribution made by its scientists through their published papers, or by the journals edited in the country. These two factors are compared in Figure 5. Each country's scientific output is shown in red and its publishing activity in blue. Many countries, such as the United States, show similar percentages for both types of contribution, while in others the values vary widely. A case in point is The Netherlands, whose scientific output was a mere 2 % while its journals published over 20 % of the pharmacological articles.

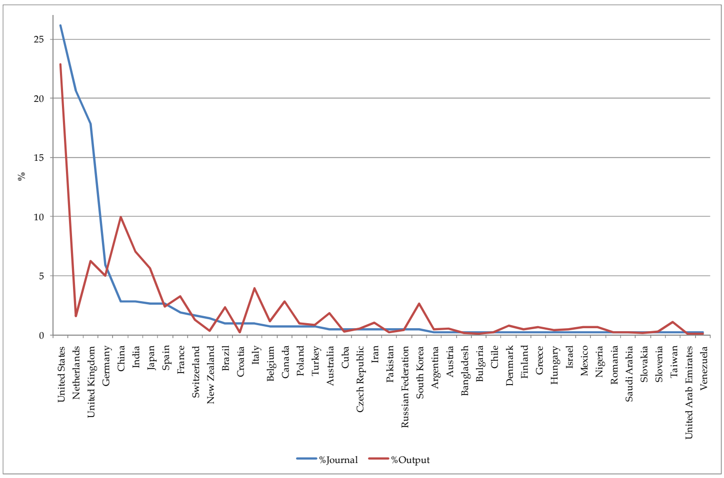

Fig. 5. Percentage of pharmacology-related journals and papers published by country (Scopus, 2009)

3.5 Scientometric indicators for pharmaceutical companies

The pharmaceutical industry, in addition to being one of the most profitable, is also one of the most globalised and fastest growing lines of business. Moreover, its large investment in research makes it an innovation-intensive activity. This innovation is the result of the direct or indirect interaction of a large number of actors: different types of companies, research institutes, financial institutions, public bodies and authorities, public and private universities, research centres, regulating bodies, governments, health systems, consumers and physicians, to name a few.

The industry comprises three categories of companies. The first covers (primarily North American and European) multinational companies that operate globally and invest huge sums in R&D, which is centralised in some cases and decentralised with laboratories in many countries and on many continents in others. The second category consists of small companies that supply their domestic markets with drugs that require no substantial R&D investment. The third includes firms that specialise in biotechnology and invest considerable sums in research despite their small size.

In 2010, biopharmaceutical companies invested an estimated 67.4 **billion** dollars in pursuit of new drugs (Figure 6). The total R&D spending by Pharmaceutical Research and Manufacturers of America (PhRMA) members, including industry majors such as AstraZeneca, Bayer, Boehringer, Ingelheim, Bristol-Myers, Squibb, Eli Lilly, Genzyme, GlaxoSmithKline, Hoffmann-La Roche, Merck, Novartis, Pfizer, and Sanofi-Aventis, as well as non-members, are shown in the figure.

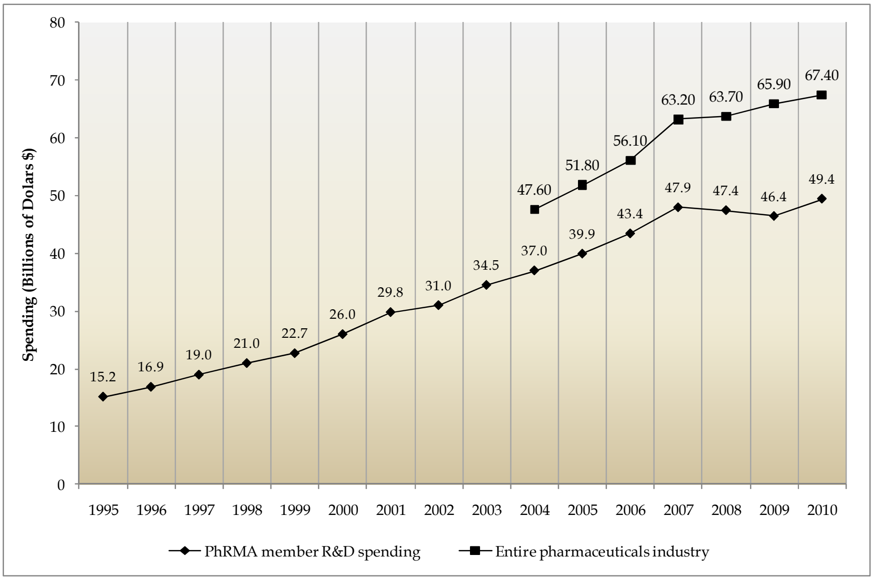

Fig. 6. Biopharmaceutical company R&D and PhRMA member R&D: 1995–2010 (Sources: Burrill and Company, analysis for PhRMA, 2005–2011 (Includes PhRMA research associates and non-members); PhRMA, PhRMA Annual Member Survey, 1996-2010)

Figure 7 shows the R&D spending by PhRMA members in and outside the United States. The total R&D investment by pharmaceutical companies has continued to rise. In 2010 PhRMA members invested 49.4 **billion** dollars, up 6 % from 2009 and 90 % since 2009.

PhRMA members spent most of their R&D budgets (76.1 %) in the United States, Western Europe (16.6 %) and Japan (1.5 %), while spreading the rest across other countries around the world (PhRMA, 2011).

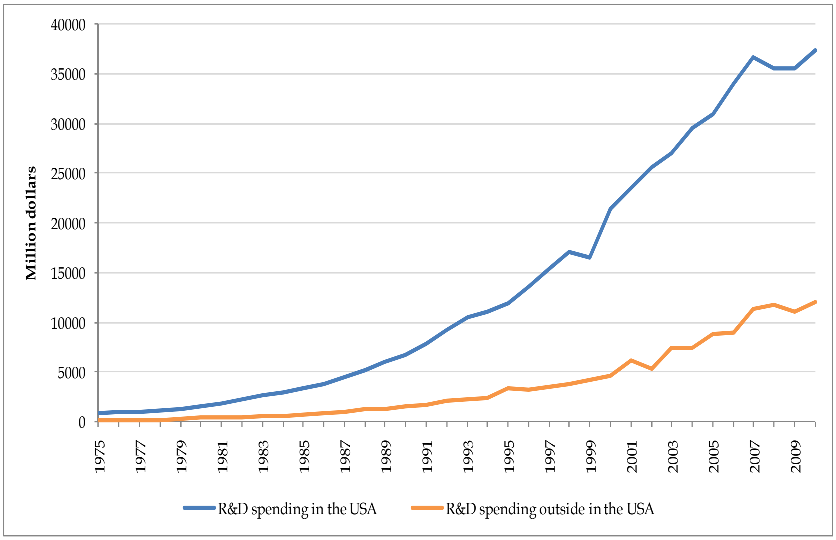

Fig. 7. R&D spending by Pharmaceutical Research and Manufacturers of America (PhRMA) members, 1975-2010 (PhRMA, 2011)

Bibliometric indicators can be constructed for the pharmaceutical industry on the grounds of the research results made public by the authors. As noted earlier, the industry has been gradually internationalising its high research and innovation potential since the mid nineteen seventies (McMillan and Hamilton, 2000).

The values of the bibliometric parameters for the pharmaceutical majors are given in Table 5. The data, which cover a seven-year period and are based on these companies' research publications, reveal a number of interesting differential characteristics. The ranking criterion followed was scientific output defined as the number of papers published in 2003-2009, initially disaggregated, although some of the companies listed had parent-subsidiary relationships.

The first significant result was the volume of scientific papers published by these companies. These elite, all of whose members published at least 125 papers in the period considered, was headed by the Pfizer headquarters site, which averaged 353 papers yearly throughout the period, followed by Merck with a yearly mean of 251.

The second statistic of interest was the citations per paper, which ranged from fairly low (7.86 for Dow Chemical Co., 8.47 for the Indian firm Dr Reddy´s and 9.26 for Sanofi-Aventis GmbH in Germany) to very high values (18.47 for Astra Zeneca in the United Kingdom and

18.21 for Hoffmann-La Roche in Switzerland). These findings suggest substantial differences in the visibility or quality of firms' scientific knowledge.

Organisation	Country	Output	Citations per paper	International collaboration	Normalised Citation	% Output in Q1
Pfizer Inc.	USA	2476	12.4	18.54	1.55	79.36
Merck & Co., Inc.	USA	1759	14.34	18.08	1.74	83.63
Eli Lilly and Company	USA	820	16.13	25.24	1.68	81.1
GlaxoSmithKline. United States	USA	788	15.17	29.7	1.77	86.68
GlaxoSmithKline. United Kigdom	GBR	781	13.76	42.77	1.74	85.66
Bristol-Myers Squibb Company	USA	677	12.97	13	1.58	87.59
Novartis	CHE	595	16.82	66.72	1.8	77.98
Abbott Laboratories United States	USA	571	14.75	12.61	1.65	88.27
Amgen	USA	497	12.27	16.9	1.59	77.46
F. Hoffmann-La Roche. Ltd.	USA	452	14.81	21.46	1.84	83.19
Pfizer Ltd	GBR	379	14.8	43.54	1.73	79.16
Bayer AG	DEU	362	10.46	36.74	1.34	64.36
Johnson & Johnson Pharmaceutical Research	USA	356	13.45	18.54	1.68	87.64
AstraZeneca R&D	SWE	294	14.64	57.82	1.8	87.07
F. Hoffmann-La Roche. Ltd.	CHE	272	18.21	55.15	1.86	83.09
Sanofi-Aventis. S.A.	FRA	224	15.64	43.75	1.55	66.52
Laboratoires SERVIER	FRA	200	17.16	37.5	1.71	91.5
Novartis Pharma SA. East Hanover	USA	192	16.2	34.9	1.89	73.96
AstraZeneca Pharmaceuticals. LP	USA	188	15.77	30.85	1.69	75
Sanofi-Aventis Deutschland GmbH	DEU	167	9.26	26.35	0.95	57.49
Schering-Plough Research Institute	USA	165	12.8	12.73	1.46	86.67
AstraZeneca	GBR	161	18.47	40.37	1.81	77.64
Novartis Institutes for Biomedical Research	USA	161	12.93	60.87	1.77	84.47
Laboratoires Pierre Fabre. S.A.	FRA	155	10.18	23.23	1.17	81.94
Novo Nordisk A/S	DNK	153	12.77	46.41	1.32	77.12
Dr. Reddy's Laboratories Ltd.	IND	150	8.47	7.33	0.88	59.33
H. Lundbeck A/S	DNK	150	18.11	45.33	1.73	91.33
GlaxoSmithKline. Italy	ITA	127	11.52	66.14	1.57	81.89
Dow Chemical Company	USA	125	7.86	34.4	0.9	66.4

Table 5. Bibliometric performance indicators for pharmaceutical firms, 2003-2009 (www.scimagoir.com)

Pharmaceuticals is generally agreed to be one of the industries whose research is most intensely internationalised, defining that to mean the proportion of the research conducted outside the headquarters country. The industry's business has become more international since the nineteen nineties as a result of the convergence of a number of processes. New industrial activities have cropped up around biotechnological research, primarily in the US;

market dynamics with a view to capitalising on research incentives has favoured the location of new laboratories in different countries; global excellence centres with research responsibilities have been created; and inter- and intra-firm networking has been intensified.

When companies were ranked in descending order of the percentage of their papers involving international collaboration, two different patterns emerged, one for European and the other for North American companies. The percentages were higher in the former than in the latter. Several explanations can be given for this difference between countries on the two sides of the Atlantic. The United States is the critical location for pharmaceutical alliances as a result of the quality of the research conducted there, but especially of the size of its research base, i.e., the number and size of universities, companies and research departments. Other factors that distinguish the European and US include the latter's easy financing and marketing terms and fairly large number of start-up incubators and venture capitalists.

The result is that companies based in the US have lower percentages of internationally co-authored papers than European companies: Abbott Laboratories 12.67 %, Schering-Plough Research Institute, 12.73 %, Bristol-Myers Squibb Company, 13 %.

Switzerland's Novartis, by contrast, co-authored 66.72 % of its papers with other countries. Its US subsidiary had a collaboration rate of 69.87 %, while the figure for the French firm Sanofi-Aventis was 43.75 %.

The final indicator analysed was normalised citation, which measures a company's impact on the scientific community as a whole and compares the quality of the research conducted by organisations of different sizes. The highest score was obtained by Swiss Novartis' North American subsidiary, with a mean citation value 89 % higher than the world-wide mean (1.89). It was followed by its parent company, which had a mean citation value 86 % higher than the world-wide mean, and the Swiss subsidiary of North America's F. Hoffman La Roche, with a score of 84 %. The lowest values were recorded for Dow Chemical's pharmaceuticals division (US) and the Dr. Reddy laboratories in India, whose citation values were below the international average.

4. Conclusions

This chapter reports on a multi-level analysis of scientific results in pharmacology. The findings confirmed that despite its scant weight in world-wide science, pharmacological scientific output is characterised by high quality and has citation per paper values higher than the mean for international scientific output as a whole.

Two regions of the world have traditionally occupied the leading positions in terms of pharmacological scientific output, North America and Western Europe. Moreover, the impact of this output is high, measured in terms of citations in other papers. When only citations outside the home region are considered, however, other regions, such as Northern Africa, prove to have higher values. The regions with the largest absolute number of citations also have the highest percentage of domestic citations. By contrast, since the regions with smaller numbers of citations in absolute terms receive fewer domestic citations, the acknowledgement coming primarily from countries outside their own region carries much heavier weight.

During the period studied, certain emerging countries such as Brazil or India joined the list of top ten producers, while China, which was already on the list, climbed almost to the summit. As might be expected, the countries in the most productive regions occupied the highest positions throughout the period analysed, but the appearance of these BRIC countries should prompt reflection on their scientific potential in the field of pharmacology.

The most productive journals, i.e., the ones that publish the largest number of pharmacological articles, do not generally earn high SJR impact values. These values are attained by journals publishing smaller numbers of papers. Consequently, journal quality and the number of papers published are inversely related. An analysis relating papers published and journals edited in each country showed that intense pharmacological publishing is not necessarily attendant upon the presence of numerous researchers working in the field (The Netherlands). US publishing in pharmacology, by contrast, is as predominant in the area as its research community.

Companies carry specific weight in pharmacology. Their investment and innovative capacity are mirrored by the scientific results attained, primarily by US and European pharmaceutical laboratories.

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6. References

Biglu, M.H. and Omidi, Y. (2010). Scientific profile of Pharmacology, Toxicology and Pharmaceutics fields in Middle East Countries: Impacts of Iranian Scientists. *International Journal of Advances in Pharmaceutical Sciences*, Vol. 1, pp. 122-127, ISSN 0976-1055

Braun, T.; Glänzel, W. and Schubert, A. Scientometric indicators: a 32-country comparative evaluation of *publishing performance and citation impact*. Singapore, Philadelphia: World Scientific, 1985, 425 p.

Congressional Budget Office. (2006). *A CBO Study: Research and Development in hte Pharmaceutical Industry*. Congress of the United States. 20/08/2011. Available from http://www.cbo.gov/ftpdocs/76xx/doc7615/10-02-DrugR-D.pdf

Fingerman, S. (2006). Web of Science and Scopus: current features and capabilities. Issues in *Science and Technology Librarianship*, Fall, ISSN 1092-1206, 20/08/2011, Available from http://www.istl.org/06-fall/electronic2.html

Gambardella, A. (1995). *Science and innovation: the US pharmaceutical industry during the 1980s.* Cambridge: Cambridge University Press. ISBN: 0521451183

González-Pereira, B.; Guerrero-Bote, V. and Moya-Anegón, F. (2009). The SJR indicator: A new indicator of journals' scientific prestige. *Arxiv Preprint* arXiv:0912.4141, 02/08/2011, Available from http://arxiv.org/ftp/arxiv/papers/0912/0912.4141.pdf

Gorraiz, J. and Schloegl, C. (2008). A bibliometric analysis of pharmacology and pharmacy journals: Scopus versus Web of Science. *Journal of Information Science*, Vol. 34, No. 5, pp. 715-725, ISSN 0165-5515

Gupta, B.M. and Kaur, H. (2009). Status of India in science and technology as reflected in its publication output in the Scopus international database, 1996-2006. *Scientometrics*, Vol. 80, No. 2, pp. 473-490, ISSN 0138-9130

Kaur, H. and Gupta, B.M. (2009). Indian Contribution in Pharmacology, Toxicology and Pharmaceutics during 1998-2007: A Scientometric Analysis. *Collnet Journal of Scientometrics and Information Management*, Vol. 3, No. 1, pp. 1-9, ISSN 0973-7766

Koening, M. (1983). Bibliometric analysis of pharmaceutical research. Research Policy, Vol. 12, No. 1, pp. 15-36, ISSN 0048-7333

LaGuardia, C. (2005). E-views and reviews: Scopus vs Web of Science. Library Journal, (January 2005), eISSN 0000-0027, 20.08.2011, Available from http://www.libraryjournal.com/article/CA491154.html

McMillan, G.S. and Hamilton, R.D. (2000). Using Bibliometrics to Measure Firm Knowledge: An Analysis of the US Pharmaceutical Industry. Technology *Analysis and Strategic Management*. Vol. 12, No. 4, pp. 465-475. ISSN 0953-7325

Noisi, J. (1999). The internationalization of industrial R&D from technology transfer to the learing organization. *Research Policy*, Vol. 28, pp. 107-117, ISSN 0048-7333

Narin, F. and Rozek, R.P. (1988). Bibliometric analysis of United States pharmaceutical industry research performance. *Research Policy*, Vol. 17, No. 3, pp. 139-154, ISSN 0048-7333

Patel, P. and Pavitt, K. (2000). National systems of innovation under strain: The internationalization of coporate R&D. In: Barrel, R.; Mason, G.; Mahony, M. (eds). *Productivity, Innovation and Economic Performance*. Cambridge: Cambridge University Press, pp. 217-235. ISBN 0521780314

Perianes-Rodríguez, A.; Rafols, I.; O'Hare, A.; Hopkins, M.M. and Nightingale, P. (2011). Benchmarking and visualizing the knowledge base of pharmaceutical firms (1995-2009). *Proceedings of the 13th ISSI Conference.* Durban: International Society for Scientometrics and Informetrics, Vol. 2, pp. 656-661, ISBN 9789081752701

Pharmaceutical Research and Manufacturers of America. *Pharmaceutical Industry Profile 2011*. Washington, DC: PhRMA, April 2011

Rafols, I.; O'Hare, A.; Perianes-Rodríguez, A.; Hopkins, M.M. and Nightingale, P. (2010). *Collaborative practices and technological trajectories in large pharmaceutical firms. Tentative Governance in Emerging Science and Technology*. Enschede: University of Twente, pp. 93-95.

Rehn, C. (2007). Bibliometric indicators: definitions and usage at Karolinska Institutet. 20/08/2011, Available from http://ki.se/content/1/c6/01/79/31/Bibliometric%20indicators%20-%20definitions_1.0.pdf

Sciverse Scopus (2011). What dos it Cover?. 2.08.2011. Available from http://www.info.sciverse.com/scopus/scopus-in-detail/facts

SJR. SCImago Research Group. *SCImago Journal and Country Rank*. 2007. 20/08/2011. Available from: http://www.scimagojr.com