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Research Article

Bibliometric Analysis of Pharmacology Publications in the United States: A State-Level Evaluation

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ABSTRACT
Bibliometrics can be used to track the growth of scientific disciplines that reveal trends, resource utilization and productivity. The purpose of this study was to evaluate the Pharmacology and Pharmacy publications in the United States at a state-by-state level and determine correlations with economic and population parameters. Pharmacology publications represent a small percentage of state publications (highest 5.4%). Fifteen states (30%) account for 71% of all Pharmacology publications and 72% of all citations. A strong correlation was found between state Pharmacology publications and GDP (r = 0.9). Bibliometric data can provide insight on factors that correlate with scientific output and may help policy makers decide what strategies might attract economically stimulating industries to their states.

Keywords: Publications, Scholarship, Faculty, Pharmaceutical sciences.

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INTRODUCTION

Pharmaceutical research involves scientific and clinical inquiry from drug discovery through clinical trial research to the therapeutics of drug use in humans and animals.[1-2] This enterprise draws on a vast array of biomedical disciplines including Chemistry, Molecular biology, Genetics, Immunology, Pharmaceutics, Pharmacology, Therapeutics and the wide number of disciplines involved in Clinical drug use.[2] Pharmaceutical research and Biotechnology are major drivers of economic development in countries around the world.[3] Growth in this sector could be considered one of several markers for economic growth of a country or region.[3] The biopharmaceutical industry represents approximately 3.8% of the total U.S. economic output in 2014, accounting for $ 1.2 trillion dollars. It is also a significant contributor to the nation's tax base in the United States. Combined federal, state and local tax contributions (directly and indirectly) accounted for more than $ 67 billion in 2014.[4] Similarly, bibliometric analysis is an indicator or a surrogate marker for assessing the growth of the Pharmaceutical research arena.[1] Therefore, understanding the issues and factors that correlate with growth of the Pharmaceutical literature and bibliometric indices is vital to stimulating the economic growth of a country or region.

Database coverage is an essential component of a bibliometric study. The three most widely used databases for bibliometric research are the WoS, Scopus and Google Scholar.[5] These are the main databases that provide citation data. Performing the same bibliometric search on each of these databases would not only be difficult because of the differences in search options, data fields and years covered but would also likely yield significantly different results.[6] In addition, consistency and accuracy issues between the three databases vary widely.[5,6] The WoS, although far from perfect, is still considered the gold standard for bibliometric studies. Google Scholar, although often providing more citation retrieval in a bibliometric search, cites many other sources than strictly scholarly journals. Scopus is a late addition to the bibliometric armamentarium, but does not cover as many years as WoS at present. Medline can both be used for bibliometric study depending on the questions asked. Total journal coverage of the two databases varies greatly (~5000 journals for Medline vs 9000 journals for WoS). As an example, pharmaceutical science journals would be better covered by WoS than Medline.[7] However, pharmacy practice journal coverage would probably be more extensive in Medline than WoS.[8,9]

The purpose of this study was to evaluate the pharmacology and pharmacy publications in the United States at a state-by-state level and determine correlations with economic and population parameters. The Web of Science database was used as a means of quantifying publications, citations and bibliometric indices at the state level.

METHODS

The Web of Science (WoS) database was used for data acquisition in this study. The search involved a ten-year inclusive timespan of 2007-2016. The last ten preceding years was chosen so that historical strength would not obscure recent trends. The most up-to-date information on publication metrics and bibliometric indices was sought to provide a current picture of the relative strength of each state normalized by either GDP, population, or state spending. Procedurally, the "Advanced Search" option on the WoS search page was first accessed. For each state searched, the two-letter abbreviation available from the search record was selected (for example: PS= "OK" for searching the State of Oklahoma). The search was then refined by "Countries/Territories" by limiting to USA records only. The search was further refined by limiting the Web of Science category to "Pharmacology/Pharmacy" records only. The "Analyze Results" feature was used to retrieve document types and organizations. The citation report feature was used to identify h-index and total citations. California, Massachusetts, Maryland, New York and Pennsylvania all had numbers of publications exceeding the citation report capability. In each of these exceptions, individual years were searched and recorded on to an Excel spreadsheet and total citations were calculated by compiling these data.

Economic and population data were obtained from the following web sites: Population data were obtained from the United States Census Bureau;[10] Gross Domestic Product (GDP) data were extracted from the United States Bureau of Economic Analysis;[11] Total State expenditures by year were taken from Ballotpedia, the Encyclopedia of American Politics.[12]

Statistical analysis involved calculating descriptive statistics and correlation coefficients for publication data versus the available economic and population data. Calculations were made for Pharmacology publications and GDP, state populations and state expenditure data. The Pearson correlation analysis (r) was calculated using ungrouped data.

RESULTS

Publication records and bibliometric indices for the state-by-state comparisons are listed in Table 1. Since bibliometric data tend to be highly skewed, mean, medians and range are given for each of the parameters measured. Correlation coefficients for total state publications vs. GDP, state expenditures and population were 0.91, 0.91 and 0.88 respectively. Correlation coefficients for pharmacy publication vs. GDP, state expenditures and population were 0.90, 0.90 and 0.87 respectively. Average subcategories of pharmacy publications were: mean articles were 64.6% $\pm$ 5.3 with a median of 64% and a high of 78% and low of 54%; mean reviews were 5.1% $\pm$ 6.6 with a median of 2.5% and a high of 29.3% and low of 0.2%; mean abstracts were 4.5% $\pm$ 0.9 with a median of 4.3% and a high of 6.9% and low of 3.1%. Figure 1 provides a scatter plot and best fit line for the correlation of state publications and state GDP.

DISCUSSION

Bibliometric data are highly skewed. These data have been described by the "80-20" rule where 80% of publications are produced by 20% of the sources, whether they be faculty, institutions, or countries.[13] In the United States, a handful of universities account for the majority of publications and citations. A recent study found that 24 universities accounted for 42% of the overall publications output for the years 2005-2009.[14] Nineteen of these universities received 47% of all the citations received. It appears, in this ongoing review of bibliometric data from American universities that the concentration of scholarly activity continues to accumulate in a small number of highly prolific universities.[14] Prathap[15] recently used citation data from Google Scholar to examine the concentration of scientific output in52 countries worldwide. Similar to previous data, Prathap[15] found that the scientific output, measured primarily by the number of citations, was more highly skewed (0.159) and more unevenly distributed than the United States (0.2) with 1.0 being absolute equity. Prathap[15] also found a very strong Pearson correlation between GDP and size-dependent research performance indications (ranging from 0.94 to 1.0). They found, similar to previous researchers[16,17] that the greater the scientific "wealth" of a nation, the more likely it is to concentrate this excellence in a few elite institutions.

Our publication data are similarly skewed. Fifteen of the 50 states (30%) accounted for 71% of the total pharmacy publications and 72% of the total citations. This suggests a concentration of pharmaceutical activity in states with size-dependent variables such as population, GDP and perhaps infrastructure support. Of course, GDP by itself would not necessarily result in additional scientific "wealth" if this did not translate into meaningful support for pharmaceutical research and development in the public and private sector. The strong Pearson correlation between total state pharmacology and pharmacy publications and state GDP suggests an association between these variables. Higher state GDP provides the resources for infrastructure support, higher education research support and economic incentives for attracting entrepreneur industries, such as pharmaceutical companies and government agencies to locate within the state. Although this is a logical inference, correlation data such as these do not allow a direct cause and effect analysis of these data.

Table 1: Total State Publications and Pharmacology Publications by U.S. State.

States	Total Publications	Pharm Publications	Pharm Pub h-index	Pharm Pubs: Total Cits	Total Pharm Publications per 100,000 population	Total Pharm Publications per $ 1,000 GDP
Alabama	81560	1943	61	22840	40.5	10.69
Alaska	12195	49	13	508	6.8	0.88
Arizona	113775	1956	63	25741	29.9	7.44
Arkansas	32452	1083	46	12318	36.9	10.09
California	889565	19518	164	264455	51.6	9.22
Colorado	151546	2554	74	37126	49.5	9.41
Connecticut	140485	5253	102	84037	146.9	21.93
Delaware	29985	1060	50	12043	116.1	17.58
Florida	242463	5737	86	66126	29.7	7.38
Georgia	193382	4074	90	64964	41.4	9.32
Hawaii	31346	456	29	4083	33.0	6.42
Idaho	18070	156	21	2332	9.8	2.68
Illinois	318879	7185	98	91646	56.0	10.40
Indiana	142277	4478	92	62759	68.7	15.20
Iowa	77158	1618	62	23094	52.7	10.65
Kansas	50326	1747	69	25648	61.0	12.87
Kentucky	59090	1956	59	25960	44.8	11.38
Louisiana	69479	1293	51	16763	28.3	5.63
Maine	18646	264	26	2593	19.9	5.04
Maryland	395601	13202	139	209747	225.7	40.87
Massachusetts	540837	13467	152	207764	203.1	32.01
Michigan	235771	5074	91	76617	51.2	12.35
Minnesota	170521	3643	78	47571	67.9	12.73
Mississippi	36914	1592	53	15343	53.5	16.12
Missouri	133724	3102	78	43257	51.6	11.76
Montana	17718	217	33	3365	21.6	5.37
Nebraska	43431	1520	54	20049	82.3	15.56
Nevada	21803	337	26	2833	12.2	2.63
New Hampshire	34284	378	37	5323	28.6	5.72
New Jersey	177292	9553	122	125580	108.1	18.71
New Mexico	65505	797	50	10772	38.7	9.02
New York	611231	12644	123	174172	64.8	10.10
North Carolina	264596	9476	121	134431	97.9	21.73
North Dakota	14302	249	29	2967	35.5	5.68
Ohio	274534	5697	96	77600	49.3	10.66
Oklahoma	46271	903	41	9105	23.8	5.42
Oregon	85810	1469	61	21302	37.7	7.60
Pennsylvania	410784	11613	118	157424	91.3	18.60
Rhode Island	47703	1168	54	15354	110.8	23.08
South Carolina	67042	1635	71	24942	34.8	9.40
South Dakota	10664	228	30	2867	27.5	5.54
Tennessee	137840	3615	90	50343	56.3	13.36
Texas	430818	8778	120	145563	33.9	6.37
Utah	72487	1897	73	29613	67.0	15.03
Vermont	19761	318	36	4890	50.8	11.62
Virginia	167863	3584	78	48591	44.1	8.31

Washington	190313	3393	89	55233	49.4	8.87
West Virginia	21643	628	47	9705	34.0	9.19
Wisconsin	126797	2325	68	31843	40.7	8.74
Wyoming	10054	124	24	1524	21.8	3.10
Mean ± SD	151,132 ± 177,200	3,700 ± 4,339	70.8 ± 35.8	52,215 ± 62,620	56.8 ± 43.2	11.4 ± 7.3
Median	79,359	1,920	65.5	25,694	47.05	9.8
Range	10,054 - 889,560	49 - 19,518	13 - 164	508 - 264,455	6.8 - 225.7	0.88 - 40.87

Table 2: Bibliometric Analysis of Pharmacology or Toxicology Research Internationally.

Author (Year)	Country	Source of Bibliometric Data	Discipline Analyzed	Major Findings
Ding, *et al.*[1] (2013)	China	Science Citation Index	Pharmacology	Number of Pharmacology publications by China increased dramatically over the decade 2001-2010, however the quality of papers did not improve significantly
Arancibia, *et al.*[3] (2016)	Cuba	Scopus	Pharmacology	Despite constraints on resources and low international collaboration, BioCubaPharm has taken the lead in Cuba as an export earner and improving national health as reflected in bibliometric indices.
Kamden *et al.*[18] (2016)	Brazil	Scopus	Pharmacology	Authors were able to correlate bibliometric indices with Brazilian National Grant awards in pharmacology
Nasir *et al.*[19] (2015)	Pakistan	Science Citation Index	Pharmacology	Global share for Pakistan was 0.25%. Pakistan ranked 13th out of 27 Asian countries for this discipline
Olmeda-Gomez, *et al.*[20] (2011)	194 Countries	Scopus	Pharmacology	The authors found that North America and Western Europe occupied the leading positions in terms of pharmacological scientific output. Emerging countries such as Brazil and India along with China were also in the top ten countries
Ahmadian *et al.*[21] (2013)	102 Countries	Scopus	Pharmacy, Pharmacology	Research and development in pharmacy areas are correlated with expenditure, particularly GDP
Delirrad *et al.*[22] (2013)	Iran/ Turkey	Science Citation Index	Toxicology	Iranian toxicologists has better bibliometric indices than Turkish toxicologists. Average citations per article favored Turkish toxicologist however.

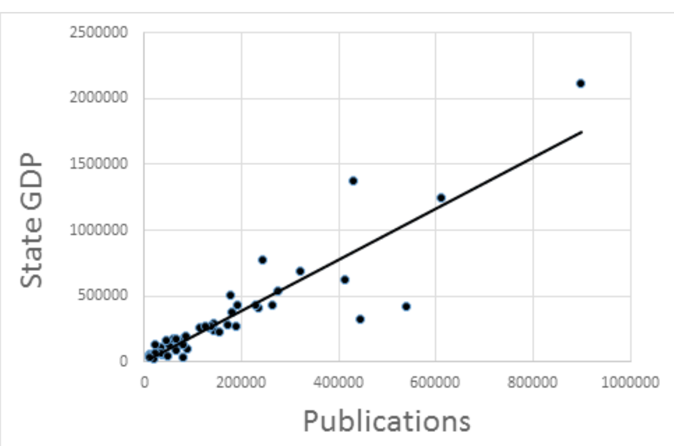

Figure 1: Scatter Plot of Pharmacy Publication vs. State GDP.

A paucity of research has examined the intricate relationship between pharmaceutical bibliometrics and individual or collective countries.[1,3,17-20] Table 2[2,3,17-21] summarizes the available data. Most studies have focused on documenting the growth of the Pharmaceutical research establishment in their particular country or comparing it to a geographically similar region. Studies have generally utilized either Scopus or Science Citation Index as the source of bibliometric data. Outcome parameters have generally been publication counts or other, more sophisticated, bibliometric indices.[8]

There is incredible regulatory and economic pressure on the drug development enterprise. Political pressures to speed up the drug approval process to bring new therapeutic agents to market involve decreasing the size of pivotal Phase III studies, shortening the length of the study and increasing the use of surrogate biomarkers which bring with it potential pitfalls.[22] Improving global access to needed medication has also been a powerful factor in motivating the drug development establishment to improve access and decrease costs[23] However, the economics of the drug development industry is complex.[24] Estimates of the cost of a single new drug brought to market vary greatly ranging from $ 92 million to $ 4.2 billion.[23] A recent study by Prasad and Mailankody[25] suggests that the figure may be on the lower end of this range. The pharmaceutical industry has had to respond to these pressures by abandoning the traditional large, fully-integrated biopharmaceutical company in favor of a smaller, more flexible model that readily outsources key steps in the drug development process to specialized partners or academic researchers.[26] These disruptive forces have no doubt created uncertainty among state leaders eager to attract these potentially lucrative enterprises to their states.

The Pharmacology and Pharmacy subject category is one of 228 subject categories in the in the WoS database. There are a total of 214 journals in the Pharmacology and Pharmacy subject category. Despite this seemingly uniform meshing of the field of pharmacology, this particular category of journals is actually quite heterogeneous. Minguet *et al.*[27] recently suggested that the Pharmacology and Pharmacy subject category be clustered into four groups: Basic Pharmacology (N= 150 journals), Clinical Pharmacology (n= 43 journals), Combination of Clinical and Basic Pharmacology (n= 16 journals) and Pharmacy (n= 5 journals). The authors concluded this by evaluating the existing Pharmacology and Pharmacy journals against the Medical Subject Headings (MeSH) for 107,847 articles included from 2013-15 in this category. They analyzed nine different hierarchical clusters to determine the best fit model.

Like all bibliometric studies, there are potential limitations to these data. Web of Science was the database utilized for the source documents in this study. Google Scholar and Scopus are also databases that could yield similar data, however WoS is the only database that can provide a comprehensive source of current and historical Pharmaceutical Science journals with citation counts and a reasonable search methodology to extract the data necessary for the this study.[5,28] Second, all databases have publication errors and WoS is no exception. However, source document errors are considered relatively miniscule considering the enormous amount of publication, citation and other data that are indexed yearly.[29] Finally, citation data itself can be misinterpreted because of self-citations, negative citations and citations from emerging new sources.[30]

CONCLUSION

Pharmacology/Pharmacy publications constitute a small portion of the total publications produced by states. Additionally, publications in this field are skewed toward a small number of states that have large GDP's or have attracted biopharmaceutical firms or pharmacology-related government activities to their states. State GDP correlates strongly with the number of pharmacology publications and citations. Bibliometric data can provide insight on factors that correlate with scientific output and may help policy makers in deciding what efforts might attract economically stimulating industries to their states.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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