·Bibliometric Research·

# Trends in ophthalmology journals: a five-year bibliometric analysis (2009-2013)

*Christopher B. Schulz*[1], *Alasdair Kennedy*[2], *Ben C. Rymer*[3]

[1]Eye Unit, Royal Bournemouth Hospital, Bournemouth, BH7 7DW, UK
[2]Department of Ophthalmology, Conquest Hospital, St. Leonards-on-Sea, TN37 7RD, UK
[3]Department of Plastic Surgery, Queen Elizabeth Hospital, Birmingham, B15 2TH, UK
**Correspondence to:** Christopher B. Schulz. Eye Unit, Royal Bournemouth Hospital, Bournemouth, BH7 7DW, UK. chrisschulz@doctors.org.uk
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## Abstract

**• AIM: To explore the trends in the ophthalmic literature over a 5-year period in relation to country, research expenditure and demographics.**

**• METHODS: Articles published between 2009 and 2013 by the 20 highest-contributing countries in the 20 top-ranked ophthalmology journals were identified by their country of affiliation. The number of articles published and mean impact factor were measured per country for each year and trends explored using regression analysis with 5-year and 10-year forecasts calculated. Data on research expenditure was collected and tested for correlation with the number of articles and mean impact factor.**

**• RESULTS: The analysis included 19 338 articles. The USA, UK and Europe accounted for 60.2% of articles published, with the USA contributing 7388 articles (34.0%). The USA also demonstrated the highest mean impact factor (3.5). Research expenditure was significantly correlated with both research output ($r$=0.86, $P$<0.001) and scholarly impact ($r$=0.42, $P$<0.001). China ($P$<0.01), Korea ($P$<0.01) and India ($P$<0.02) demonstrated a significant growth in research output over the study period. The research contribution of these three countries combined is forecasted to overtake that of Europe within ten years, with China expected to be the second-largest contributor within five years. These countries were also among those demonstrating the greatest growth in research expenditure.**

**• CONCLUSION: While the USA and European countries are major contributors of ophthalmic research, the productivity of some Asian countries is growing impressively. The contribution of China, Korea and India is forecasted to outweigh that of Europe by 2023. Research expenditure is highly correlated with research productivity and these trends reflect the differing economic priorities across the world.**

**• KEYWORDS:** bibliometrics; ophthalmology; journal impact factor
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## INTRODUCTION

We live in an era of globalization, in which individuals and institutions from around the world play a role in the advances of ophthalmic research. In order for individual clinicians, health commisioners and governments to tackle the future burden of ocular disease that is specific to their own patient population, it is important that the evidence base is targeted to their own population's needs. Peer-reviewed publications form the basis of this evidence base. One method to quantitatively evaluate research output is through bibliometric analysis. Studying the origin, format, type and citation count of published journal articles provides an insight into the quantity and scholarly impact of research produced within a certain field. The number of articles published and the impact factor (IF) of articles can be used as a proxy for research productivity [1-2]. Recognizing and understanding the international trends in research output provides valuable insight into the direction of future ophthalmology research, and the future of our individual patients. Ohba [3] and Guerin *et al* [4] have previously (in 2005 and 2009, respectively) reported on the global publication output in ophthalmology journals. A country's expenditure on research has been shown to correlate with their productivity in ophthalmology research. The cause-effect relationship is poorly understood; although an increase in funding would be expected to equate to improved research productivity, it is also true that the publication track record of an individual researcher, organization and country affects where future investment is made. The global economic decline of 2009 (as defined by the International Monetary Fund [5]) provides a unique opportunity to provide an updated look on where global ophthalmology research is heading since the work of Ohba[3] and Guerin *et al*[4]. It also allows us to explore in more detail how differences in economic priority and research expenditure interplay with research output.

The aim of this study was to use bibliometric analysis to answer the following questions: 1) which countries contribute the most to the ophthalmic literature and how has the output and scholarly impact of each country evolved over the 5-year period between 2009 and 2013? 2) how has global expenditure on research evolved in the 5-year since the international economic recession of 2009? 3) what is the correlation between a country's gross expenditure on research and their research output in the field of ophthalmology?

## MATERIALS AND METHODS

We ranked the top 20 countries that contributed to ophthalmic research in 2013, using SCImago [6], which includes the journals and country indicators contained in the Scopus® database. Countries were ranked by the number of citations to all ophthalmology articles affiliated with that country between 2009 and 2013. The number of citations was used as a proxy measure of both productivity and impact of research.

We ranked ophthalmology-specific journals by mean 2-year IF between 2009 and 2013 using Thomson-Reuter's Journal Citation Reports®, and selected the top 20 for inclusion[7]. Although the 5-year IF could be used to rank journals, the 5-year version may give an unbalanced bias toward articles that were published earlier within the preceding 5-year and so have had a longer timeframe in which to gain citations. To reduce this bias, we used the 2-year IF for each of the five years and calculated a mean IF. The IF for any journals that underwent a change in title during this period was recalculated using data from both before and after this change. Any journals without an IF for each of the five years were excluded. The PubMed® database[8] was used to identify the number of scientific articles published in each of the 20 selected journals between the years 2009 and 2013. Editorials, letters, comments and congress abstracts were excluded. The first author's country of affiliation for each article was identified at this stage as recorded in the PubMed database. The number of articles published by the first author of each country was used as the primary measure of a country's productivity.

A secondary measure of a country's productivity was to explore the scholarly impact of published articles. Each country's total IF per year was calculated by adding the multiples of each journal IF for each year and the number of articles published by that country in that journal. A country's mean IF for each year was calculated by dividing its total IF by the total number of articles published by that country in that year. We sourced data regarding the number of ophthalmologists in each country based on previous work conducted by the International Council of Ophthalmology in 2010 [9]. Demographic data for each country between 2009 and 2013 was collected using the Organization for Economic Cooperation and Development (OECD) database [10] and the World Data Bank [11]. Data collected included population, gross domestic product (GDP) and gross expenditure on research and development (GERD).

We conducted regression analysis to explore trends in the number of articles published, the mean IF, and GERD for each country over the 5-year study period and to forecast the number of published articles expected in 2018 (5-year) and 2023 (10-year). Spearman's correlation coefficient was calculated to test the association between both GERD and GERD/GDP in each country with both the number of articles published and the mean IF for that country. We also tested for correlation between the number of registered ophthalmologists in a given country, with the countries' number of publications.

## RESULTS

The top 20 countries ranked by the number of citations for all ophthalmology articles are listed in Table 1. The top 20 ophthalmology-specific journals included for analysis are detailed in Table 2. Between 2009 and 2013, a total of 21 737 articles were identified as being eligible for inclusion in this study. Of these, 19 338 (89.0%) were affiliated with one of the included 20 countries and underwent further analysis.

The USA published 7388 articles between 2009 and 2013, 34.0% of the entire sample included. Other major contributors in terms of absolute quantity of publications include the UK (9.6%), Japan (6.9%), China (4.9%), Germany (4.9%) and Australia (4.5%). For all countries, we looked at the trend over five years by performing regression analysis. Only three countries demonstrated a statistically significant positive trend over 5-year: China ($P$<0.01), Korea ($P$ <0.01) and India ($P$ <0.02). No country showed a statistically significant negative trend in the number of publications in the study timeframe. The trends in this analysis were used to forecast the percentage contribution to ophthalmology research, categorized by geographical location in 2018 (5-year) and 2023 (10-year). These forecasts are depicted in Figure 1.

**Scholarly Impact of Ophthalmic Research Output by Country** The USA had the highest mean IF of 3.48 for articles published between 2009 and 2013. Most countries had a mean IF greater than 3.00, with the Netherlands, Singapore, Japan and France completing the top 5 countries ranked by mean IF in the study timeframe. Of the 20 included countries, three showed a significantly positive trend in the mean IF over the study period: Singapore ($P$<0.05), Korea ($P$=0.04) and Spain ($P$=0.02). No country showed a significantly negative trend in mean IF over the 5-year period (Table 3).

**Table 1 Top 20 countries contributing to ophthalmology journals**

| Countries | Citable documents | Citations |
|---|---|---|
| USA | 3310 | 9563 |
| UK | 938 | 2474 |
| Germany | 837 | 2160 |
| Japan | 1058 | 1680 |
| Australia | 540 | 1664 |
| China | 1992 | 1541 |
| Spain | 446 | 982 |
| Italy | 350 | 949 |
| Canada | 351 | 911 |
| Korea | 405 | 832 |
| India | 513 | 756 |
| France | 358 | 736 |
| Turkey | 589 | 681 |
| Switzerland | 188 | 549 |
| The Netherlands | 174 | 547 |
| Brazil | 330 | 519 |
| Singapore | 177 | 482 |
| Greece | 138 | 430 |
| Austria | 124 | 394 |
| Hong Kong (China) | 115 | 311 |

Ranked by the number of citations for each article, as identified from the Scopus® database[6].

**Table 2 Top 20 ophthalmology journals ranked by mean IF for the years 2009-2013**

| Journals | Mean IF[a] | Total articles published[b] |
|---|---|---|
| *Progress in Retinal and Eye Research* | 9.4 | 155 |
| *Ophthalmology* | 5.5 | 1749 |
| *American Journal of Ophthalmology* | 4.0 | 1359 |
| *JAMA Ophthalmology/Archives of Ophthalmology* | 3.9 | 1196 |
| *The Ocular Surface* | 3.6 | 129 |
| *Investigative Ophthalmology and Visual Science* | 3.5 | 4863 |
| *Survey of Ophthalmology* | 3.0 | 226 |
| *Experimental Eye Research* | 2.9 | 1078 |
| *Retina* | 2.9 | 1454 |
| *British Journal of Ophthalmology* | 2.9 | 1582 |
| *Journal of Vision* | 2.9 | 1452 |
| *Journal of Cataract & Refractive Surgery* | 2.6 | 1562 |
| *Current Opinion in Ophthalmology* | 2.6 | 418 |
| *Journal of Refractive Surgery* | 2.5 | 634 |
| *ActaOphthalmologica* | 2.5 | 980 |
| *Eye* | 1.9 | 1186 |
| *Journal of Glaucoma* | 1.9 | 626 |
| *Clinical & Experimental Ophthalmology* | 1.8 | 549 |
| *Visual Neuroscience* | 1.7 | 170 |
| *Ophthalmic & Physiological Optics* | 1.7 | 368 |

[a]Based on Thomson-Reuter's Journal Citation Reports® [7]; [b]Excluding editorials, letters, comments and congress abstracts.

**Number of Ophthalmologists** The top 5 countries ranked by the number of articles published per registered ophthalmologist per year were Singapore (0.54), Australia (0.22), Hong Kong (China) (0.19), the UK (0.13) and Canada (0.09). The number of ophthalmologists registered in a country was significantly correlated with the number of articles published in that country ($r$=0.47, $P$=0.036; Pearson's) (Table 4).

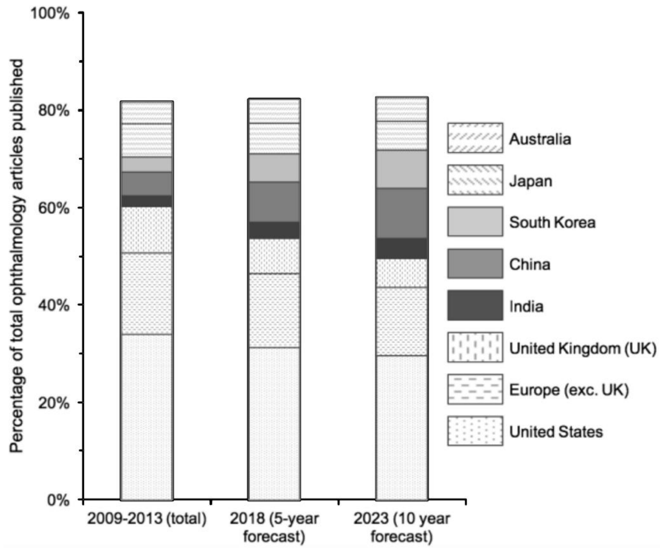


**Figure 1 Proportion of ophthalmology research published by country of affiliation between 2009 and 2013, compared with forecasted data for 2018 and 2023.**

**Gross Expenditure on Research and Development** GERD was positively correlated with both the number of articles published ($r$=0.79; $P$<0.0001; Pearson's) and the mean IF ($r$=0.36; $P$<0.0008) in each country. We also found a significant correlation between research expenditure as a percentage of GDP (GERD/GDP) and both the number of articles published ($r$=0.48; $P$<0.0001) and mean IF ($r$=0.58; $P$<0.0001). The countries with the greatest increase in GERD per year (Table 4) were China (20.8% of 2009 GERD per year; $P$<0.001), Turkey (12.9%; $P$<0.001), Korea (12.6%; $P$<0.001), Brazil (9.9%; $P$=0.057) and India (9.8%; $P$<0.001). Data was unavailable for Hong Kong and Switzerland and they were excluded from GERD analysis.

## DISCUSSION

**Research Output and Growth** The USA, UK and Europe account for around 60% of articles published within the ophthalmology literature between 2009 and 2013 (Figure 1). As in other medical and surgical specialties[2,12], the USA is by far the greatest contributor of ophthalmic research, with north American institutions being affiliated with over a third of publications in this study. Based on Ohba's [3] study between 1988 and 2002, and the work of Guerin *et al*[4] between 2002 and 2006, the USA's foothold at the forefront of research continues to stand the test of time. Indeed, the top 5 contributing countries in terms of publication volume has changed little since the time of either of these studies. The exception to this is that China is now ranked 4th (previously ranked 10th in 2002-2006.) Based on Guerin *et al*'s [4] data, China contributed 1.1% of the global ophthalmic literature in 2002, with India contributing 1.0%. By 2006 this had grown to 2.1% and 1.7% respectively. Since the global economic downturn of 2009 [5], our study demonstrates continued significant growth in the ophthalmic research output of both

**Table 3 Bibliometric analysis of published articles in the top 20 ophthalmology journals between 2009 and 2013, listed by country of affiliation**

| Country | Articles | | | % change per year in number of articles published | | | Mean IF[c] | Rank | Change in IF per year | |
|---|---|---|---|---|---|---|---|---|---|---|
| | No. of included journal articles[a] | % of total | Rank | CI[b] | *P* | Rank | | | CI[d] | *P* |
| Australia | 987 | 4.5 | 6 | +1.6 (-5.3 to 8.4) | 0.52 | 9 | 3.1 | 13 | +0.08 (-0.10 to 0.26) | 0.26 |
| Austria | 233 | 1.1 | 17 | +3.3 (-19.5 to 26.0) | 0.68 | 6 | 3.2 | 11 | -0.05 (-0.23 to 0.13) | 0.42 |
| Brazil | 216 | 1.0 | 19 | -1.1 (-14.5 to 12.4) | 0.82 | 15 | 3.0 | 17 | +0.02 (-0.09 to 0.14) | 0.55 |
| Canada | 536 | 2.5 | 9 | +1.7 (-8.1 to 11.4) | 0.62 | 8 | 3.2 | 8 | +0.07 (-0.01 to 0.15) | 0.08 |
| China | 1062 | 4.9 | 4 | +14.0 (8.6 to 19.3) | <0.01 | 3 | 3.2 | 7 | +0.1 (-0.03 to 0.23) | 0.08 |
| France | 403 | 1.9 | 13 | +1.5 (-15.6 to 18.6) | 0.80 | 10 | 3.3 | 5 | +0.01 (-0.19 to 0.21) | 0.88 |
| Germany | 1004 | 4.6 | 5 | -2.8 (-9.9 to 4.3) | 0.30 | 17 | 3.0 | 14 | +0.05 (-0.06 to 0.15) | 0.24 |
| Greece | 140 | 0.6 | 20 | -3.6 (-17.5 to 10.2) | 0.46 | 18 | 2.8 | 19 | +0.06 (-0.06 to 0.18) | 0.21 |
| Hong Kong (China) | 217 | 1.0 | 18 | -0.2 (-7.2 to 6.7) | 0.93 | 13 | 3.2 | 6 | +0.24 (-0.10 to 0.58) | 0.11 |
| India | 463 | 2.1 | 11 | +14.9 (5.1 to 24.6) | <0.02 | 2 | 3.0 | 15 | +0.13 (-0.09 to 0.35) | 0.16 |
| Italy | 516 | 2.4 | 10 | +4.3 (-3.9 to 12.5) | 0.19 | 5 | 3.1 | 12 | +0.06 (-0.01 to 0.13) | 0.08 |
| Japan | 1490 | 6.9 | 3 | -0.4 (-2.9 to 2.1) | 0.65 | 14 | 3.3 | 4 | +0.05 (-0.06 to 0.16) | 0.25 |
| The Netherlands | 407 | 1.9 | 12 | +0.1 (-11.5 to 11.7) | 0.98 | 11 | 3.5 | 2 | +0.14 (-0.08 to 0.35) | 0.14 |
| Singapore | 356 | 1.6 | 14 | +8.0 (-5.6 to 21.7) | 0.16 | 4 | 3.4 | 3 | +0.10 (0.003 to 0.20) | <0.05 |
| Korea | 673 | 3.1 | 7 | +32.5 (15.6 to 49.4) | <0.01 | 1 | 3.2 | 9 | +0.10 (0.01 to 0.19) | 0.04 |
| Spain | 670 | 3.1 | 8 | +2.4 (-3.0 to 7.9) | 0.25 | 7 | 3.0 | 16 | +0.10 (0.03 to 0.17) | 0.02 |
| Switzerland | 250 | 1.2 | 15 | -8.1 (-21.6 to 5.5) | 0.15 | 20 | 3.2 | 10 | +0.06 (-0.13 to 0.25) | 0.39 |
| Turkey | 248 | 1.1 | 16 | -5.5 (-15.7 to 4.8) | 0.19 | 19 | 2.6 | 20 | +0.03 (-0.09 to 0.14) | 0.52 |
| UK | 2079 | 9.6 | 2 | -2.4 (-8.2 to 3.5) | 0.29 | 16 | 2.8 | 18 | +0.06 (-0.07 to 0.20) | 0.24 |
| USA | 7388 | 34.0 | 1 | -0.1 (-6.3 to 6.0) | 0.96 | 12 | 3.5 | 1 | +0.09 (-0.03 to 0.22) | 0.09 |
| Other | 2399 | 11.0 | | +0.5 (-6.9 to 7.82) | 0.86 | | | | | |
| All publications | 21737 | 100.0 | | | | | 3.13 | | | |

[a]Excluding editorials, letters, comments and congress abstracts; [b]Calculated using regression analysis over the period of 2009-2013 and presented as a percentage of articles published in 2009; [c]Mean IF represents the multiple of 2-year journal IF and number of articles published in that journal divided by the total number of articles published; [d]Calculated using regression analysis over the period 2009-2013.

**Table 4 Demographics of the top 20 countries contributing to the ophthalmic literature**

| Country | Articles | | | GERD | | | | GERD/GDP | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Ophthalm-ologists[a] | Articles per ophthalmologist per year | Rank | Average GERD/year[b] | % change in GERD/year (CI)[c] | *P* | Rank | GERD /GDP[d] | % change in GERD/GDP/year (CI)[c] | *P* | Rank |
| Australia | 895 | 0.22 | 2 | 2355.07 | +2.0 (0.6 to 3.5) | 0.020 | 14 | 0.2 | -2.3 (-3.9 to -0.8) | 0.017 | 15 |
| Austria | 800 | 0.06 | 10 | 10109.04 | +7.0 (5.0 to 9.0) | 0.001 | 7 | 2.7 | +3.0 (0.8 to 5.3) | 0.022 | 6 |
| Brazil | 14679 | 0.00 | 20 | 32846.27 | +9.9 (-1.4 to 21.2) | 0.057 | 4 | 1.2 | +1.9 (-15.4 to 19.1) | 0.401 | 7 |
| Canada | 1137 | 0.09 | 5 | 25027.25 | -0.3 (-1.6 to 0.9) | 0.457 | 17 | 1.8 | -4.1 (-4.6 to -3.7) | <0.001 | 18 |
| China | 28338 | 0.01 | 19 | 254951.47 | +20.8 (17.3 to 24.4) | <0.001 | 1 | 1.9 | +5.7 (4.0 to 7.4) | 0.002 | 2 |
| France | 7000 | 0.01 | 17 | 52734.91 | +3.0 (1.7 to 4.2) | 0.005 | 12 | 2.2 | +0.0 (-0.6 to 0.5) | 0.832 | 11 |
| Germany | 6638 | 0.03 | 12 | 93723.41 | +5.9 (2.9 to 9.0) | 0.009 | 9 | 2.8 | +1.6 (0.1 to 3.2) | 0.043 | 8 |
| Greece | 2000 | 0.01 | 15 | 2052.78 | +1.4 (-6.2 to 9.0) | 0.590 | 15 | 0.7 | +7.2 (-0.8 to 15.2) | 0.065 | 1 |
| Hong Kong (China) | 230 | 0.19 | 3 | - | - | - | - | | | | |
| India | 11000 | 0.01 | 18 | 43110.01 | +9.8 (1.5 to 18.1) | 0.042 | 5 | 0.8 | -0.8 (-14.4 to 12.9) | 0.600 | 12 |
| Italy | 4074 | 0.03 | 13 | 25787.93 | +2.2 (0.7 to 3.7) | 0.018 | 13 | 1.2 | +1.1 (-0.8 to 3.0) | 0.155 | 9 |
| Japan | 13911 | 0.02 | 14 | 147601.49 | +4.2 (3.1 to 5.3) | 0.001 | 10 | 3.4 | +0.6 (-1.2 to 2.4) | 0.359 | 10 |
| The Netherlands | 916 | 0.09 | 6 | 14075.45 | +6.7 (2.6 to 10.8) | 0.014 | 8 | 1.8 | +4.5 (1.6 to 7.5) | 0.016 | 4 |
| Singapore | 131 | 0.54 | 1 | 7596.96 | +8.7 (-3.0 to 20.4) | 0.085 | 6 | 2.1 | -1.6 (-9.7 to 6.5) | 0.489 | 14 |
| Korea | 2026 | 0.07 | 8 | 57986.98 | +12.7 (11.3 to 14.0) | <0.001 | 3 | 3.7 | +5.4 (4.3 to 6.6) | 0.001 | 3 |
| Spain | 3305 | 0.04 | 11 | 19925.23 | -1.8 (-2.6 to -1.0) | 0.005 | 18 | 1.3 | -2.4 (-2.7 to -2.1) | <0.001 | 16 |
| Switzerland | 758 | 0.07 | 9 | - | - | - | - | | | | |
| Turkey | 3550 | 0.01 | 16 | 11142.222 | +12.9 (11.3 to 14.6) | <0.001 | 2 | 0.9 | +3.2 (1.5 to 5.0) | 0.010 | 5 |
| UK | 3200 | 0.13 | 4 | 39083.084 | +0.4 (-1.4 to 2.2) | 0.525 | 16 | 1.7 | -2.5 (-4.3 to -0.8) | 0.020 | 17 |
| USA | 18805 | 0.08 | 7 | 427659.6 | +3.1 (1.9 to 4.4) | 0.004 | 11 | 2.7 | -0.8 (-1.9 to 0.3) | 0.107 | 13 |

[a]Based on 2010 data[9]; [b]GERD reported in million dollars of purchasing power parity where data available; [c]Calculated using regression analysis over the period 2009-2013; [d]Calculated using GDP reported in dollars of purchasing power parity; Data for Hong Kong and Switzerland were not available.

China and India, in addition to Korea. This is in contrast to the static nature of the USA and other countries. Specifically, between 1988 and 2002, the USA produced 49.5% of ophthalmology articles and during this time Ohba [3] also observed a relative decline. Between 2002 and 2006 the USA's contribution to the global ophthalmic literature was observed to be 44.1% based on the work of Guerin *et al* 's[4]. Since the economic downturn of 2009, we have shown that the USA's contribution to the ophthalmic literature has continued to lessen in relative terms, so that American centres now account for 34% of ophthalmology publications between 2009 and 2013. As in Guerin *et al* 's [4] study, we noted a possible negative trend in the publication counts of the UK and Germany (both traditionally major contributors) although these trends did not reach statistical significance (Table 3). If the trends that we observed in this five-year period continue, we would expect China to be the second largest contributor by 2018 (Figure 1). While we expect the USA to remain the dominant figure in ophthalmic research for at least the next 10y, the combined research output of China, Korea and India may exceed the total research contribution of the UK and Europe by 2023. This finding is reflected in other global economic studies that show a shift in research and development from the west to the east [13-16]. Since 2009, the strong economic growth of Asian countries is found to be in stark contrast to the tepid economic recovery of the USA and Europe. This is highlighted by the finding that the research output is significantly correlated with both GERD and GERD/GDP. While a number of Asian countries continue to have aspirations for innovation-based growth and aggressive plans for research and development, the recent economic priorities of Europe and the USA have been to reduce public deficit and government debt. This is reflected in our study; China, Korea and India are all ranked within the top 5 countries with the greatest growth in GERD.

Considering GERD as a proportion of GDP, China and Korea demonstrated the most significant 5-year growth (Table 4). Indeed, China has seen a 12% -20% growth in GERD consistently for the past twenty years and its financial commitment to research and development is expected to surpass that of the USA by 2022[14-16]. This is in stark contrast to the USA and UK that demonstrated slower rates of growth in GERD, being ranked 11$^{th}$ and 16$^{th}$ respectively for growth in GERD (Table 3). Austria, the Netherlands and Germany were the only European countries to be ranked in the top ten for GERD, despite the inclusion of nine European countries in this study. As a proportion of GDP, we noted that Spain, the UK and Canada showed significant depreciation in GERD (Table Our findings that both GERD and GERD/GDP are strongly correlated with the output of ophthalmology research is in agreement with other more general studies[12,17-19].

**Scholarly Impact** In terms of scholarly impact, we attempted to quantify this by calculating a mean IF for each country's contribution to the ophthalmology literature, as has been done in other studies of this kind [2,12]. In parallel with these studies, the USA tops this table with a mean IF of 3.5. Despite being the second highest contributor in terms of volume of ophthalmic research, we were intrigued to find that the UK was ranked 18$^{th}$ out of 20 based on its mean IF. A similar finding was found in a bibliometric study of plastic and reconstructive surgery literature [12]. Our finding that research expenditure in each country is correlated with the mean IF of articles published in that country expands on the work of Svider *et al* [20]. In that study, the funding of research was associated with the scholarly impact of ophthalmic publications in American institutions. Now it is becoming increasingly clear that there is an inextricable link between a country's research expenditure and both the volume and impact of their ophthalmic research output.

**Research Output per Ophthalmologist** We also ranked countries by their research output per ophthalmologist. Some studies have commented on the ratio of publications to the size of a country's population [2,12]. However, we believe that number of ophthalmologists in each country is a more useful indicator as it factors in population size, resources, the burden of eye disease and a country's commitment to ophthalmic services. The number of ophthalmologists was significantly correlated with both the quantity and scholarly impact (mean IF) of published articles. Singapore, Australia, Hong Kong (China), UK and Canada were the top 5 ranked countries for articles published per ophthalmologist. A more focused study is needed to explain why some countries with fewer ophthalmic clinicians produce higher volumes of research. Previous research does provide some speculation. For instance,it has been previously suggested that in Australia, productivity is correlated to the number of active researchers [21]. A study of ophthalmology research in Canada demonstrated that both institutional funding and the activity of individual researchers were important factors that were associated with research output[22].

**Disease Burden and Trends in Ophthalmic Research** Although we did not examine specific research topics, the above trends may also provide some indication as to the likely future direction of global ophthalmic research. The disease burden varies from country to country and it follows that the research priorities will also differ. The USA, UK, Australia and European countries accounted for a two-thirds share of the global ophthalmic research output based on our study. Considering the high proportion of visual impairment attributable to age-related macular degeneration (AMD) and diabetic eye disease in these countries, the recent advances in treating those diseases will come as little surprise [23]. As the research contribution of countries such as China, Korea and India grow, we expect that the research priorities of these countries will reflect their own disease burden. In these countries, a smaller proportion of visual impairment is caused by AMD and diabetes, whereas cataract and glaucoma are more common causes of blindness [23]. Indeed, the case of glaucoma highlights that prevalence of disease is not the only difference between the current top-ranked countries for research and those that are rapidly growing. There is also a notable difference in disease aetiology. More than 60 million people suffer from glaucoma worldwide and glaucomatous optic neuropathy causes around 10%-20% of blindness globally [24-25]. Research in traditional high output countries (USA, Europe, Australia) has focused on open angle glaucoma (OAG), which accounts for 90% of glaucoma cases in these populations [26]. This is in comparison to angle closure glaucoma (ACG), which blinds ten times more people than OAG [25], and of which 85% of cases are to be found in China, India and south-east Asia [26]. It is speculated that as the research contribution of these countries grow, future scientific advances will reflect the differing ophthalmic needs of these populations. It should also be noted that no African country contributed enough to the ophthalmic literature to be included in our study, despite Africa having the greatest prevalence of blindness and visual impairment worldwide [24]. The imbalance between global research and global blindness has been observed previously [27], but a more in-depth analysis would be required in order to comment on whether progress is being made in this region. As clinicians, it is essential that we understand the differences between the patients that we serve and the populations on which our evidence is based.

**Limitations** Articles were identified and categorized according to the country of the first author using data submitted to the PubMed database. Global collaboration is ever more commonplace. For example, in 2013, 28.52% of the USA contribution to medical journals included authors from other countries[6]. It could be perceived that considering only the primary author's institution neglects the contribution of other countries in a global research network, particularly where the senior author is from another country. Unfortunately, when multiple authors are assigned to an article, it is difficult to make any judgement about the relative contribution of each author. This will certainly vary between articles. That said, it is reasonable to assume that in almost all cases, the first author will have played a key role in the research and article submission process [28]. With the size of our dataset, it is reasonable to accept that the primary author's country of affiliation is the most reliable indicator for comparing the research contribution of different countries.

Another potential limitation is the number of journals that were cross-examined in this study. Indeed, Thomson-Reuter's Journal Citation Reports® includes 57 ophthalmology specific journals in 2013 [7]. However, we feel that the top 20 journals that have been included in our study give an acceptable overview of the ophthalmic literature. It should be noted that all of these journals are published in the English language, which is generally regarded as the predominant language in contemporary medical research [29]. However, it should be appreciated that this may produce a bias toward English-speaking countries. Additionally, it was outside the scope of this study to look at any articles published in journals that are not ophthalmology-specific. That said that our study was able to analyse a very large sample of the overall population of ophthalmic research articles. It is unclear exactly what proportion of this population our sample represents. There are likely important differences between our sample and the overall population. For example, those articles that are published in more general medical and scientific journals might be skewed particularly toward higher quality research with a higher rate of citation. Chen and Jhanji[30] noted that around 25% of ophthalmic systematic reviews and Meta-analyses are published in non-ophthalmic journals. While it is difficult to comment on the differences between the contribution of countries to ophthalmic or non-ophthalmic journals, it is somewhat reassuring that the major contributing countries of articles in Chen and Jhanji[30] study are similar to those found in ours.

Our study explored 19 338 articles published annually in 20 countries and 20 journals over a 5-year period. The inclusion of more countries may provide an even more comprehensive overview, although would only have provided an additional 2399 articles (11.0%). None of the excluded countries would be expected to individually account for more than 1% of our data, with most contributing significantly less. It is reassuring that all top 10 countries identified in previous reports are accounted for in our dataset.

We used the 2-year journal IF as a general measure of scholarly impact. In essence, this indicates the average number of times an article published within the preceding 2y in that journal is likely to be cited. It is the most established and well-understood metric [1]. The advantage of using the IF over other popular metrics (such as the H-index) in our study is that the IF accounts for all articles within a single journal over 2y, rather than only a small proportion of highly cited articles. We studied around 90% of articles in each of the included journals over that time frame, and the IF gives a reasonable overview of all of these articles. That said, it should be recognized that there are some reservations with the use of IF as an absolute guide for scholarly impact and quality of research[31].

It should be noted that this study was not able to explore the subspecialty topic of research, the study design or the level of evidence of each article. It is anticipated that this will vary between countries but further work would be needed to explore this in detail.

The global trends in ophthalmology research continue to evolve. While the USA and Europe remain the major contributors, the output of Asian countries such as China, Korea, and India is increasing at an impressive rate. The expenditure of these countries on research and development reflects their growing economies and is in contrast to the economic difficulties of the USA and Europe. This shift in research may have implications for the direction of future ophthalmic research, and the findings of this study provide an important context to the evidence base that is relied on by governments, researchers and ophthalmic clinicians. Although the globalization of research clearly has benefits to patients worldwide, we must remember how to best apply this international evidence base to the needs of our own patient population. Even in times of austerity, in order to tackle the specific needs of a country's own ocular disease burden, governments and financial sponsors must be made aware of the inextricable link between research funding and output.

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