International Comparative Performance of Netherlands' Research Base - 2015

A report prepared by Elsevier's Analytical Services for AWTI

Executive summary International Comparative Performance of Netherlands' Research Base

The Netherlands produced nearly 228,000 publications from 2009-2013. Its overall output grew at a rate of 4.3%, which is higher than both the EU28 and the world. The overall field-weighted citation impact of the Netherlands' output is 1.78, or 78% higher than the world average. Moreover, although it comprises only 2% of the world's total output, the Netherlands accounts for around 6% of the world's top 1% most highly cited publications.

One contributing factor to the high overall FWCI of Netherlands' research is the country's international collaboration rate. Over half of the Netherlands' publications have at least one international co-author, and such internationally collaborative publications achieve a FWCI of 2.19, well above that of the country's overall publications. Across all subject areas, the Netherlands collaborates the most internationally in the Earth & Planetary Sciences; Physics & Astronomy; and Agricultural & Biological Sciences.

In contrast to the country's high levels of international collaboration, academic-corporate collaborations comprise a much smaller share of the country's total output (7.1%), and this share has declined slightly over time (-3.1% annually). Across all subject areas, the Netherlands sees the highest relative level of academic-corporate collaboration in Materials Science; Chemistry; and Chemical Engineering.

Using novel indicators of knowledge transfer such as corporate downloads and patent citations, this report examines the extent to which the corporate sector uses Netherlands' research across different subject areas. In all subject areas except for Multidisciplinary, the Netherlands' world corporate download share is higher than the corresponding world publication share. This implies that the Netherlands' publications are downloaded more frequently by the corporate sector than the world average. Netherlands' research in the Veterinary Sciences particularly stands out as its world corporate download share is three times that of its world publication share. Netherlands' research across nearly all subject areas is also cited in patents at rates higher than expected given their world publication share.

The Netherlands produces a high absolute and relative amount of research in Medicine (19,500 publications in 2013 alone and 48% more than the world average given the country's total research output size), and publications in this subject area achieve a high relative citation impact (1.91). Moreover, Netherlands' research in Medicine accounts for 8.9% or almost 1 out of every 11 publications in the world's top 1% most cited in Medicine. More generally, the country produces both a high relative share of and highly impactful research in the Life and Health Sciences.

Within Medicine, the Netherlands performs exceptionally well in several sub-areas. Netherlands' research in Rheumatology achieves a relative activity index of 2.29 (twice as much relative activity in this sub-area than the world average) and a FWCI of 2.16. Furthermore, the Netherlands account for 27.9% of the world's top 1% most cited research in Rheumatology (compared to a 6.9% world publication share).

In terms of knowledge transfer, the country's world corporate download share for Genetics (clinical) (17.9%) is nearly twice the value of the country's world publication output share, and publications from 2009-2013 have already garnered 102 patent citations.

Another subject area of focus for the country is Computer Science. The Netherlands has seen a slight decline in the overall absolute levels of output (-1.25% annually). The FWCI of its output in this area is 1.64, or 64% above the world average. Within Computer Science, the Netherlands achieves the highest FWCI in the sub-area of Information Systems (2.01). The country also performs well in the sub-area of Human-Computer Interaction; although Netherlands' research comprises only 2.7% of the world publication share, it accounts for 6.24% of world's top 1% most cited.

Key Findings

TOTAL PUBLICATION OUTPUT, 2009-2013

227,854

FIELD-WEIGHTED CITATION IMPACT

1.78, 78% above world average

INTERNATIONAL COLLABORATION RATE

51.7%

KNOWELDGE TRANSFER | RELATIVE PATENT CITATIONS

1.98, nearly twice the world average

RESEARCH EXCELLENCE IN MEDICINE

Rheumatology

Netherlands accounts for 27.9% of the world's top 1% most cited research in this sub-area

RESEARCH EXCELLENCE IN COMPUTER SCIENCE

Human-Computer Interaction

Netherlands accounts for 6.24% of the world's top 1% most cited research in this sub-area

Preface

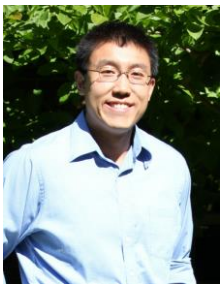
Elsevier is proud to be commissioned by the Advisory Council for Science, Technology, and Innovation (Adviesraad voor wetenschap, technologie en innovatie) in the Netherlands, also known as AWTI, to conduct an objective, bibliometrics-based assessment of Netherland's research performance compared to several comparator countries in the EU and outside of the EU, as well as the EU28 and the world as a whole.

The Advisory Council for Science, Technology and Innovation advises the Netherlands' government and parliament on policy in the areas of scientific research, technological development and innovation.

The purpose of this report is to provide a snapshot of the current status of research in Netherlands, with a particular focus on Medicine and Computer Science. By analyzing research from 2009-2013, the report provides a high level analysis of the country's research along multiple indicators of performance, collaboration, and knowledge transfer.

Elsevier hopes that this assessment will provide AWTI with a deeper understanding of the Netherlands' research performance and contribute to strategic decision-making in the future.

DR. THOMAS GURNEY



GEORGE LAN

DR. LEI PAN

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Introduction

A deep understanding of the current status of research performance of a country is important for its strategic policy making for future development. In this report, we give a comprehensive overview of the Netherlands' research output, growth, impact, usage, collaboration, and knowledge transfer. We also provide deeper analysis of two subject areas: Medicine and Computer Science.

The report provides both an internal comparative perspective (how does the Netherlands' research in Agricultural & Biological Sciences compare to the Netherlands' research in Biochemistry, Genetics, & Molecular Biology) and external benchmarks (how does the Netherlands' research in Computer Science compare to the EU28 or the USA's research in Computer Science).

The report is structured as follows: In Chapter 1, we present results on research output impact. We focus on the absolute number of publications, the compound annual growth rate (CAGR) of the publications, and the relative citation impact of the publications. In Chapter 2, we investigate to what extent the Netherlands' research is internationally collaborative and linked and used by the corporate sector. Chapter 3 focuses on the subject of Medicine and Chapter 4 shows the results on the subject of Computer Science. The details of the methodology and definitions of the indicators used in this report can be found in Appendix A.

"De AWTI wil een bijdrage leveren aan een kennissamenleving waarin iedereen met zijn talenten woekert, een cultuur waarin weetgierigheid, ondernemingszin en creativiteit tot bloei komen, en een toekomst waarin wij allemaal willen wonen."

The website of AWTI at http://www.awti.nl/

Chapter 1
Research Output and Impact

This chapter gives an overview of the Netherlands' research output and impact using the world and EU28 as the benchmarks.

1.1 Key Findings

TOTAL PUBLICATION OUTPUT

227,854

In 2009-2013, the Netherlands produced nearly 228,000 publications, thereby accounting for 2% of the world's total output in this period.

EU28 OUTPUT SHARE

6.7%

In 2009-2013, the Netherlands' publications accounted for 6.7% of the EU28's total output in this period.

COMPOUND ANNUAL GROWTH RATE

4.3%

Increasing its total publication output at 4.3% per year between 2009 and 2013, the Netherlands is growing faster than both the EU28 and the world.

FIELD-WEIGHTED CITATION IMPACT

1.78

The average field-weighted citation impact (FWCI) of the Netherlands in 2009-2013 is 78% above the world average.

TOP SUBJECT

Medicine

The Netherlands is highly prolific in Medicine in terms of absolute numbers of publications (almost 19,500 in 2013), output share (close to 40% in 2013) and in relative activity (publishing nearly 50% more in Medicine, relative to the world). It is also highly impactful, with an average 2009-2013 FWCI of 1.91.

1.2 Publication output

A traditional indicator of research intensity of a country is its scholarly output, as measured by the number of journal articles, conference proceedings, and reviews. **Figure *1.1*** presents the total output of the Netherlands from 2009 to 2013 (227,854 publications). Increasing from nearly 41,600 publications in 2009 to nearly 49,200 publications in 2013, the Netherlands shows a compound annual growth rate (CAGR)[1] of 4.3%. This is a higher growth rate than both the EU28 (3.6%) and the world (3.9%) for the same period. However, as the difference between these growth rates is small, the Netherlands' share of the EU28 and world output has been quite stable for 2009-2013, as seen in **Figure *1.2***. The Netherlands' share of the total EU28 output increased slightly from 6.6% to 6.8%. Its share of the total world output is just over 2% for most years – quite high considering its share of the world population (only 0.2%).

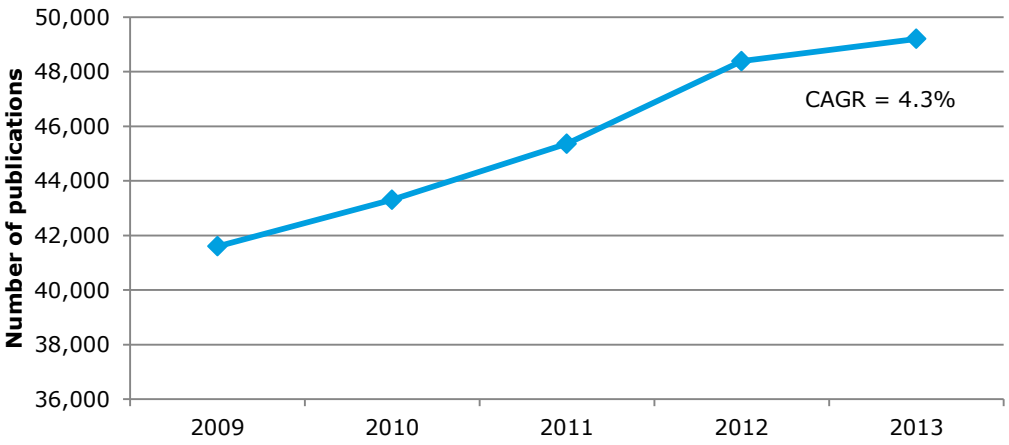


Figure 1.1— *Total number of publications of the Netherlands, per year, 2009-2013*

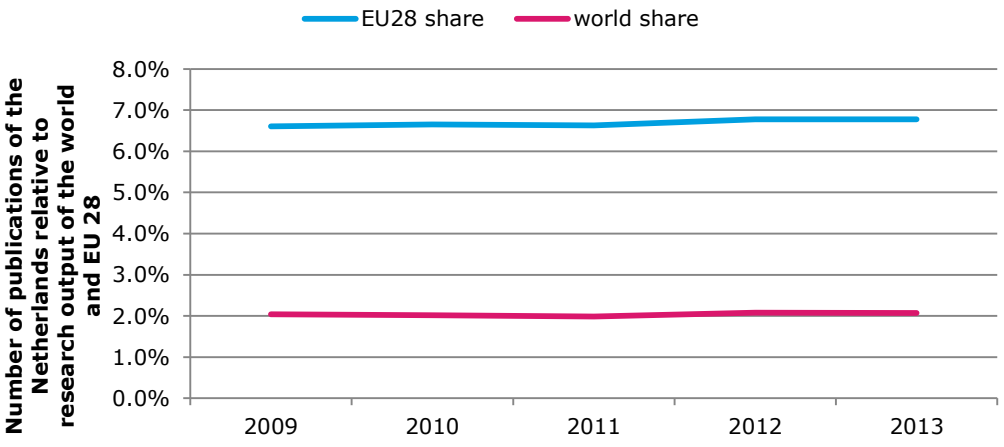


Figure 1.2— *The Netherlands' number of publications relative to EU28 and world output, per year, 2009-2013*

[1] Compound annual growth rate is defined as the year-over-year constant growth rate over a specified period of time. Starting with the first value in any series and applying this rate for each of the time intervals yields the amount in the final value of the series.

Zooming in to the subject level in **Figure *1.3***, we see that the Netherlands is most prolific in Medicine. With almost 19,500 publications in this subject in 2013, it accounts for 39.6% of the Netherlands' total research output of that year. Despite its already significant output, the increase in absolute number of publications in Medicine between 2009 and 2013 is by far the highest, and shows a CAGR of 6.2%; higher than the Netherlands' overall growth rate. On the other hand, the largest relative increase can be seen in Arts & Humanities. Increasing from 718 publications in 2009 to 2,338 publications in 2013, this subject area shows an incredibly high CAGR of 34.3%.

While most subjects increased in output – if not in their share of the total output, then at least in the absolute number of publications – there are a few subjects whose output decreased. Most notable among these are Engineering and Computer Science. Both published less in 2013 than in 2009, and show negative growth rates of -1.25% and -0.53%, respectively.[2]

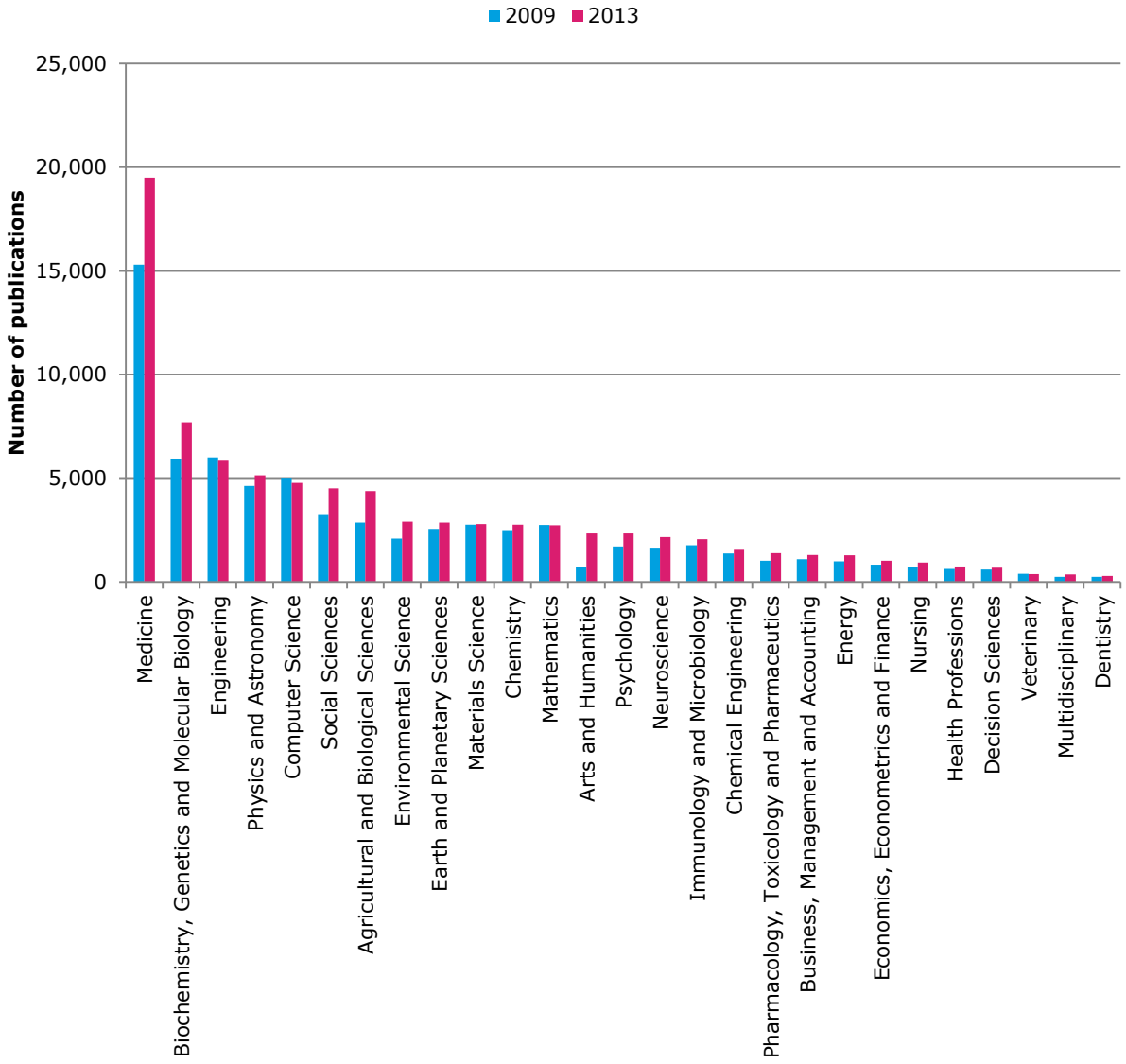


Figure 1.3— *Total number of publications of the Netherlands, per subject, 2009 and 2013*

In order to see where the Netherlands' research focus lies compared to the EU28 and the world, we calculate a relative activity index (RAI): each subject's share of the Netherlands' total output relative to the

[2] The slight decline in Computer Science output otherwise follows world trends – the total world output in Computer Science grew only 0.24% per year from 2009 to 2013. The decline in the Netherlands' Engineering output, however, is quite different from the world trend, which saw output in Engineering grow 5.14% per year from 2009 to 2013.

world's share in the same subject. For example, in 2009-2013 the Netherlands published 86,346 articles in Medicine, and 227,854 articles in total. In the same period, the world published 2,858,355 articles in Medicine and 11,177,089 articles in total. The RAI for the Netherlands in Medicine is therefore (86,346 / 227,854) / (2,858,355 / 11,177,089) = 1.48. This means that the Netherlands publishes 48% more in Medicine than the world average. So the Netherlands is highly prolific in Medicine in terms of the absolute number of publications, and also relatively more active in this subject. **Figure *1.4*** presents the RAI of the Netherlands and the EU28 for each subject.

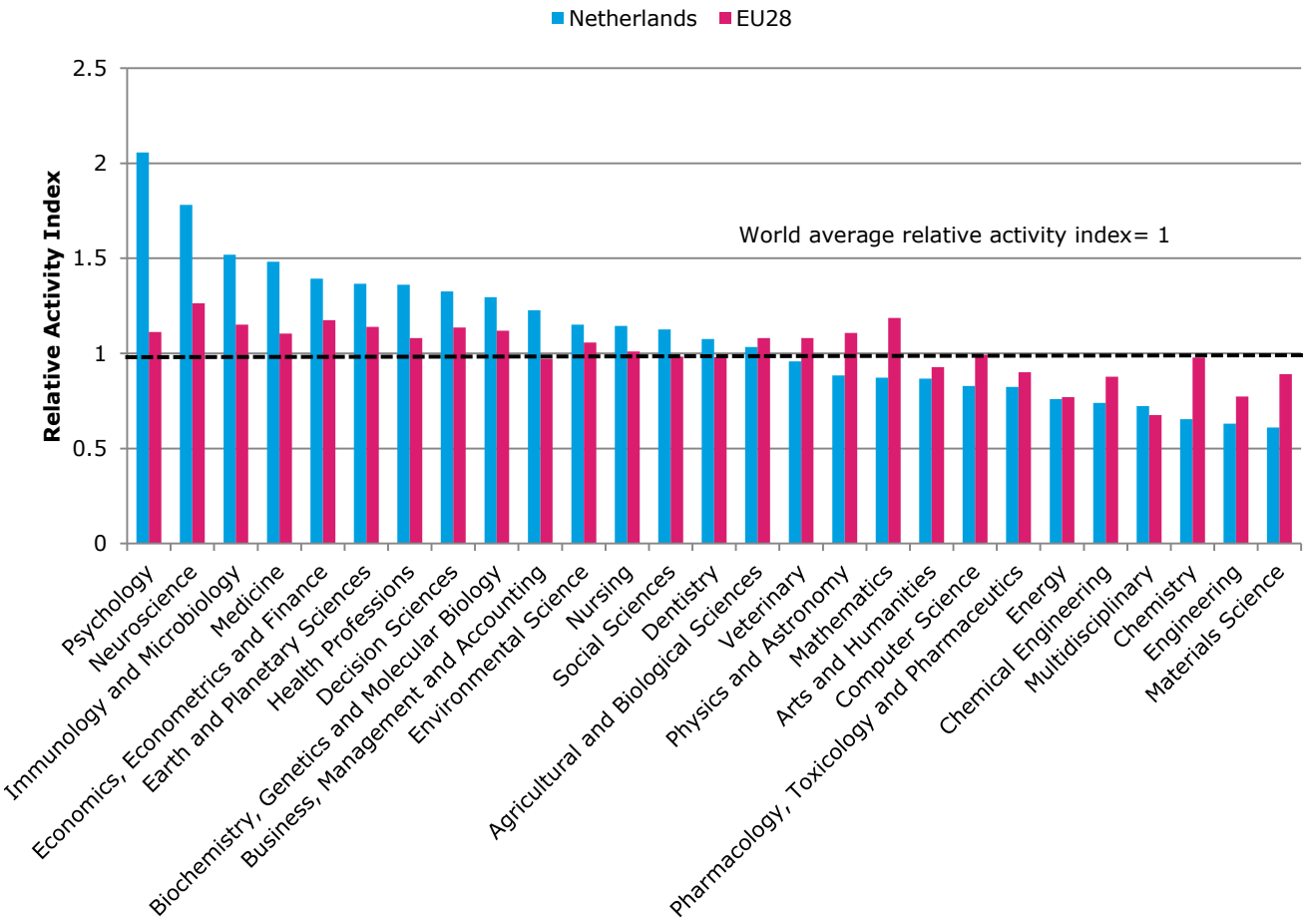


Figure 1.4— *Relative Activity Index for the Netherlands and EU28, per subject, 2009-2013*

As **Figure *1.4*** shows, the Netherlands' has a distinct focus on the Life Sciences[3] and Health Sciences[4] compared to the EU28 and world average. In relative terms, the Netherlands' level of activity is twice of the world average in Psychology, and 50% or more in Neuroscience; Immunology & Microbiology; and Medicine. On the other end of the spectrum, we see a lesser focus on Materials Science; Engineering; and Chemistry. In contrast to the Netherlands, the EU28 shows a relative activity that is equal to or higher than the world average in the Physical Sciences, such as Computer Science, Mathematics, and Physics & Astronomy.

[3] Includes subjects: Agricultural & Biological Sciences; Biochemistry, Genetics & Molecular Biology; Immunology & Microbiology; Neuroscience; Pharmacology, Toxicology & Pharmaceutics.

[4] Includes subjects: Medicine, Nursing, Veterinary, Dentistry, Health Professions.

1.3 Citation impact

When assessing research performance, in addition to publication volume, it is important to measure the quality of publications. Citations are widely recognized as a possible proxy for quality[5]. However, absolute counts of citations and citations per publication are not comparable across fields. Different subject fields have different citation behaviors (e.g., publications in Medicine often receive more citations than those in Mathematics), and may publish as different types of document (e.g., reviews often receive more citations than articles).

For this reason, we use Field-weighted Citation Impact (FWCI) as our main measure of citation impact. It is a measure of citation impact that normalizes for differences in citation activity by subject field, article type, and publication year, thus also making values comparable across these three dimensions. The world is indexed to a value of 1.00, meaning that values above 1.00 indicate above average citation impact. For example, a value of 1.78 indicates a citation impact that is 1.78 times the average or 78% above the average.

Figure *1.5* shows that the average FWCI of the Netherlands is consistently higher than the world average (by about 80%) and the EU28 average. However, whereas the FWCI of the Netherlands remains more or less at the same level, that of the EU28 slightly increased, from 1.23 in 2009 to 1.27 in 2013.

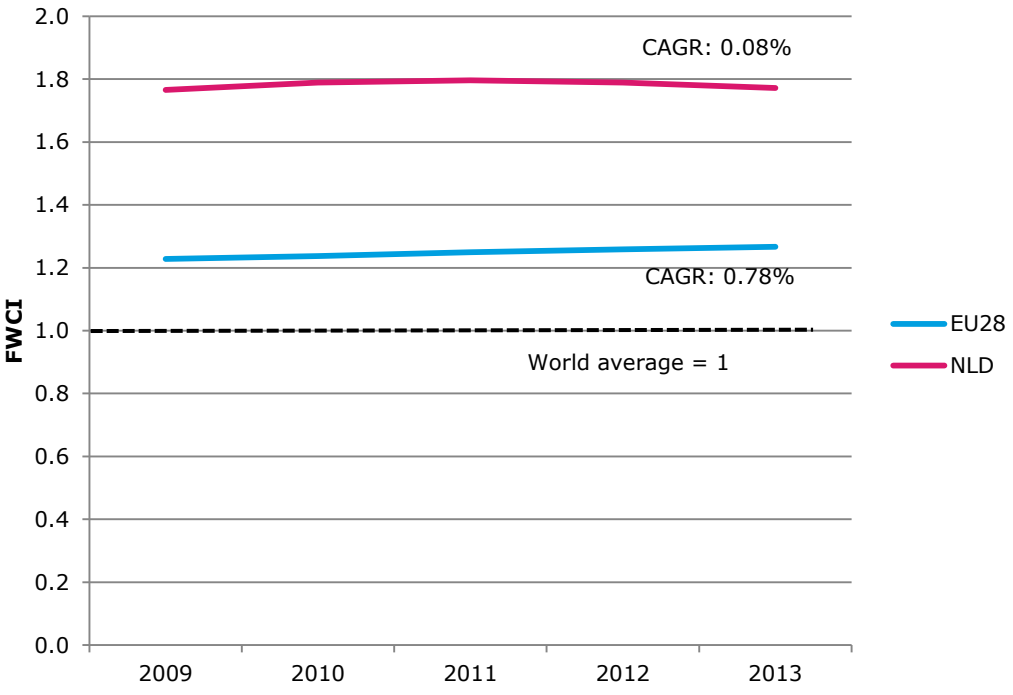


Figure 1.5— *Field-weighted citation impact of the Netherlands and EU28, all subjects, per year, 2009-2013*

As the FWCI in each subject has remained equally stable (changes ranging between -0.2 and +0.2), we forgo a comparison between years, and instead compare the average 2009-2013 FWCI of each subject with their total publication output over 2009-2013 in **Figure *1.6***.

[5] Davis, P. (2009) Reward or persuasion? The battle to define the meaning of a citation. Learned Publishing 22(1) pp. 5-11.

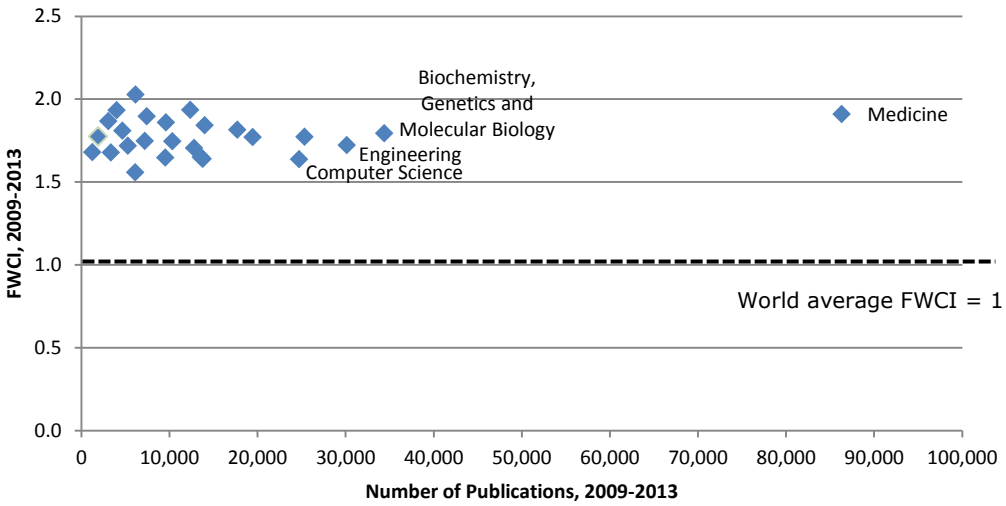


Figure 1.6— *FWCI vs number of publications for the Netherlands, per subject, 2009-2013*

In 2009-2013, all subjects achieve an average FWCI that is well above the world average: nearly all subjects are cited between 50% and 100% more. Business, Management & Accounting ranks first, with a FWCI of 2.03. As we had already seen, Medicine is by far the most prolific subject for the Netherlands. So prolific, in fact, that it skews the chart, making it difficult to see the differences between the other subjects.

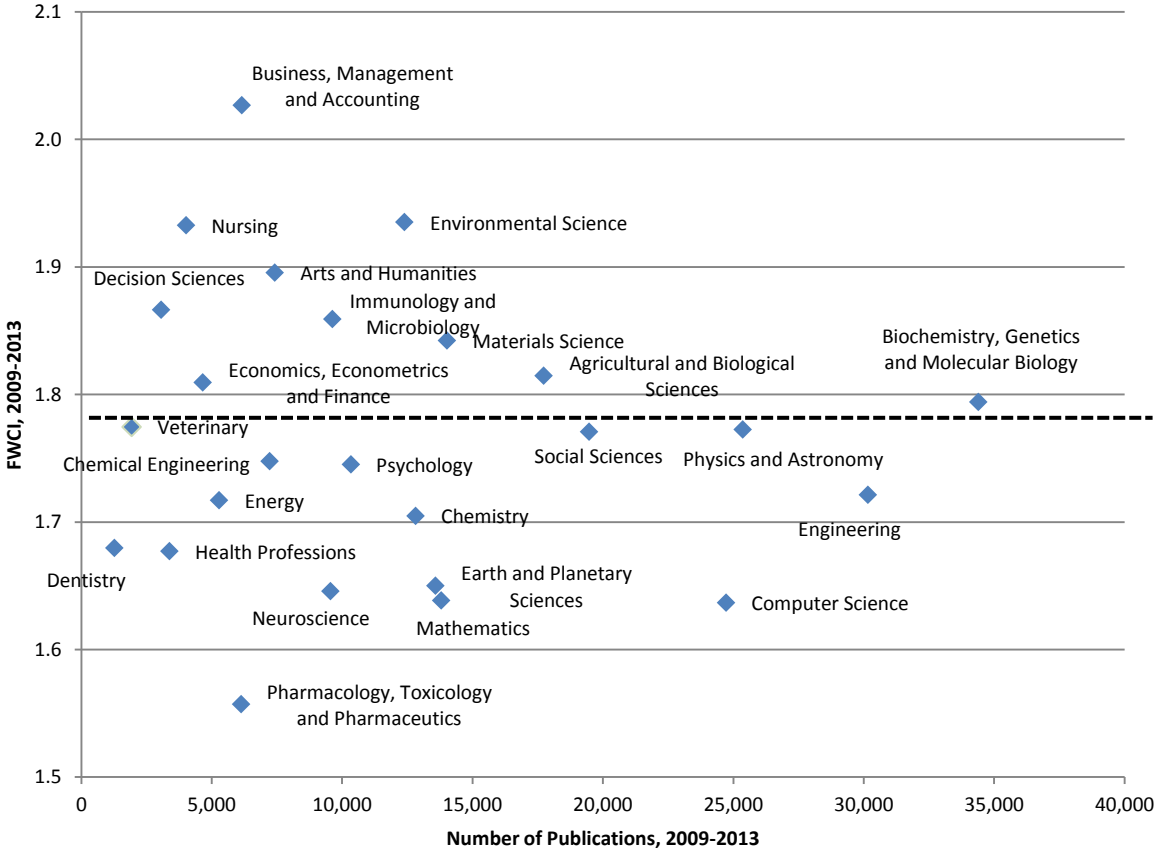


Figure 1.7 therefore zooms in on these subjects.

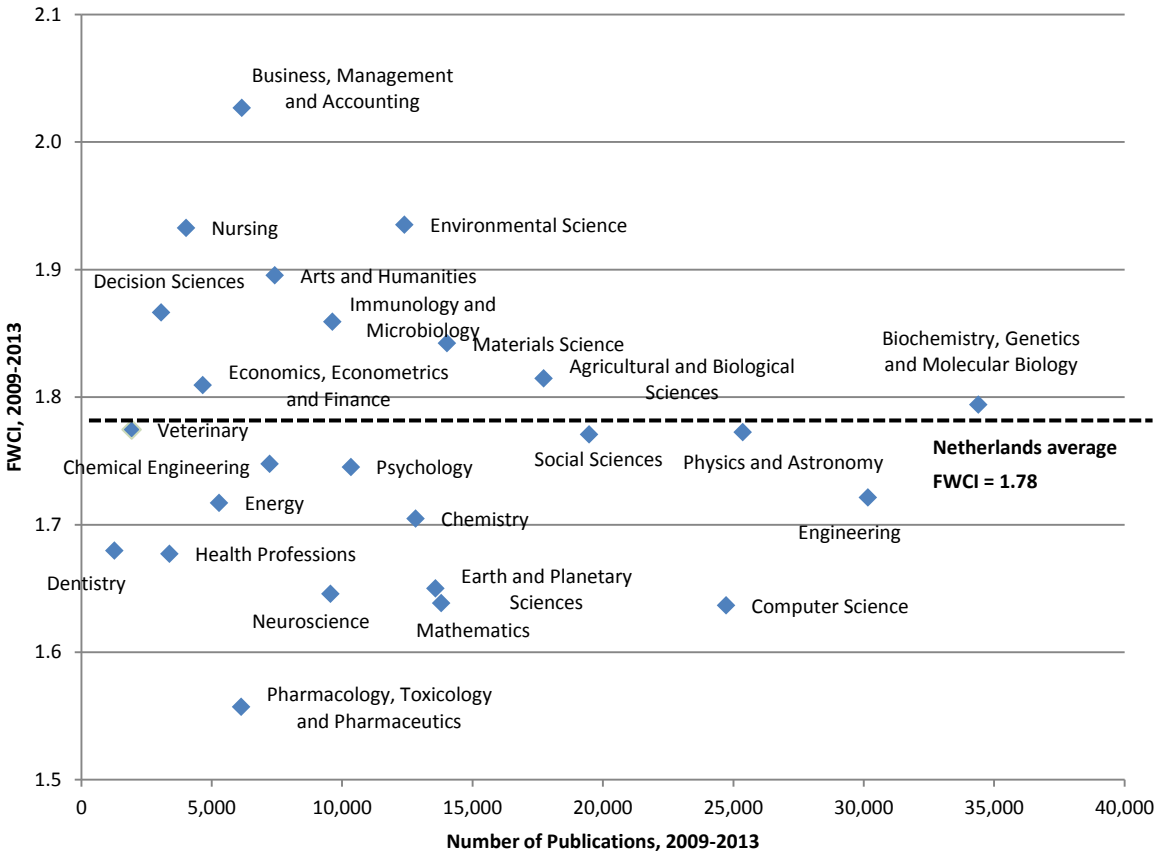


Figure 1.7— *Zoom in on FWCI vs number of publications for the Netherlands, per subject (excl. Medicine), 2009-2013*

The close-up chart shows that the subjects in which the Netherlands is most prolific or relatively active are not necessarily the most highly cited. Psychology for example – the subject with the highest relative activity index – has a FWCI of 1.75. While this is well above the world average, it is below the Netherlands' overall average FWCI. The same goes for Neuroscience – 2nd highest RAI – which has a FWCI of 1.65. Engineering and Computer Science are among the largest subjects by total publication output, but both score below the Netherlands' average in FWCI. Biochemistry, Genetics & Molecular on the other hand again scores well; its FWCI is just above the Netherlands' average, at 1.79. Immunology & Microbiology, which has the 3rd highest RAI, also has an above average FWCI, as does Economics, Econometrics & Finance, which has the 5th highest RAI.

Combining publication output share, RAI and FWCI into a single figure, we get **Figure *1.8***: a spie chart.[6, 7] In this chart the indicators are as follows:

- **Angle** represents a subject's share of the Netherlands' total publication output. The wider the angle, the larger the subject's share.
- **Radius** represents the Netherlands' relative activity in this subject. The longer the radius, the more the Netherlands publishes in this field compared to the world average. The red dotted line indicates the world average activity of 1.
- **Color** represents FWCI. A gradual single-colour scale is used, wherein light green indicates a lower FWCI, and bright green a higher FWCI.

[6] http://www.cs.huji.ac.il/~feit/papers/Spie03TR.pdf

[7] A spie chart is a combination of two pie charts: one sets the angles of the slices, and the other sets their areas, by manipulating the radius of each slice individually. This enables a visual representation of two different indicators in a single pie chart. A third indicator may be added by using a colour scale for each of the slices.

The subject areas in **Figure *1.8*** are arranged in a way that subjects in the Natural Science domain are in the top-right corner of the pie. If we go clockwise, we have Engineering, subjects related to Agriculture, then Medicine-related subject areas. Subjects in the Social Science domain are in the top-left of the chart. It is clear that the Netherland's strength lies in the Medicine-related subject areas. Many subjects in this domain have a large number of research output, a high RAI, and a high FWCI. Apart from the obvious outlier – Medicine – Biochemistry, Genetics & Molecular Biology stands out as having both a high share of the Netherlands' total output (15.1%) and being relatively more active (30%). The Netherlands has below world average RAI in all subjects in the Natural Sciences and Engineering. The FWCI of the publications in these subject areas is also relatively lower than that of other subject areas.

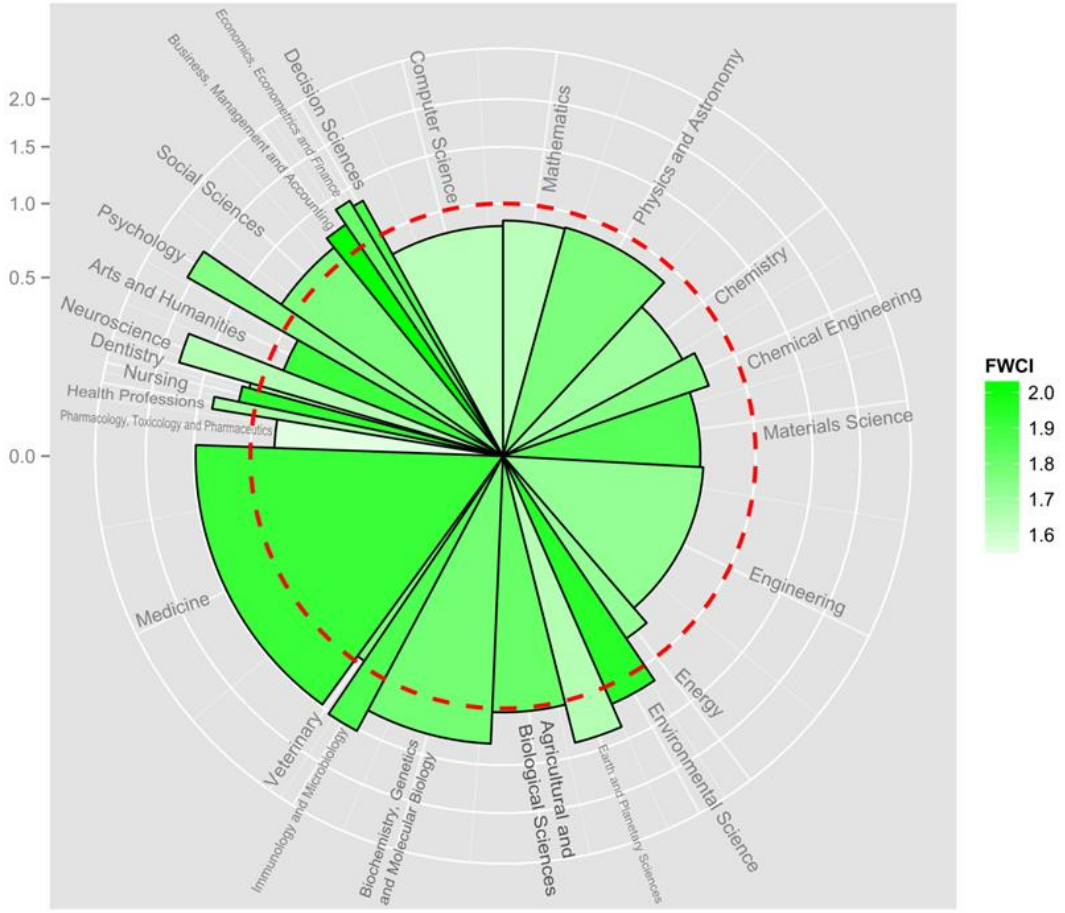


Figure 1.8— *Spie chart of the Netherlands: publication output, relative activity index, and FWCI, per subject, 2009-2013*

Another way of measuring quality of research is by looking at highly cited percentiles; that is, the number of publications that belong to the world's top x% of most cited publications. In this report we examine the Netherlands' publications belonging to the top 1% of most cited publications, in absolute numbers and world share.

Figure *1.9* shows a similar pattern as we saw previously for the Netherlands' total publication output: a strong increase from 2009 to 2012, which plateaus between 2012 and 2013. Overall, the Netherlands' absolute number of publications belonging to the world's top cited articles shows a CAGR of 4.2%, only slightly lower than its CAGR of publications overall. However, the lower increase between 2012-2013 means its share of the world's top cited articles decreases slightly in these years, as seen in **Figure *1.10***. Overall, the Netherlands' produced around 6% of the world's top 1% highly cited publications. This is very impressive, considering that the country's share of the world's publication output is only 2%. Around 14%, or one in seven of EU28's top 1% highly cited publications have at least one author from the Netherlands. This number is also larger than the Netherlands' EU28 publication share at 6.6%.

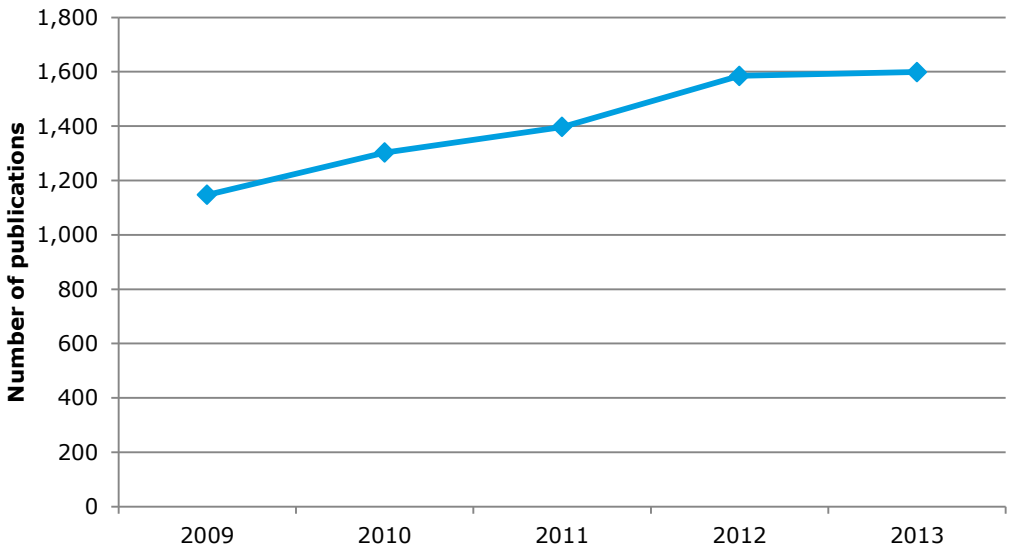


Figure 1.9— *Total number of publications in the world's top 1% most cited, per year, 2009-2013*

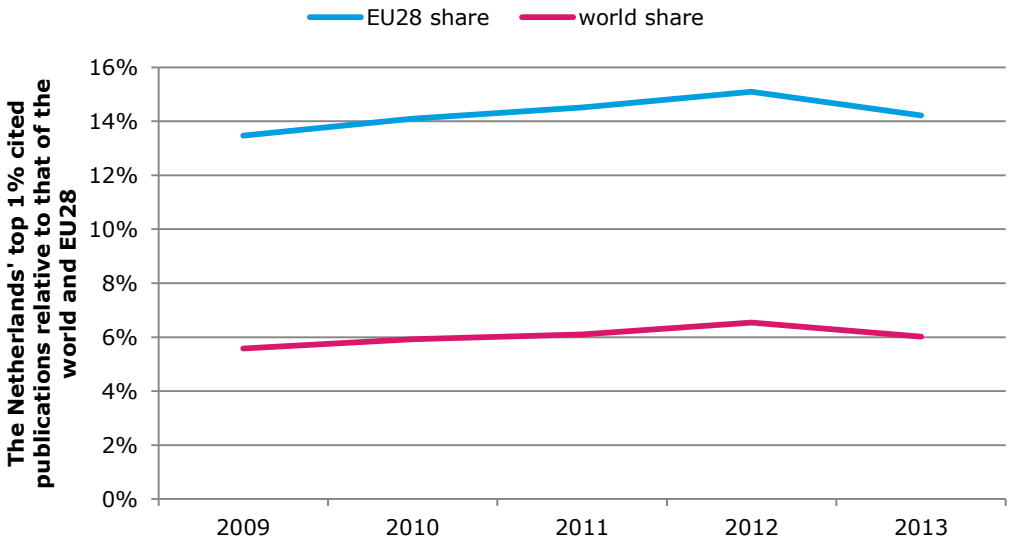


Figure 1.10— *The Netherlands' top 1% most cited relative to that of EU28 and the world, per year, 2009-2013*

On average, around 1.5% of the EU28's publications belong to the world's top 1% cited articles. The corresponding number for the Netherlands is much higher. In 2009, 2.8% of the Netherlands' publications belong to the world's top 1% and it increased to 3.3% in 2013.

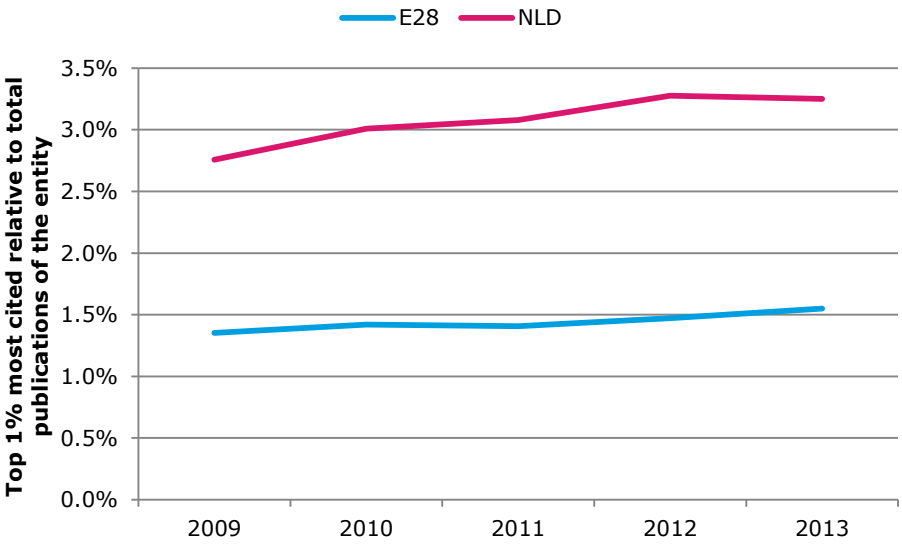


Figure 1.11—*Top 1% most cited relative to total publications of the entity for the Netherlands and the EU28, per year, 2009-2013*

Of the Netherlands' total output in the period 2009-2013, about 3.1% belongs to the world's top 1% most cited. To see where these shares come from, we again divide the output by subject, in

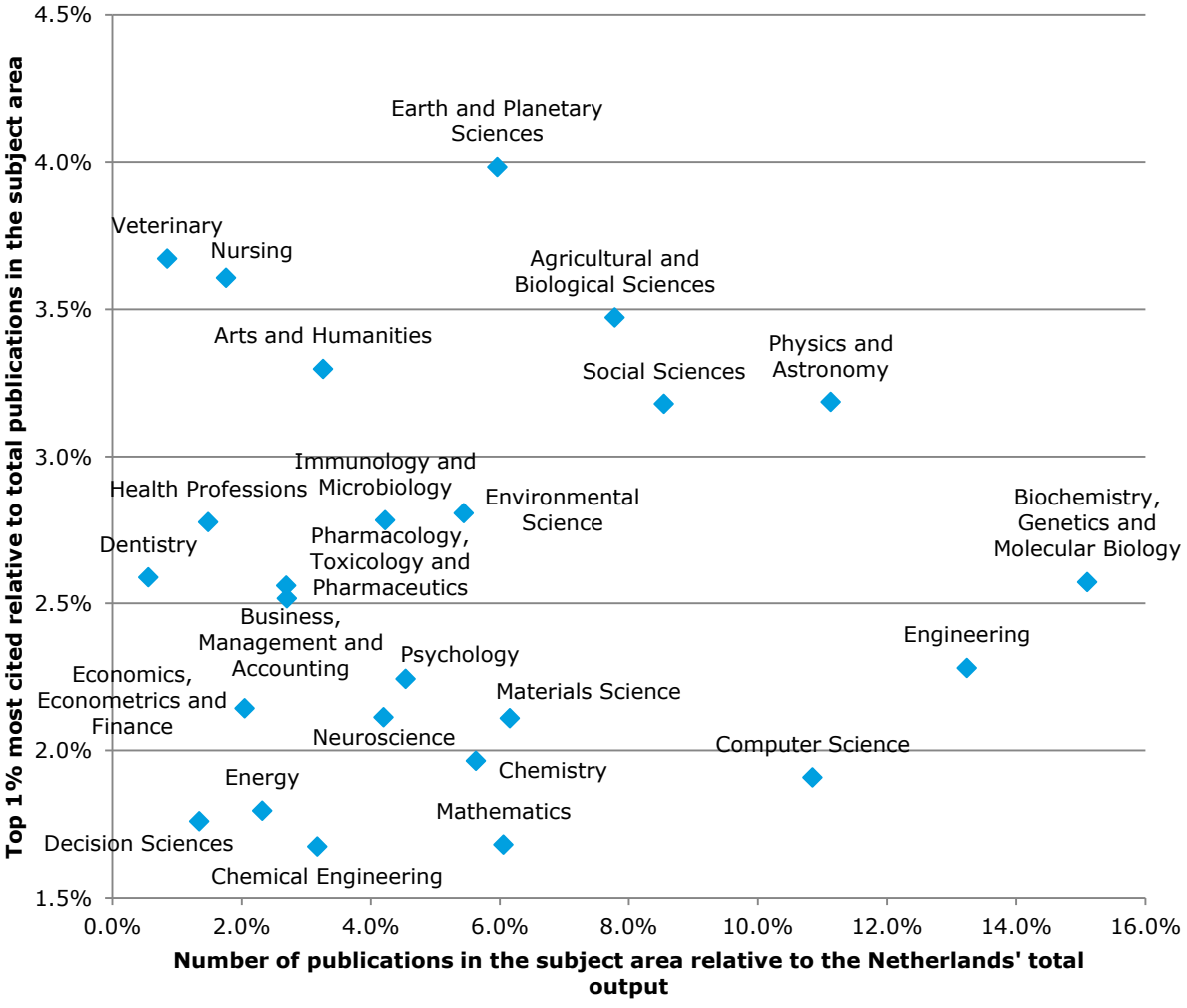


Figure 1.12. For readability, Medicine (37.9% of the Netherlands' total output and 3% of top cited articles out of subject total) and multidisciplinary articles (0.6% of the Netherlands' total output and 6.7% of top cited articles out of subject total) have been left out of this chart. Among the remaining subjects, Earth & Planetary Sciences has the highest share of its publications belonging to the world's top 1% most cited, and accounts for a decent share of the Netherlands' total output as well. Engineering and Computer Science again have relatively low shares, while Physics & Astronomy, Social Sciences, and Agricultural & Biological Sciences show shares that are above the Netherlands' overall share.

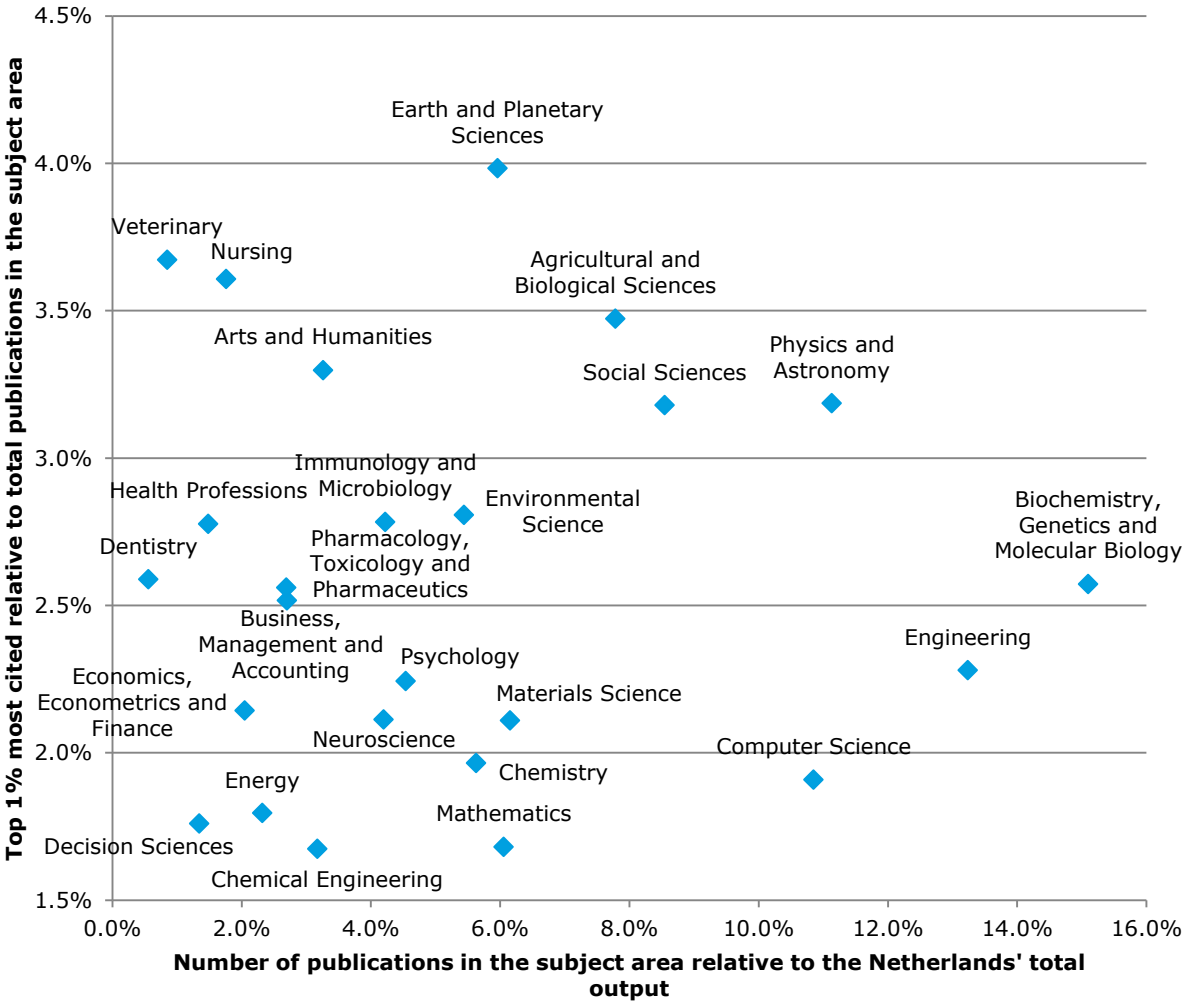


Figure 1.12— *The number publications in the subject area relative to the Netherlands' total output, and the number of top 1% most cited relative to the total publications in the subject area, per subject, 2009-2013*

Chapter 2
Research Collaboration and Usage

This chapter presents the findings on the collaboration of the Netherlands' research with the international community and with the corporate sector. It also presents the results on two indicators of the usage of research output: corporate downloads and patent citations.

2.1 Key Findings

HIGHLY INTERNATIONALLY COLLABORATIVE

51.7%

Over half of the Netherlands' publications in the period 2009-2013have at least one international co-author.

HIGH FIELD-WEIGHTED CITATION IMPACT

2.19

The Netherlands' internationally collaborative publications are cited more than twice the world average.

ACADEMIC-CORPORATE COLLABORATION

7.1%

Around 7.1% of the Netherlands' publications in the period 2009-2013 are co-authored with the corporate sector.

RELATIVE PATENT CITATION SHARE

1.98

The Netherlands' publications are cited close to twice more than the world average in patent citations.

2.2 International collaboration

As technological advances facilitate long-distance communication and low-cost travel, researchers are increasingly collaborating with international partners.[8] Moreover, past research suggests that such collaborations are quite productive. Internationally co-authored articles are associated with higher field-weighted citation impact.[9] For this report, international collaboration is defined as a publication with multiple authors where at least one co-author is from another country.

Overall, the Netherlands is highly internationally collaborative: over half (51.7%) of its total 2009-2013 publications have an international co-author. As can be seen in **Figure 2.1**, this share is steadily increasing at a compound annual growth rate (CAGR) of 2.9%, from 48.6% in 2009 to 54.4% in 2013. In terms of absolute numbers of publications, the total number of the Netherlands' internationally collaborative publication has increased from 20,208 to 26,750 publications, resulting in a CAGR of 7.3%. This is again higher than the EU28's corresponding growth rate (6.8%).

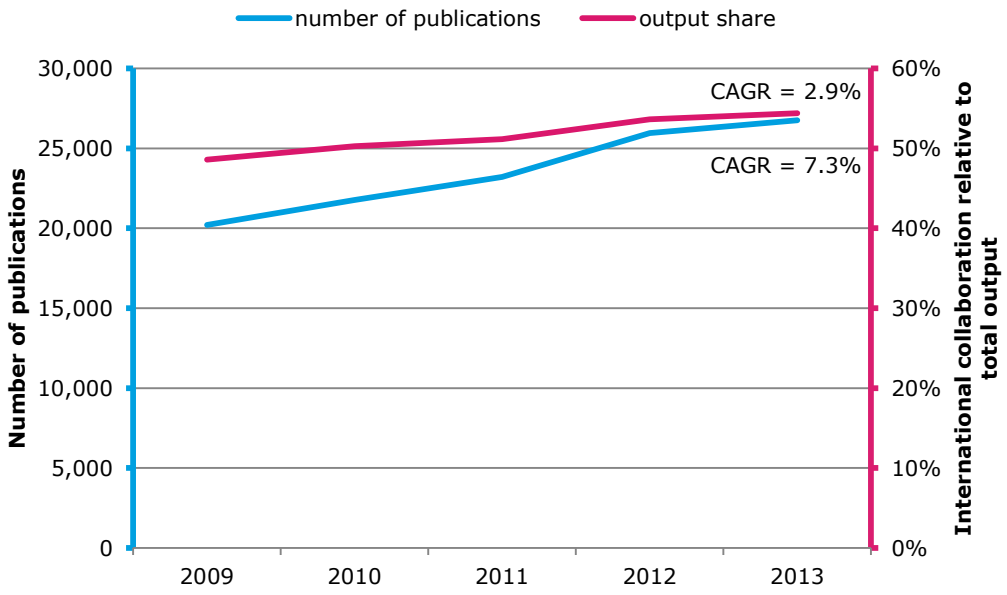


Figure 2.1 — *Number of publications and the percentage of internationally collaborative publications relative to the total output of the Netherlands, per year, 2009-2013*

Figure 2.2 presents the share of internationally collaborative publications per subject. This shows that a great majority - almost 81% - of the Netherlands' articles in Multidisciplinary (e.g. journals such as Nature, Science, etc.) have at least one international co-author. Other subjects in which the Netherlands is highly internationally collaborative are Earth & Planetary Sciences (74.1%), Physics & Astronomy (67.9%) and Agricultural & Biological Sciences (67.1%). Arts & Humanities and Social Sciences have the lowest percentages of international collaboration, which is unsurprising, given that the number of authors on articles in these subjects is usually small. However, even here, about one third of the output of each

[8] Pan, R. K., Kaski, K., & Fortunato, S. (2012). World citation and collaboration networks: uncovering the role of geography in science. Scientific reports, 2, 902. Retrieved from http://www.nature.com/srep/2012/121129/srep00902/full/srep00902.html

[9] Kamalski, J., & Plume, A. (2013). Comparative Benchmarking of European and US Research Collaboration and Researcher Mobility. Retrieved from http://www.scienceeurope.org/uploads/Public documents and speeches/SE and Elsevier Report Final.pdf; Wilson, J., Clarke, L., Day, N., Elliot, T., Harden-Davies, H., McBride, T., Zaman, R. (2011, March 1). Knowledge, networks and nations: global scientific collaboration in the 21st century. The Royal Society. Retrieved from http://royalsociety.org/policy/projects/knowledge-networks-nations/report/

subject has at least one international co-author. In each subject, the Netherlands has a higher share of international collaboration than the EU28.

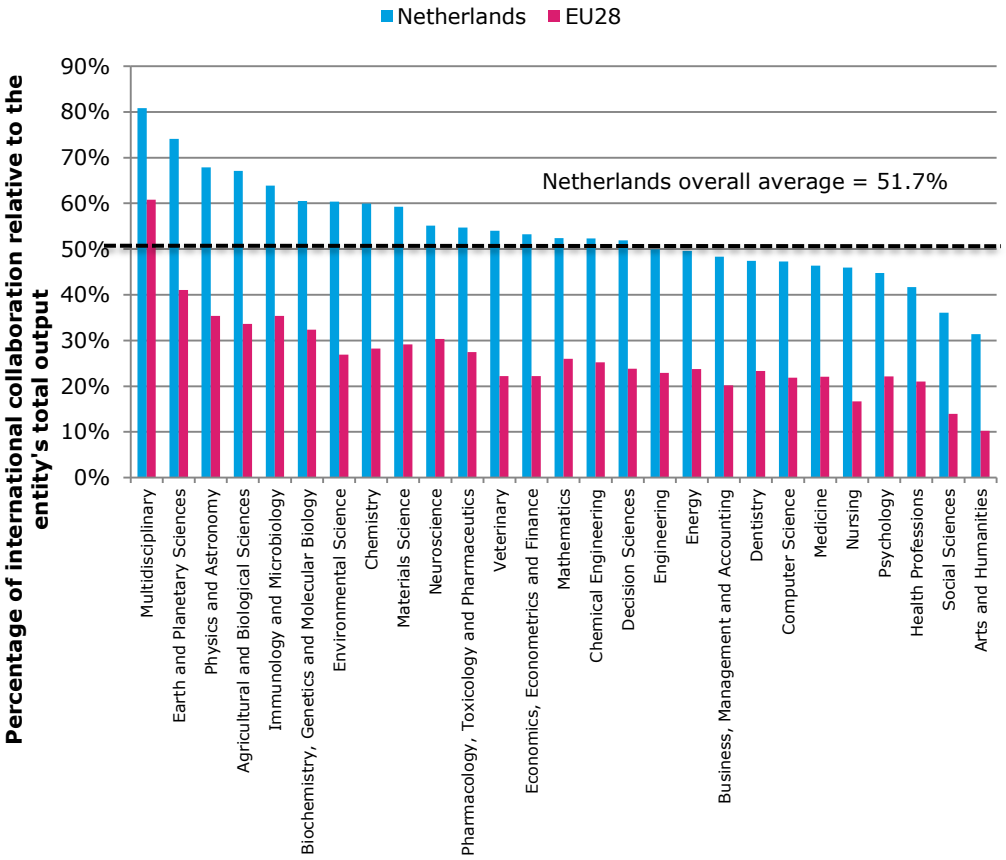


Figure 2.2— *Percentage of internationally collaborative publications for the Netherlands and EU28, per subject, 2009-2013*

The field-weighted citation impact (FWCI) of internationally collaborative publications is higher than that of the overall FWCI of the Netherlands, both for all subjects combined and at the subject level. For all subjects combined, the average 2009-2013 FWCI is 2.19, meaning the Netherlands' internationally collaborative publications are cited more than twice as much as the world average.

Figure 2.3 presents the FWCI on a subject level, plotted against the share of international collaboration per subject. Multidisciplinary (share = 80.8%, FWCI = 7.1) has been left out for readability. Apart from Pharmacology, Toxicology & Pharmaceutics and Chemistry, international collaboration results in a FWCI that is higher than the Netherlands' average FWCI for all subjects. Arts & Humanities' FWCI of 2.94 is rather exceptional, considering its (comparatively) low international collaboration share. While research in this subject is clearly of high quality, a partial explanation for this high FWCI is its low publication output. As the number of internationally collaborative publications in this subject area increased, from 118 in 2009 to 879 in 2013, the average FWCI of these publications decreased from 3.83 to 2.74; the highly cited outliers are gradually balanced out by the lesser cited articles. The same trends can be found in Nursing and Business, Management & Accounting, albeit to a much lesser extent.

This is not the case for larger subjects such as Medicine. Despite its surprisingly rapid increase in international collaboration (10.3% CAGR in absolute number of internationally collaborative publications, 3.9% CAGR in international collaboration share), internationally collaborative output in Medicine maintains a fairly stable and high FWCI. There are also a few subjects in which the FWCI of its internationally collaborated publications is increasing. Notable examples of this are Environmental Science and Immunology & Microbiology, whose FWCI rose slightly from above 2.0 in 2009 to 2.25 in

2013. At the same time, their already considerable share of international collaboration (both over 60%) continues to increase as well.

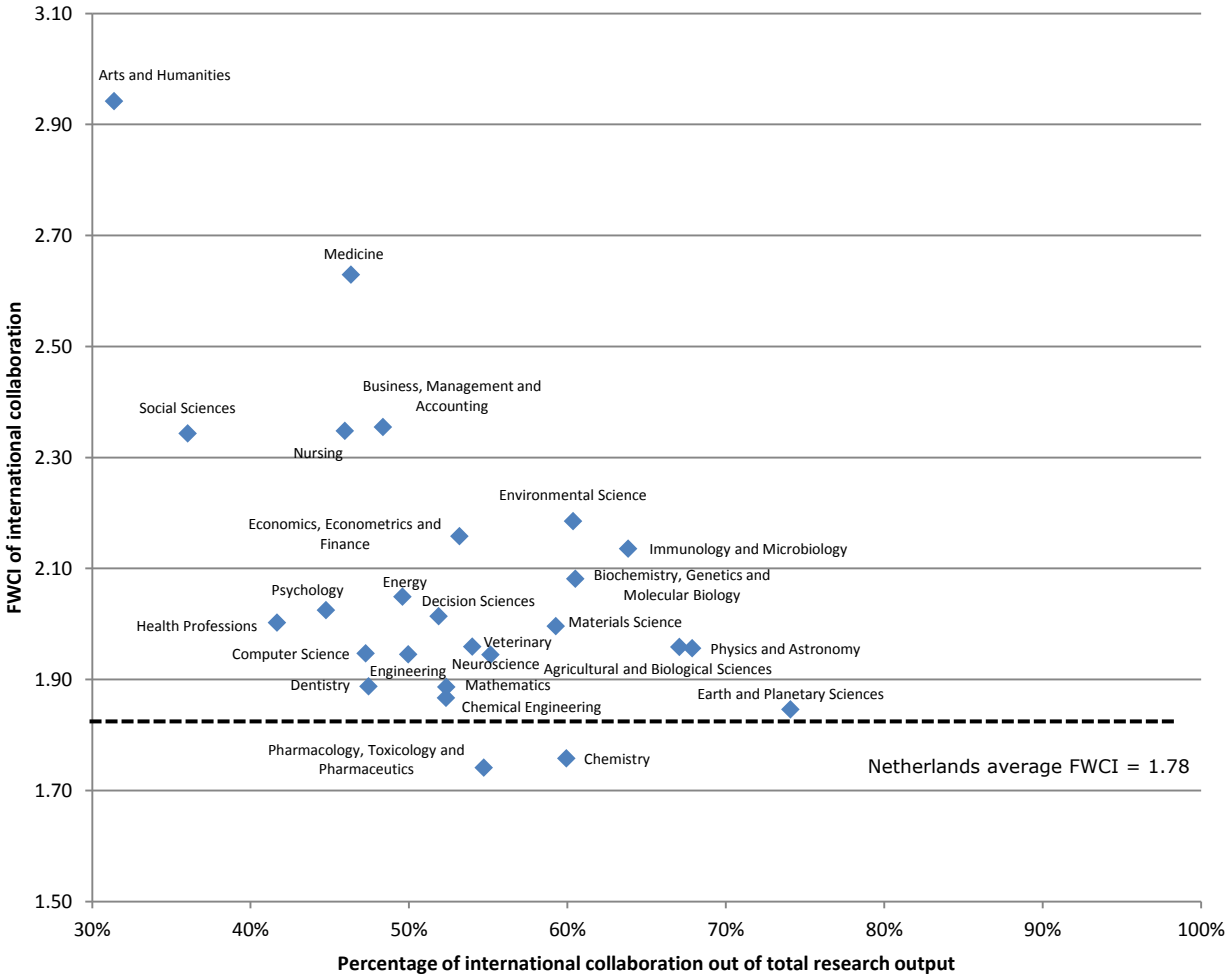


Figure 2.3— *FWCI vs percentage of international collaboration out of total research output, per subject, 2009-2013*

2.3 Academic-corporate collaboration

An additional perspective on research impact is gained by looking at the strength of the links between academia and industry. There has been on-going research on understanding the implications and benefits of academic- and commercially oriented research, exploring complementarities that exist between the two sectors[10]. Co-authored publications between academic and corporate sector is one output that can be measured (other forms of output include patent applications, commercial consultations and innovation enterprise spinoffs), and serves as a proxy to the extent of knowledge exchange.

In 2009-2013, the Netherlands produced 16,119 publications through academic-corporate collaboration, which amounts to about 7.1% of its total output in this period. After a minor decrease between 2009 and 2010, the Netherlands' academic-corporate collaborated output started a rapid increase, yet after 2012 decreased again with equal speed. Due to this lower output in 2013, the compound annual growth rate (CAGR) ends up being rather low: just 1.1%. The academic-corporate collaboration as share of the total output shows a decrease in 3 out of the 4 intervals between years (from 7.4% in 2009 to 6.5% in 2013), thus resulting in a negative growth rate of -3.1%.

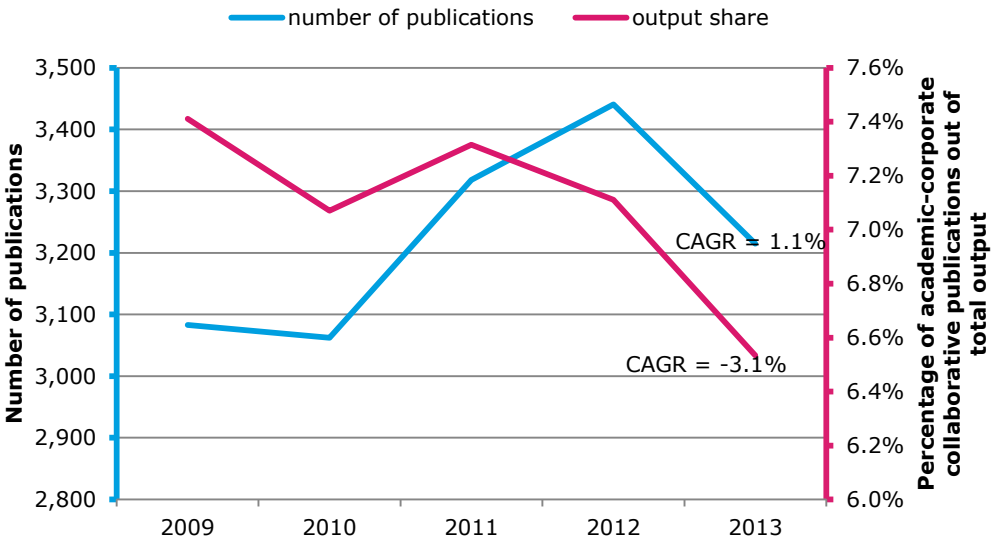


Figure 2.4— *Number of publications and percentage of academic-corporate collaborative publications out of the Netherlands' total publications, all subjects, per year 2009-2013*

As discussed in the previous section on international collaboration, the larger a subject's output, the larger the chance of a large number of academic-corporate collaborated publications. Looking at the absolute numbers of publications therefore shows no surprises: Medicine has the highest output, at over 4,000 publications in 2009-2013, followed by Engineering (more than 3,800 publications) and Physics & Astronomy (over 3,100 publications). The top 5 further consists of Biochemistry, Genetics & Molecular Biology (2,565) and Computer Science (2,441). Sorting by share of academic-corporate collaboration, as done in **Figure *2.5***, offers a different perspective. In this case, Medicine (4.7%) falls well below the Netherlands' average share of academic-corporate collaboration. Engineering and Physics & Astronomy,

[10] Mindruta Theresa Larsen, (2011) *The implications of academic enterprise for public science: An overview of the empirical evidence.* Research Policy, 40(1) pp. 6-19

while no longer part of the top 3, still rank very high with 12.7% and 12.5% of their respective outputs having been co-authored with collaborators from the corporate sector.

Relative to the subject's total publication output, the Netherlands is most active in academic-corporate collaboration in Materials Science: 15.9% of the publications in this subject (a total of 2,226 articles) have at least one corporate co-author. Chemistry ranks second with a 14% academic-corporate collaboration share (1,784 articles), and bridging the gap between Chemistry and Engineering is Chemical Engineering. Its 975 corporate co-authored publications make up 13.5% of its total output.

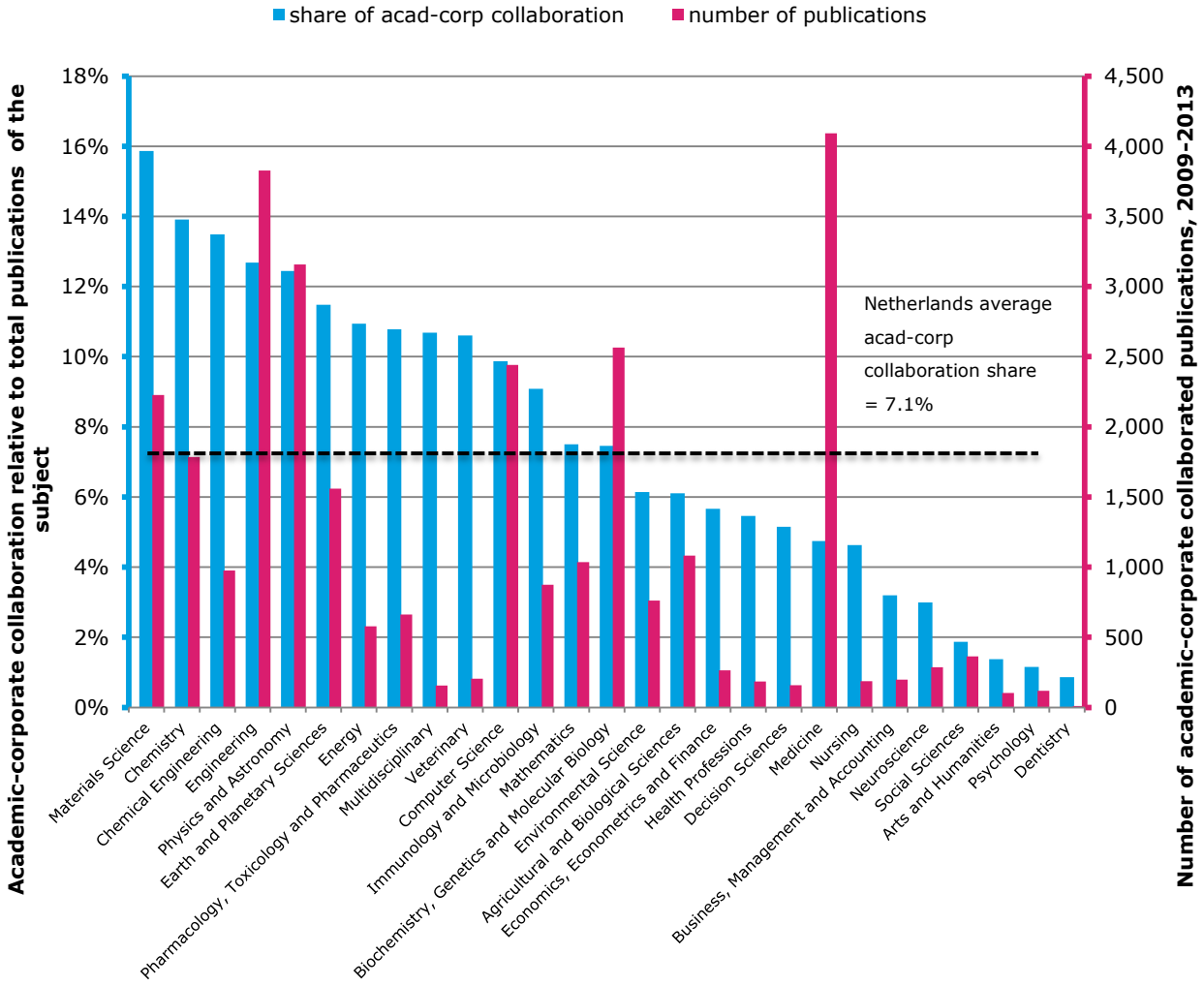


Figure 2.5— *Number of publications and percentage of academic-corporate collaboration out of total publications for the subject for the Netherlands, per subject, 2009-2013*

Plotting the FWCI of each subject's academic-corporate collaborations versus each subject's share of the Netherlands' total publication output gives us **Figure *2.6***. Medicine is a clear outlier (not shown): its collaborative publications with the corporate sector have an incredibly high FWCI of 4.73. Biochemistry, Genetics & Molecular Biology also performs well, both in output share (7.5%) and FWCI (2.90). On the other hand Chemistry and Chemical Engineering have an average FWCI that is marginally lower than the Netherlands' overall average FWCI, even though these two subject areas have co-authored a high share of their publications with the corporate sector (**Figure *2.5***). In fact, the majority of the subjects are in the range of 2 to 3 times the world average in terms of FWCI.

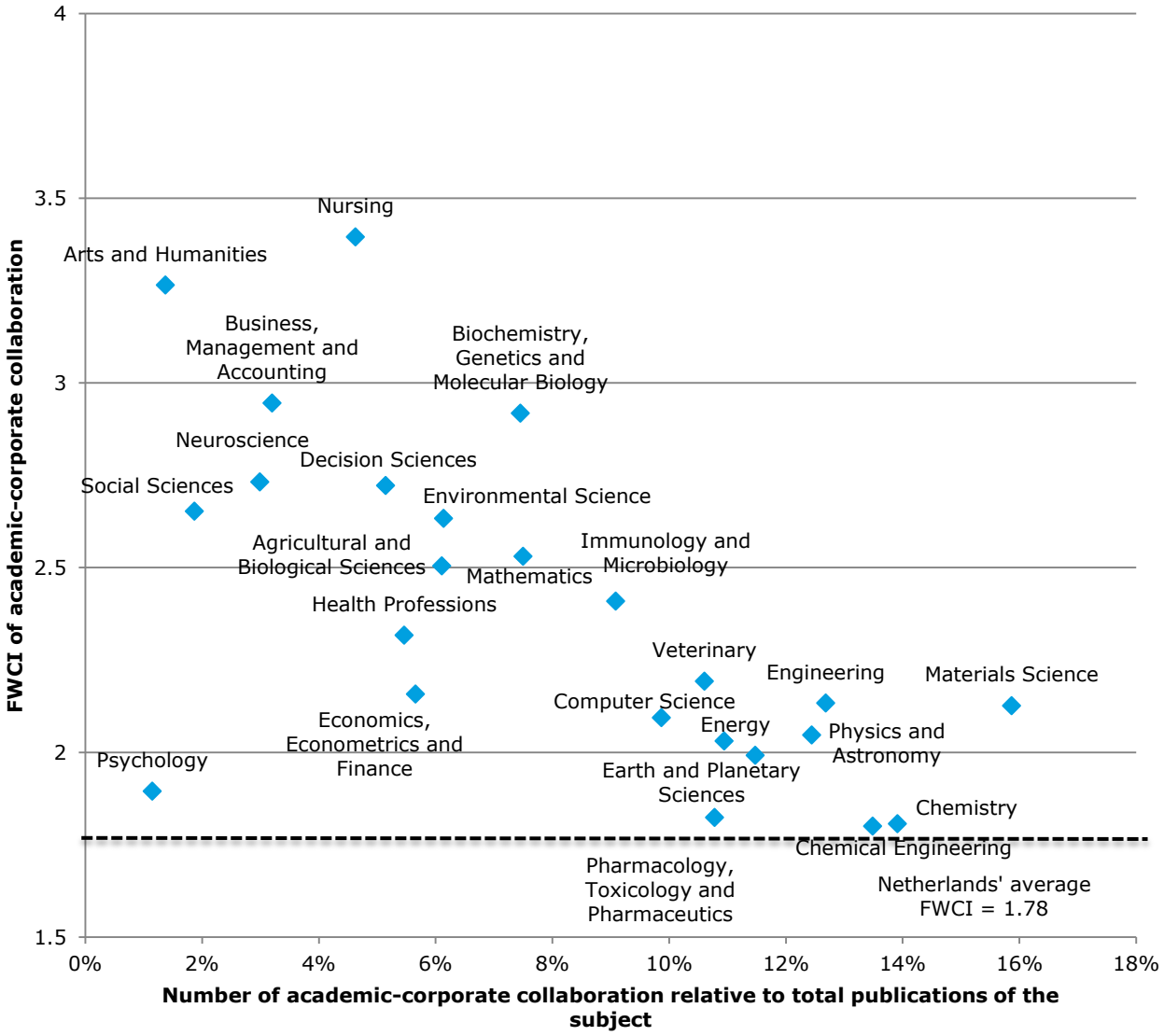


Figure 2.6— *FWCI of academic-corporate collaboration vs number of academic-corporate publications relative to the total publications of the subject, per subject (except Medicine and Multidisciplinary), 2009-2013*

2.4 Corporate downloads

Full-text article download data derived from Elsevier's ScienceDirect database (which provides approximately 20% of the world's published journal articles) offers an alternate perspective from citations and may be interpreted as representing the interest in or usefulness of an article to the community it is aimed at. Measuring impact by looking at citations requires time: articles need to be read, after which they might influence studies that will be carried out, which are then written up and published; only after these steps are completed, a citation can be counted. For this reason, investigating downloads has become an appealing alternative. When measuring downloads, one can start counting immediately after the publication of an article, instead of having to wait months or even years for a citation to be made. Currently, more research is being done in the bibliometric community on download measurements and its full implications[11].

Here, a download is defined as either downloading a pdf of an article on ScienceDirect, Elsevier's full-text platform, or looking at the full-text online on ScienceDirect, without downloading the actual pdf. Views of abstract are not included in the definition. Multiple views or downloads of the same article in the same format during a user session, will be filtered out, in accordance with the COUNTER Code of Practice[12]. In this study, downloads measure is used as a proxy to the usage of research output. Downloads from the particularly corporate sector can be seen as an early indication of corporate interest in research and can be used as a measure of usage of research output by the corporate sector.

For most of the subject areas, the Netherlands receives between 2% and 7.2% of the world's downloads from the corporate sector (**Figure 2.7**). Psychology leads in this indicator among all subject areas; 7.2% of the world's corporate downloads are received by publications from the Netherlands in this subject area. The subject areas in which the Netherlands has a high world share in corporate downloads belong to either Life Sciences or Social Sciences and the Humanities.

[11] Kurtz, M.J., & Bollen, J. (2012). Usage Bibliometrics. Annual Review of Information Science and Technology
Volume 44, Issue 1. Retrieved online from
http://onlinelibrary.wiley.com/doi/10.1002/aris.2010.1440440108/pdf.

[12] http://usagereports.elsevier.com/asp/main.aspx, WHAT TO COUNT & WHAT NOT? Elsevier White Paper retrieved from:
http://www.info.sciverse.com/UserFiles/Files/sciencedirect/sd_white_paper_2004_02.pdf,
http://www.projectcounter.org/code_practice.html

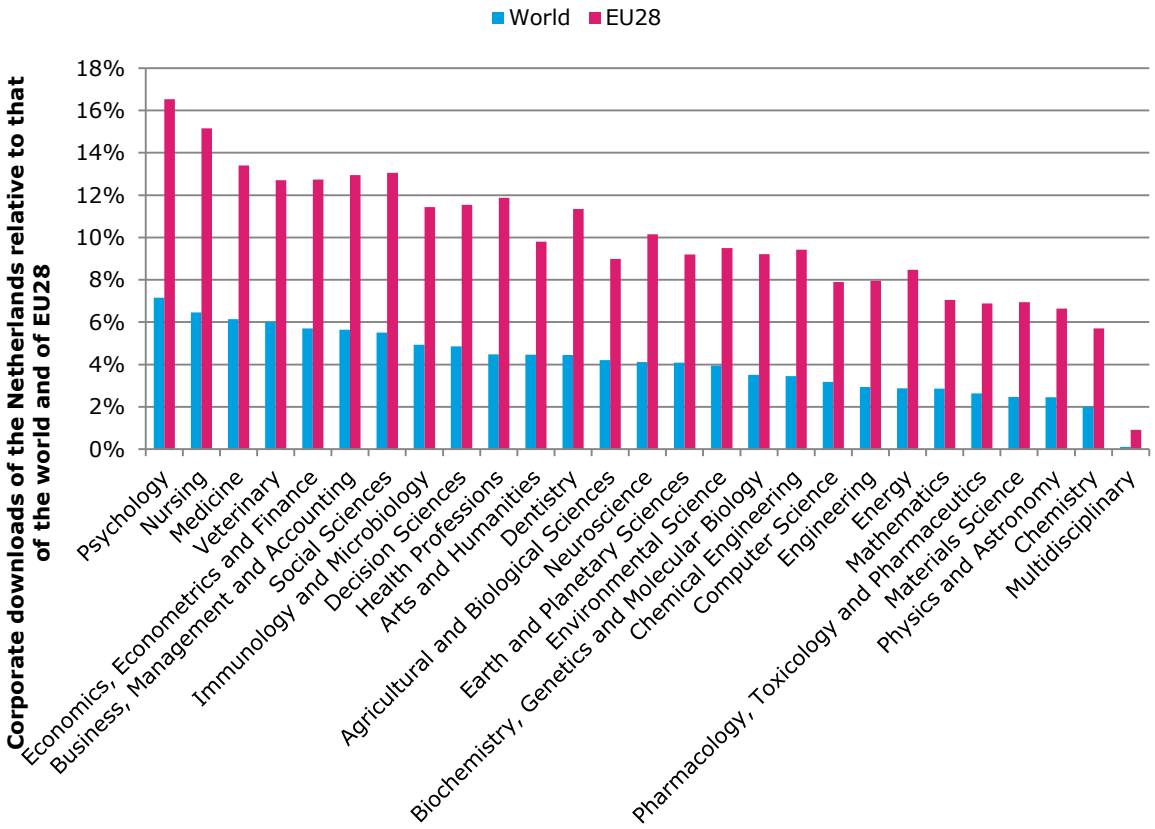


Figure 2.7— *Corporate downloads of the Netherlands relative to that of the world and of EU28, per subject, 2009-2013*

In all subject areas except Multidisciplinary, the Netherlands' world corporate download share is higher than the corresponding world publication share (**Figure 2.8**). This implies that the Netherlands' publications are downloaded more frequently by the corporate sector than the world average. Veterinary leads in this indicator: the Netherlands' world corporate download share is more than three times of its world publication share. It is followed by Nursing (2.76) and Arts & Humanities (2.52).

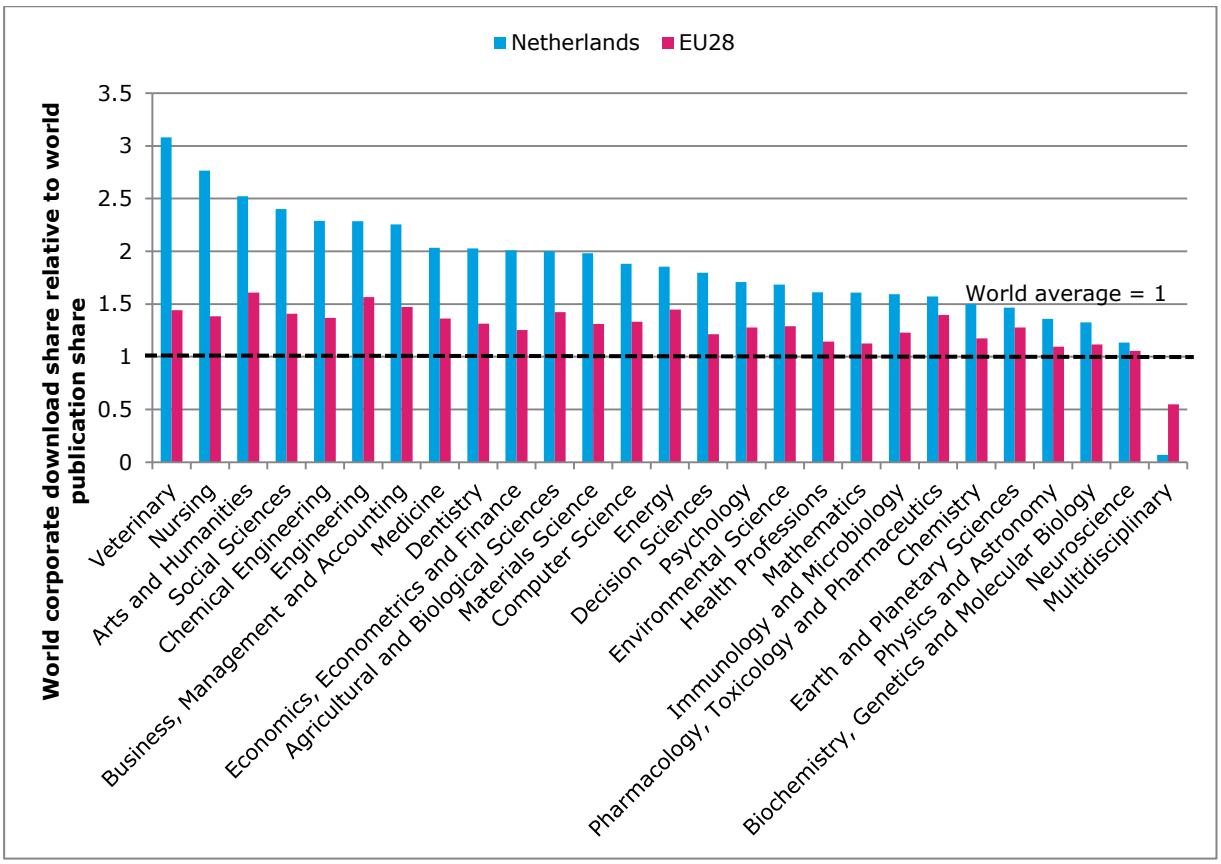


Figure 2.8— *World corporate download share relative to world publication share for the Netherlands and EU28, per subject, 2009-2013*

2.5 Patent citations

In early citation studies, technological progress was viewed as more or less a direct result of scientific progress. To paraphrase Bassecoulard and Zitt (2004)[13], it had been assumed that there is a diachronic relationship in which the science of today is the technology of tomorrow. However, as many authors have since made clear, there are several issues related to using a linear model. Over the last decades 'science' (being more theoretical) and 'technology' (more practical) have become closely intertwined. It is even becoming increasingly common for a researcher to be active in both worlds; i.e. one may work at a corporate R&D lab, but also hold an academic position (adjunct professorship) or vice versa.

In this section, we analyze the number of patent citations, an indication of the usage of scientific publications ("science") to generate "technology". The fairest comparison between countries can be made by taking patent data from WIPO, the international patent office. Selecting the US Patent and Trademark Office may show a bias towards US, and the same applies for the other national patent offices.

Patent citations are very similar to publication citations in both nature and proclivity. In many cases, patent citations are legally required by each patent office in order to bolster requirements of novelty and utility. Patent citations exhibit a time lag between the publication year of the patent and the citation year. Additionally, each technology field and patent office has their own idiosyncrasies in terms of proclivity and requirement to cite other data sources. Due to these characteristics, we examine the overall share of citations, rather than absolute numbers.

Figure *2.9* shows the Netherlands' share of patent citations of the world and EU28. Despite the naturally 'lower' number of citations in each subsequent year, the Netherlands' share of the total EU28 and world patent citations has remained fairly stable throughout 2009-2013.

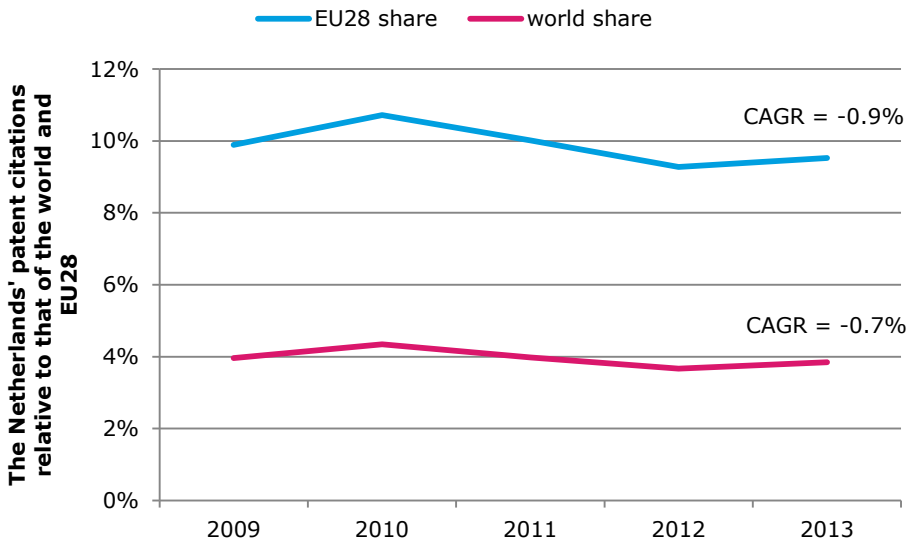


Figure 2.9— *The Netherlands' number of patent citations relative to that of the world and EU28, all subjects, per year, 2009-2013*

Figure 2.10 presents the absolute numbers of patent citations per subject for the whole 2009-2013 period. We can see here that although the Netherlands published 2.5 times as many articles in 2009-2013 in Medicine as it did in Biochemistry, Genetics & Molecular Biology (**Figure *1.3***), publications from

[13] Bassecoulard, E., Zitt, M. (2004). Patents and publications: The Lexical Connection. In: H.F. Moed, W. Glänzel, U. Schmoch. (eds), *Handbook of quantitative science and technology research*, pp.665-694. Kluwer Academic Publishers, the Netherlands.

the latter have received more patent citations. Both of these subjects are remarkably highly cited in patents. In fact, articles in Medicine received over three times as many patent citations as the 3rd most cited subject, Immunology & Microbiology. Together, Biochemistry, Genetics & Molecular Biology and Medicine account for about 46.6% of the Netherland's patent citations. However, as a publication can be categorized in more than one subject, this is actually double-counting: the total number of patent citations received by the Netherlands in 2009-2013 is 3,874, or 4.0% of the world's patent citations.

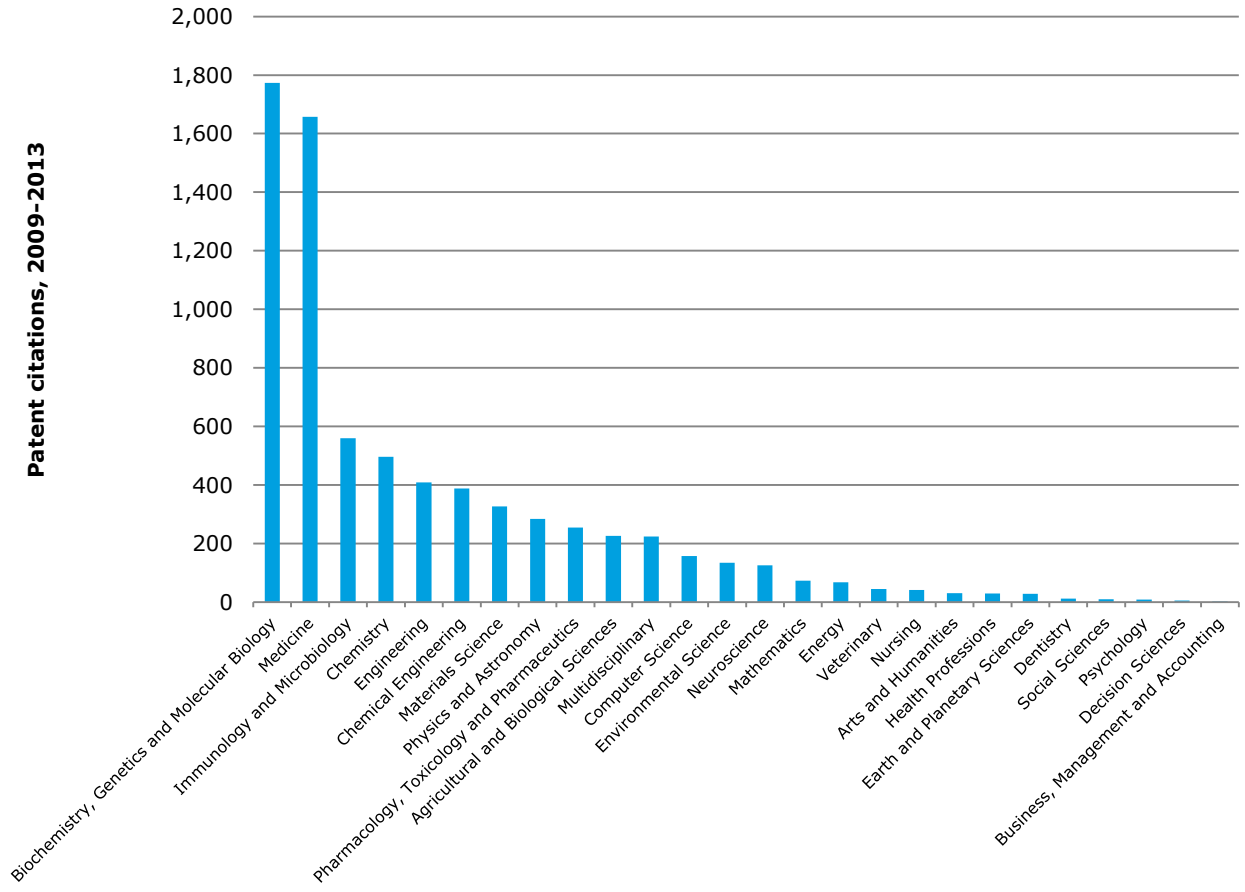


Figure 2.10— *The Netherlands' absolute number of patent citations, per subject, 2009-2013*

It is natural that subject areas with a larger number of publications tend to receive more patent citations. It is therefore necessary to take into consideration the number of publications when we assess in which subject areas the Netherlands' research are used, as measured by patent citations. The indicator we use is named "relative patent citation share". It is defined as the world patent citation share of a certain subject divided by the world publication share of the same subject. For example, if the Netherlands publishes 2% of the world's publications in subject A and receives 4% of the world's patent citations in subject A, the Netherlands' relative patent citation share is equal to 2. This means that the Netherlands' publications in subject A is more frequently cited in patent application than the world average. We present the relative patent citation share in **Figure *2.11***. We see that many Medicine-related subject areas (e.g., Nursing, Dentistry, and Veterinary), Chemistry Engineering, Engineering, and Materials Science are leading in this indicator. This is no surprise as most of the patents are closely linked to applied research in the Natural Science and Health domain. Arts & Humanities may seem to have a high relative patent citation share, but the publications in this subject only received 30 citations in patents. The high share based on a very small citation number should be treated with caution.

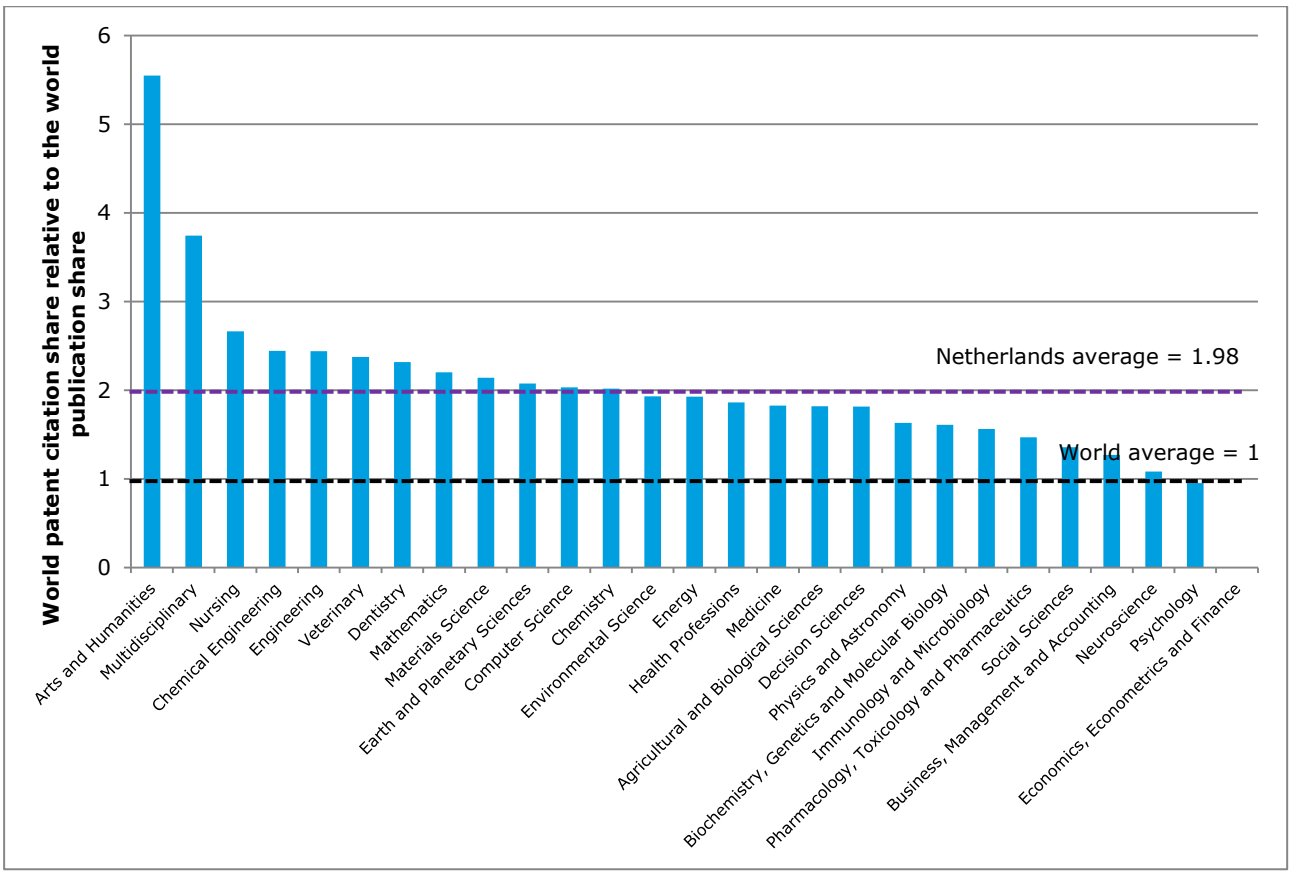


Figure 2.11— *World patent citation share relative to world publication share for the Netherlands, per subject, 2009-2013*

2.6 Overview of the Netherlands' research performance

In **Table *2.1***, we provide an overview of the main indicators we used in Chapter 1 and Chapter 2 to summarize the Netherlands' research performance in the 27 main subject areas. The key message from **Table *2.1*** is that indicators should always be used in combinations. Subject areas often perform well in some indicators but not in others. It is important to compare the indicators and draw the right conclusions. Medicine, for instance, has a large number of publications, high citation impact and high percentage of top 1% publications. It performs less well in the collaboration indicators. Computer Sciences also has a large number of publications and a high level of collaboration with the corporate sector, but it ranks low among the 27 subject areas in the two measures of research quality – FWCI and the top 1% publications out of the total research output in the subject area.

Subject Name	Publications	FWCI	Top 1%/Total output	International collaboration/Total output	Academic-corporate collaboration/Total output	World corporate download share/World publication share	World patent citation share/World publication share
Agricultural and Biological Sciences	17737	1.83	3.5%	67.1%	6.1%	2.00	1.82
Arts and Humanities	7428	1.89	3.3%	31.4%	1.4%	2.52	5.55
Biochemistry, Genetics and Molecular Biology	34402	1.81	2.6%	60.5%	7.5%	1.33	1.61
Business, Management and Accounting	6158	2.02	2.5%	48.4%	3.2%	2.26	1.27
Chemical Engineering	7228	1.74	1.7%	52.4%	13.5%	2.29	2.44
Chemistry	12823	1.70	2.0%	59.9%	13.9%	1.50	2.02
Computer Science	24728	1.64	1.9%	47.3%	9.9%	1.88	2.03
Decision Sciences	3069	1.87	1.8%	51.9%	5.1%	1.80	1.81
Dentistry	1275	1.66	2.6%	47.5%	0.9%	2.03	2.32
Earth and Planetary Sciences	13582	1.68	4.0%	74.1%	11.5%	1.46	2.08
Economics, Econometrics and Finance	4665	1.79	2.1%	53.2%	5.7%	2.01	0.00
Energy	5291	1.75	1.8%	49.6%	10.9%	1.86	1.93
Engineering	30167	1.72	2.3%	50.0%	12.7%	2.29	2.44
Environmental Science	12398	1.95	2.8%	60.4%	6.1%	1.68	1.93
Health Professions	3386	1.69	2.8%	41.7%	5.5%	1.61	1.86
Immunology and Microbiology	9628	1.86	2.8%	63.9%	9.1%	1.59	1.56
Materials Science	14028	1.86	2.1%	59.3%	15.9%	1.98	2.14
Mathematics	13801	1.64	1.7%	52.4%	7.5%	1.61	2.20
Medicine	86346	1.91	3.0%	46.3%	4.7%	2.03	1.83
Neuroscience	9562	1.66	2.1%	55.2%	3.0%	1.13	1.08
Nursing	4019	1.95	3.6%	46.0%	4.6%	2.76	2.66
Pharmacology, Toxicology and Pharmaceutics	6132	1.57	2.6%	54.7%	10.8%	1.57	1.47
Physics and Astronomy	25364	1.77	3.2%	67.9%	12.4%	1.36	1.63
Psychology	10341	1.76	2.2%	44.8%	1.2%	1.71	0.95
Social Sciences	19471	1.79	3.2%	36.0%	1.9%	2.40	1.36
Veterinary	1933	1.75	3.7%	54.0%	10.6%	3.08	2.38

Table 2.1 — *Overview of the main indicators of the Netherlands' research performance, per subject (except Multidisciplinary), 2009-2013. The color (from red to green) indicates the increase in value.*

Chapter 3
Subject focus: Medicine

This section provides an in-depth analysis of Netherland's research performance in Medicine and its sub-areas. It examines the country's total research output and impact, collaboration (international and academic-corporate) and top collaborators, and performance along novel indicators of knowledge transfer (corporate downloads and patent citations).

3.1 Key Findings

COMPOUND ANNUAL GROWTH RATE IN MEDICINE RESEARCH OUTPUT

6.2%

Higher than world CAGR for Medicine (4.4%)

FIELD-WEIGHTED CITATION IMPACT IN MEDICINE

1.91

91% higher than the world average and the highest among all comparator countries, EU or non-EU.

HIGH RELATIVE ACTIVITY INDEX AND CITATION IMPACT

Rheumatology

Netherlands' research in this sub-area achieves a relative activity index of 2.29 (twice as much relative activity in this sub-area than the world average) and a FWCI of 2.16.

RESEARCH EXCELLENCE

8.9%

Netherlands' research in Medicine accounts for almost 1 out of every 11 publications that are amongst the world's top 1% most cited.

INTERNATIONAL COLLABORATION RATE

46.3%

of all Netherlands' publications in Medicine were co-authored with an international partner. Within specific sub-areas, Genetics (clinical) had highest international collaboration rate.

ACADEMIC-CORPORATE COLLABORATION SHARE

Pharmacology (medical)

10.2% of all Netherlands' publications in this sub-area are co-authored with at least one corporate researcher.

3.2 Publication output and impact

3.2.1 Publication output and growth

Figure *3.1* presents the total output of the Netherlands in Medicine from 2009 to 2013. In increasing its output from ~15,300 publications in 2009 to ~19,500 publications in 2013, the Netherlands shows a CAGR of 6.2%. This is higher than the country's overall growth rate in publications (4.3%) and higher than that of the growth rates of EU28 (3.7%), the world as a whole (4.4%), and all but 2 [Australia and China] of its top ten comparator countries' publications in Medicine.[14] From 2009-2013, the Netherlands' output in Medicine comprised about 3% of the world's total output. In comparison, the USA comprised 28.5%, China 8.9%, the UK 7.8%, and Germany 6.3%. As **Figure *3.2*** shows, China has experienced a very strong growth rate (15.9% CAGR in overall publications in Medicine, 5.0% CAGR in world publication share).

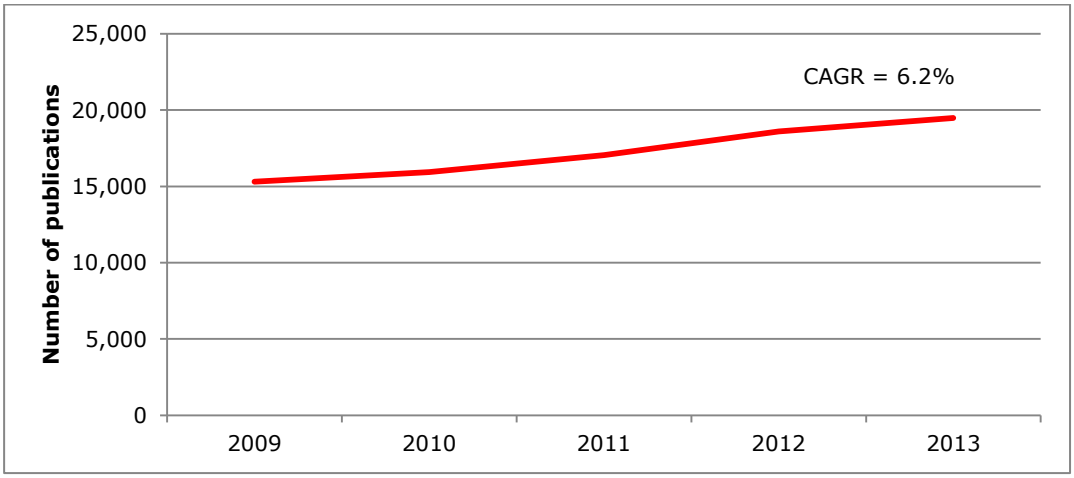
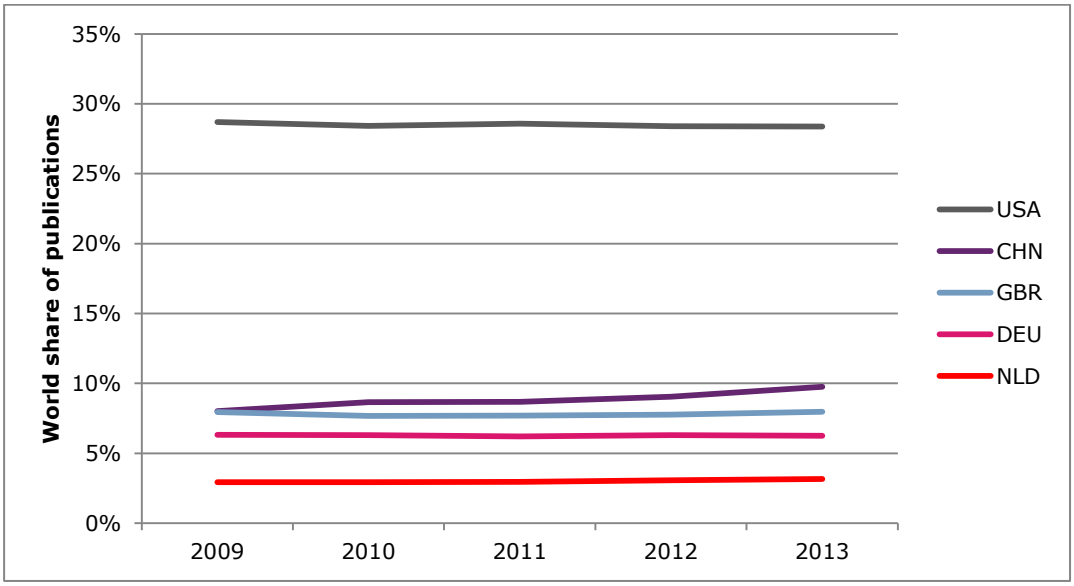


Figure 3.1 — *Total number of publications in Medicine by the Netherlands, per year, 2009-2013*



[14] From 2009-2013, the top five EU countries (excluding the Netherlands) in terms of output in Medicine were: the UK, Germany, Italy, France, and Spain. The top five non-EU countries were: the USA, China, Japan, Canada, and Australia.

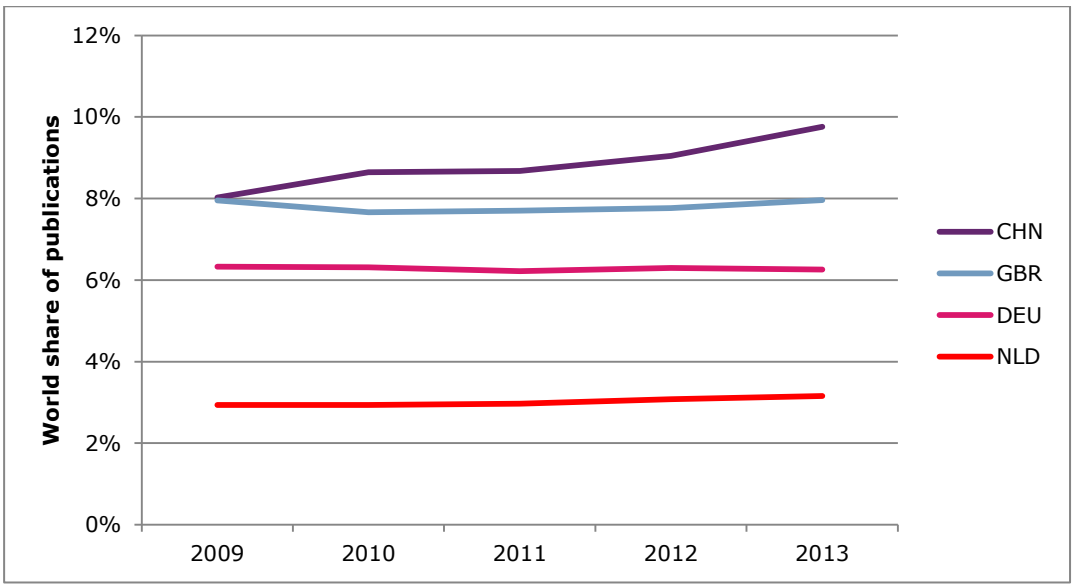


Figure 3.2— *Number of publications from the Netherlands' and top 2 EU and top 2 non-EU comparator countries in Medicine relative to world output, per year, 2009-2013 [second chart excludes USA for ease of viewing]*

As the first chapter noted, across all subject areas, the Netherlands produces the most output in Medicine. Within Medicine, the Netherlands produces the most output in the sub-areas of General Medicine (over 16,800 publications from 2009-2013); Cardiology and Cardiovascular Medicine (~7,300 publications); Oncology (~57,00); Psychiatry and Mental Health (~5,700); Neurology (clinical) (~5,300); and Radiology, Nuclear Medicine and Imaging (~4,900).

Zooming in on the specific sub-areas within Medicine in **Figure *3.3***, we see that despite the country's already significant output in the sub-area, Psychiatry and Mental Health grew the most from 2009 to 2013 (10.1% CAGR). Other sub-areas with exceptionally high relative growth rates are: Health Policy (12.9% CAGR, more than double the Netherlands' CAGR in Medicine overall), Epidemiology (9.4% CAGR), and Health Informatics (18.4%).

Most sub-areas show an absolute increase in output from 2009 to 2013, but there are a few exceptions. Most notable among these are Physiology; Internal Medicine; Dermatology; and Histology. Other sub-areas with significant levels of output exhibited relatively small growth rates, including Surgery (2.4% CAGR, less than half the Netherlands' CAGR in Medicine overall) and Pediatrics, Perinatology & Child Health [1.8% CAGR).

In order to see where the Netherlands' research focus in Medicine lies compared to the EU28 and the world, we calculate a relative activity index (RAI) for each sub-area. This is analogous to the way we calculate the RAI at the subject level, dividing each sub-areas share of Netherland's total output in Medicine relative to the world's share in the same sub-area. For example, from 2009-2013, the Netherlands produced 2,925 publications in Endocrinology and 86,346 publications in Medicine overall. The world produced 83,260 publications in Endocrinology and 2,858,355 publications in Medicine overall. The RAI of the Netherlands in Endocrinology is then 490/86,346)/(83,360/2,858,355 = 1.16. This means that relative to the world average, the Netherlands produces 16% more publications in Endocrinology than those in other Medicine sub-areas. **Figure *3.4*** presents the RAI of the Netherlands and the EU28 for each sub-area within Medicine.

Here, we can see that the Netherlands has a distinct focus on Rheumatology (RAI of 2.29); Genetics (clinical) (RAI of 2.29); and Family Practice (RAI of 2.05). Although the Netherlands' research in these sub-areas comprise a smaller proportion of its total output in Medicine (between 0.8% and 3.3% as **Figure *3.5*** shows), the country's RAI values for those sub-areas are above two, which means that relative to the

world average, the Netherlands' produced more than twice as much output as expected in these sub-areas.

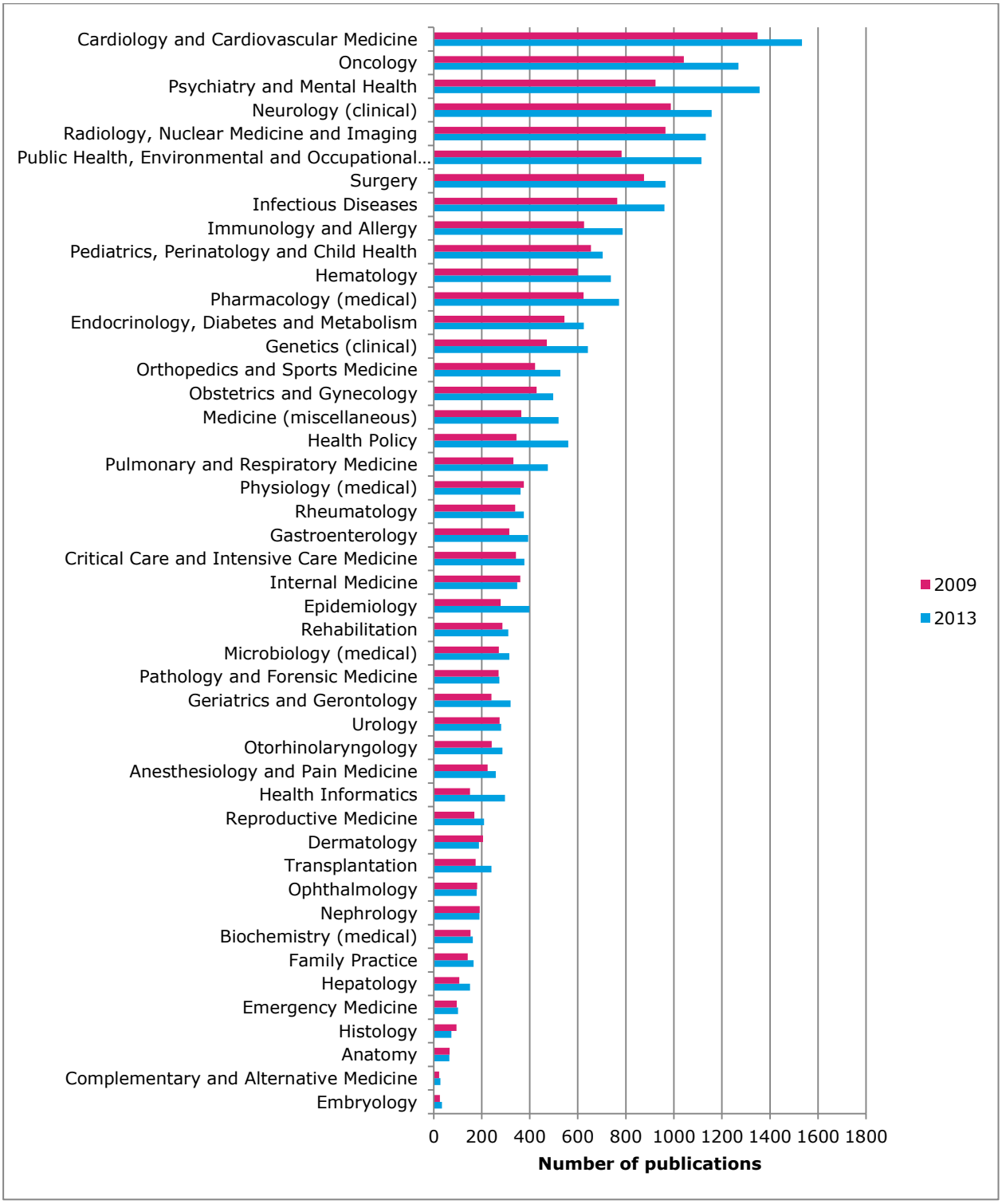


Figure 3.3— *Total number of publications in Medicine by the Netherlands, per sub-area, 2009 and 2013 (General Medicine is excluded for ease of viewing)*

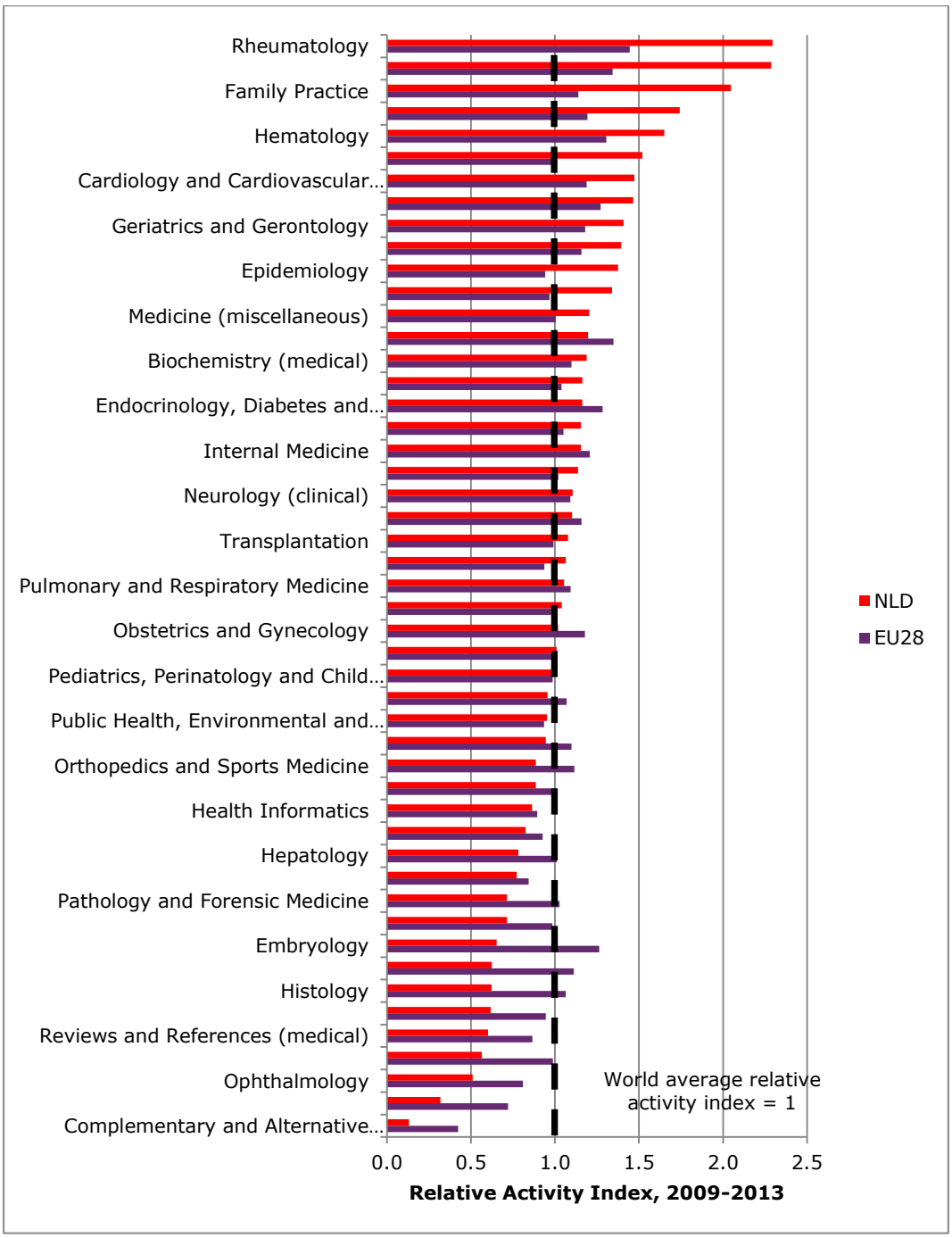


Figure 3.4— *Relative Activity Index for the Netherlands and EU28 in Medicine, per sub-area, 2009-2013*

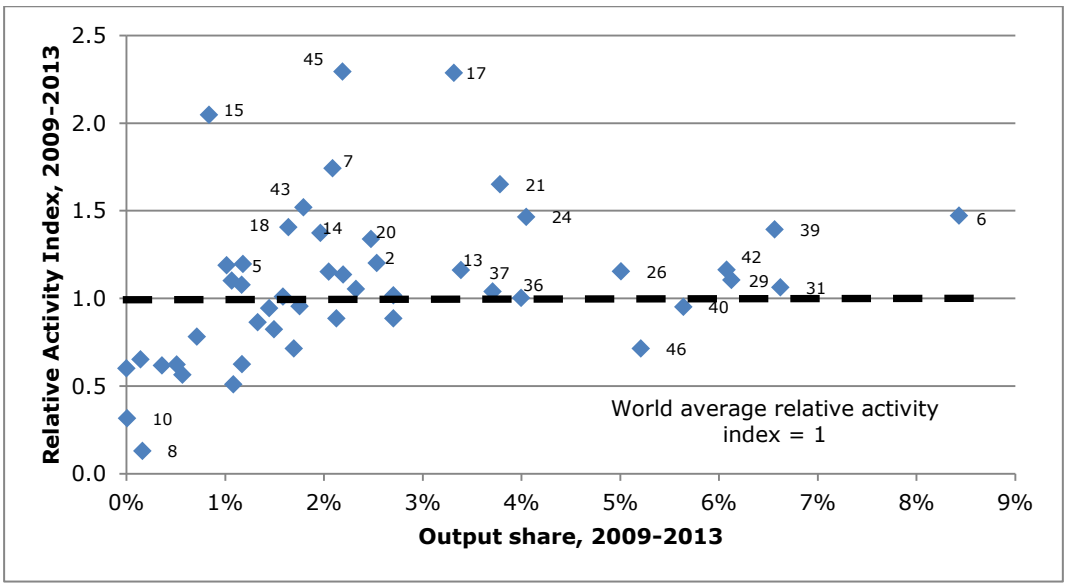


Figure 3.5— *Relative Activity Index versus number of publications in sub-area relative to total publications in Medicine for the Netherlands, per sub-area, 2009-2013. See table in Appendix B for translation of numbers to sub-areas. General Medicine is excluded for ease of viewing.*

3.2.2 Citation impact and excellence

As **Figure *3.6*** shows, the FWCI of the Netherlands' research in Medicine is consistently higher than the world average (1.91) and the highest among all comparator countries (e.g., the five most prolific EU and non-EU countries). The next closest comparator country in terms of FWCI in Medicine is Canada at 1.75. Among the top 2 comparator countries inside and outside the EU, FWCI is generally stable. Among all EU comparator countries, Spain has grown its FWCI the most from 2009-2013, increasing from 1.13 to 1.38, while among non-EU comparator countries, China has grown its FWCI the most, increasing from 0.57 to 0.81. These high growth rates are partly attributable to those countries "catching" up with their global peers.

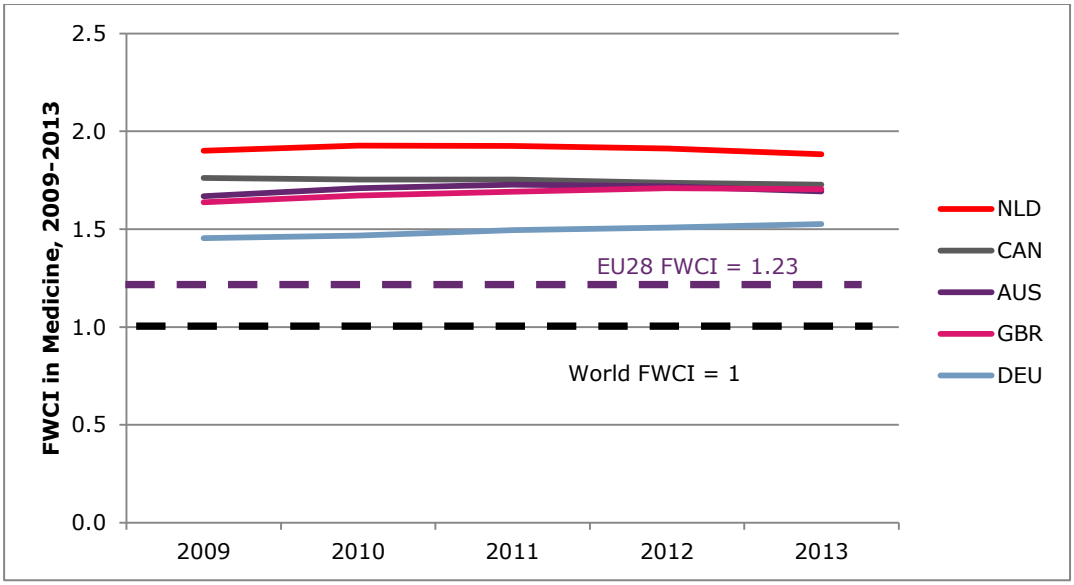


Figure 3.6— *Field-weighted citation impact of the Netherlands and top 2 EU and top 2 non-EU comparator countries in Medicine, per year, 2009-2013*

To further examine the distribution of the Netherlands' output in different sub-areas within Medicine, **Figure *3.7*** plots the FWCI of outputs in those sub-areas against the amount of the country's output in

those sub-areas. Please see Appendix B for a full table of the Medicine sub-areas corresponding to each number label.

Given the high overall FWCI of the country's output in Medicine, it is unsurprising that its most prolific sub-areas attain high FWCI relative to the world average (1.0), that of the Netherlands' research output overall (1.78), and that of the Netherlands research in all Medicine sub-areas (1.91).[15] For example, the FWCIs of the Netherlands' output in General Medicine (1, not included in **Figure *3.7*** for ease of viewing other points) and Cardiology and Cardiovascular Medicine (6) are 2.73 and 1.93, respectively. Other sub-areas with especially high FWCI include Urology (48, FWCI of 2.21) and Rheumatology (45, FWCI of 2.16).

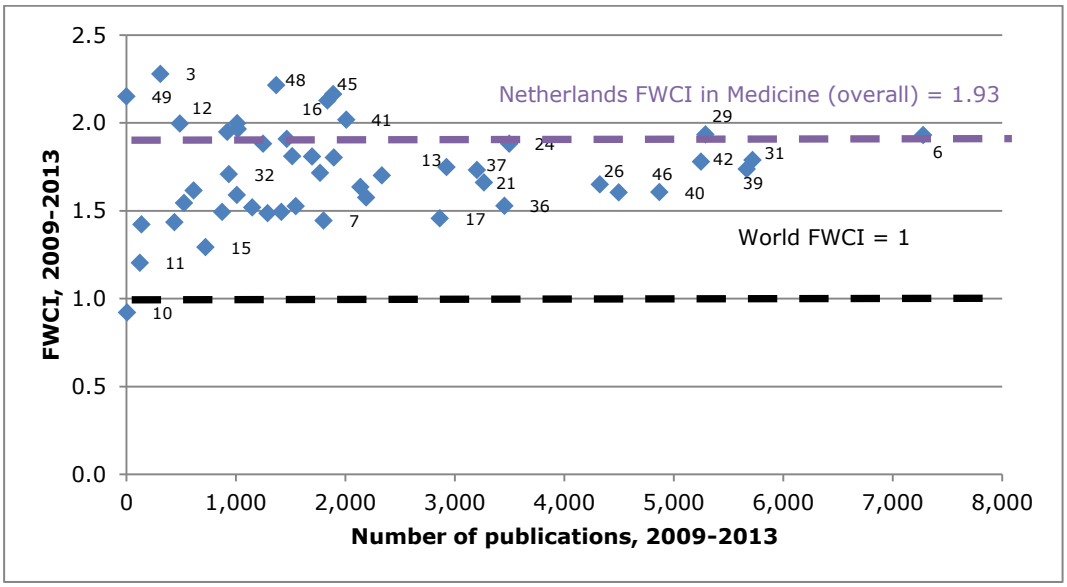


Figure 3.7— *FWCI versus number of publications in Medicine by the Netherlands, per sub-area, 2009 and 2013 (General Medicine, which achieved a FWCI of 2.73, is excluded from this graph for ease of viewing).*

From 2009-2013, the Netherlands produced 2,605 publications in Medicine that were among the world's top 1% most cited. Such publications comprise more than 3% of the country's total output in Medicine. This means that the relative rate in which the Netherlands produces publications among the world top 1% most cited is three times the world average. As **Figure *3.8*** shows, the Netherlands leads all comparator countries in this research performance indicator, though its growth rate (4.5%) lags behind that of EU28 as a whole (5.1%) as well as other top comparator countries such as the UK (6.1% CAGR) and France (7.3% CAGR).

Moreover, although the Netherlands produces an order of magnitude fewer publications in Medicine (and overall) than countries such as the USA (which produced 810,000 publications in Medicine from 2009-2013, compared to 86,000 for the Netherlands), Netherlands' authors account for 8.9% of all Medicine output in the world's top 1% most cited. **Figure *3.9*** displays the trends in the Netherlands' and top comparator countries' world shares of the world's top 1% most cited. Although the USA accounts for a staggering 58.4%, that share has been slightly decreasing (-1.3% CAGR).

[15] In fact, across all 49 sub-areas of Medicine, the only sub-area in which the Netherlands achieves a FWCI below the world average is Drug Guides. The country produced only 7 publications in this area, however, from 2009-2013, so one should interpret the FWCI value with caution.

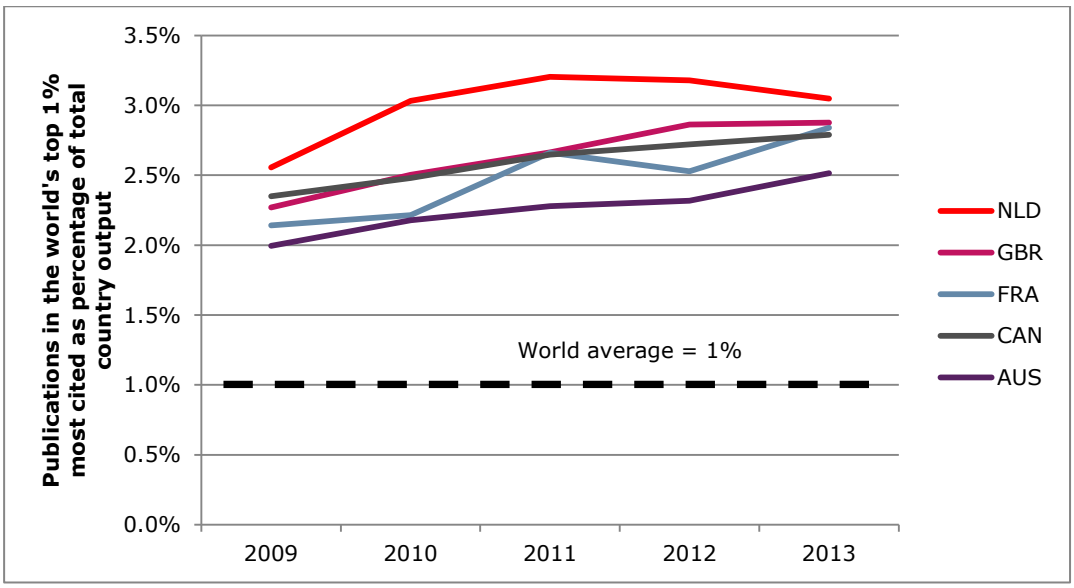


Figure 3.8—*Top 1% most cited in Medicine by the Netherlands and top 2 EU and top 2 non-EU comparator countries relative to total publications of the entity, per year, 2009-2013*

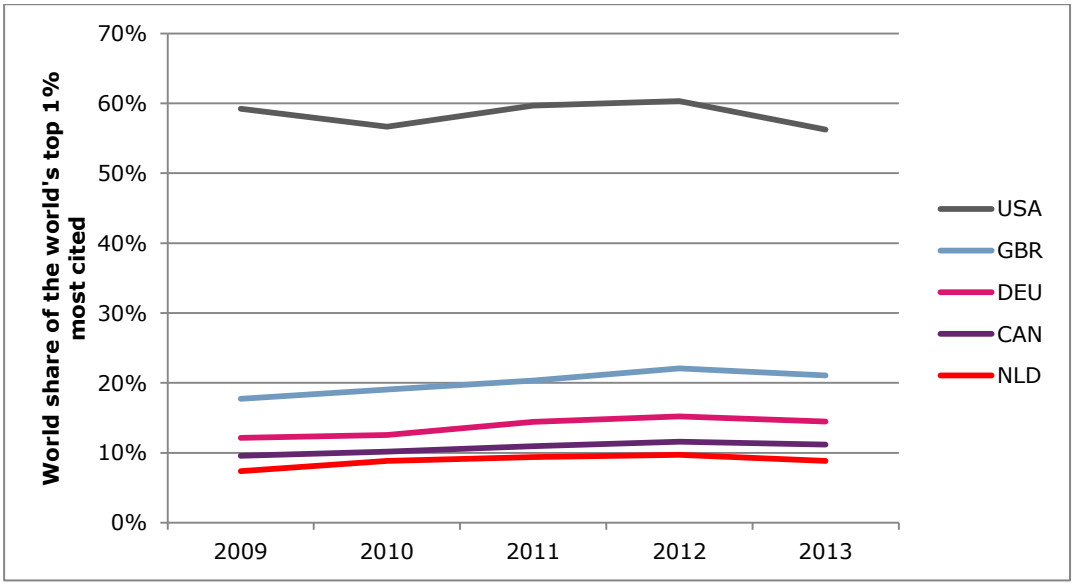


Figure 3.9—*Top 1% most cited in Medicine by the Netherlands and top 2 EU and top 2 non-EU comparator countries relative to that of the world, per year, 2009-2013*

Figure *3.10* provides a closer analysis of the Netherlands' output in the world's top 1% most cited across all of the Medicine sub-areas. The y-axis shows the Netherlands' share of the world's top 1% most cited, and the x-axis shows the Netherland's share of the total world output in the sub-area. For example, from 2009-2013, the Netherlands produced 1,890 publications in Rheumatology, while the world as a whole produced 27,269. Of those, 280 publications amassed enough citations to be considered among the world's top 1% most cited[16], and the Netherlands' authors accounted for 78 of those 280 publications. Thus, the x-value for Rheumatology is 6.9% (1,890/27,269), while the y-value is 27.9% (78/280).

[16] The exact citation count threshold is calculated per year, and if multiple publications have the same citation count, they are all considered in the world's top 1% most cited, even if their aggregate share is greater than 1%. This is why calculations of the world's top 1% most cited is not exactly 1% of the total amount of publications (either overall or in a given sub-area).

Dots or sub-areas above the dotted line (y=x) indicate that the Netherlands produces a higher proportion of the world's top 1% most cited publications in that sub-area than the country's output share would otherwise suggest. In other words, the country punches well above its weight in that sub-area.

In addition to Rheumatology, the Netherlands punches well above its weight in other Medicine sub-areas such as Urology (48, 18.0% top 1% most cited world share compared to 3.1% output world share), Genetics (clinical) (17) and Hematology (21).

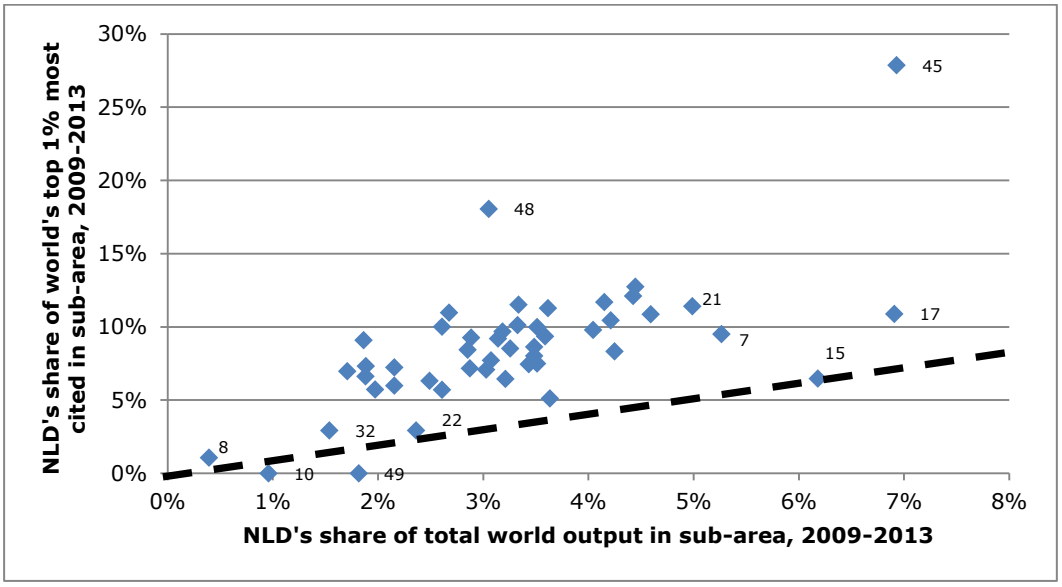


Figure 3.10—*The Netherlands top 1% most cited publications relative to that of the world versus the Netherlands publications in sub-area relative to that of the world, per sub-area, 2009-2013*

3.3 Collaboration

3.3.1 International collaboration

Similar to the overall countries' trends, nearly half (46.3%) of all Netherlands' publications in Medicine were co-authored with an international collaborator. As **Figure *3.11*** shows, relative to the next top EU and non-EU countries, the Netherlands' international collaboration rate is the highest. Moreover, despite the already high levels, the country's international collaboration rate in Medicine continues to grow steadily, increasing 3.9% from 2009 to 2013. This parallels the trends in comparator countries for both Medicine in particular and across all subject areas in general.

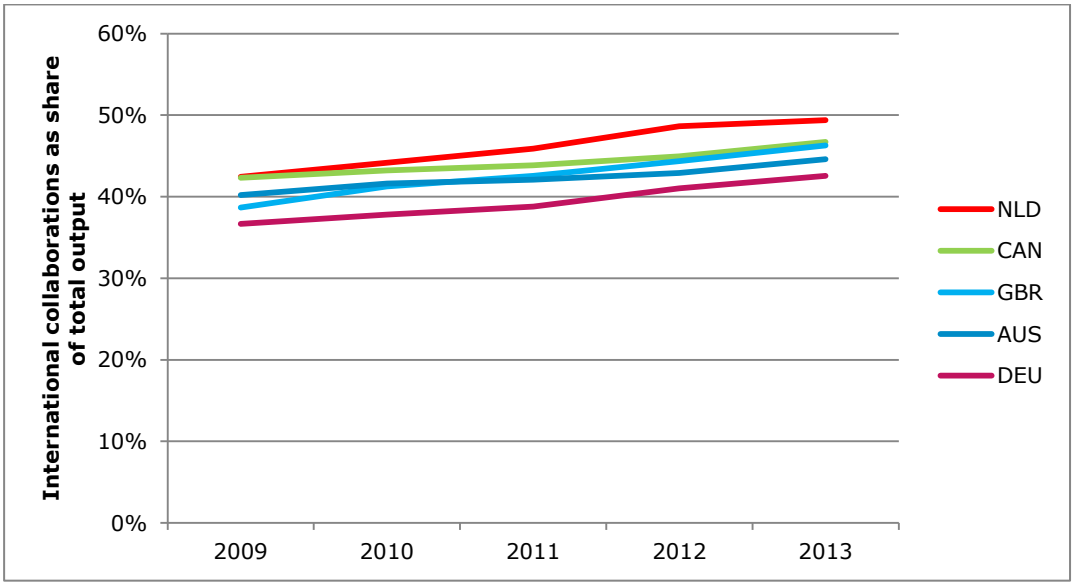


Figure 3.11— *Number of international collaborations relative to total country output in Medicine for the Netherlands and top 2 EU and top 2 non-EU comparator countries, per year, 2009-2013*

Figure *3.12* provides a deeper breakdown of the relative international collaboration rates for Netherlands' research in the various Medicine sub-areas. Genetics (clinical) and Complementary & Alternative Medicine displayed the highest levels of international collaboration at 68.2% and 64.3%, respectively. These are much higher than the country's overall international collaboration rate in Medicine (46.3%) and overall (51.7%).

Figure *3.13* provides another way to analyze the relative size or level of international collaboration activity for a given sub-area. Here, the y-axis displays the number of Netherlands' international collaborations for a given Medicine sub-area divided by the total number of Netherlands' international collaborations in Medicine, while the x-axis displays the output share for a given sub-area.

Dots or sub-areas above the dotted line (y=x) indicate that the Netherlands collaborates internationally on a higher proportion of its publications in that sub-area than expected given that sub-area's output share. Once again, Genetics (clinical) stands out – international collaborations in that sub-area account for 4.9% of all Netherlands' international collaborations in Medicine, while publications in that sub-area account for only 3.3% of all Netherlands' total output in Medicine.

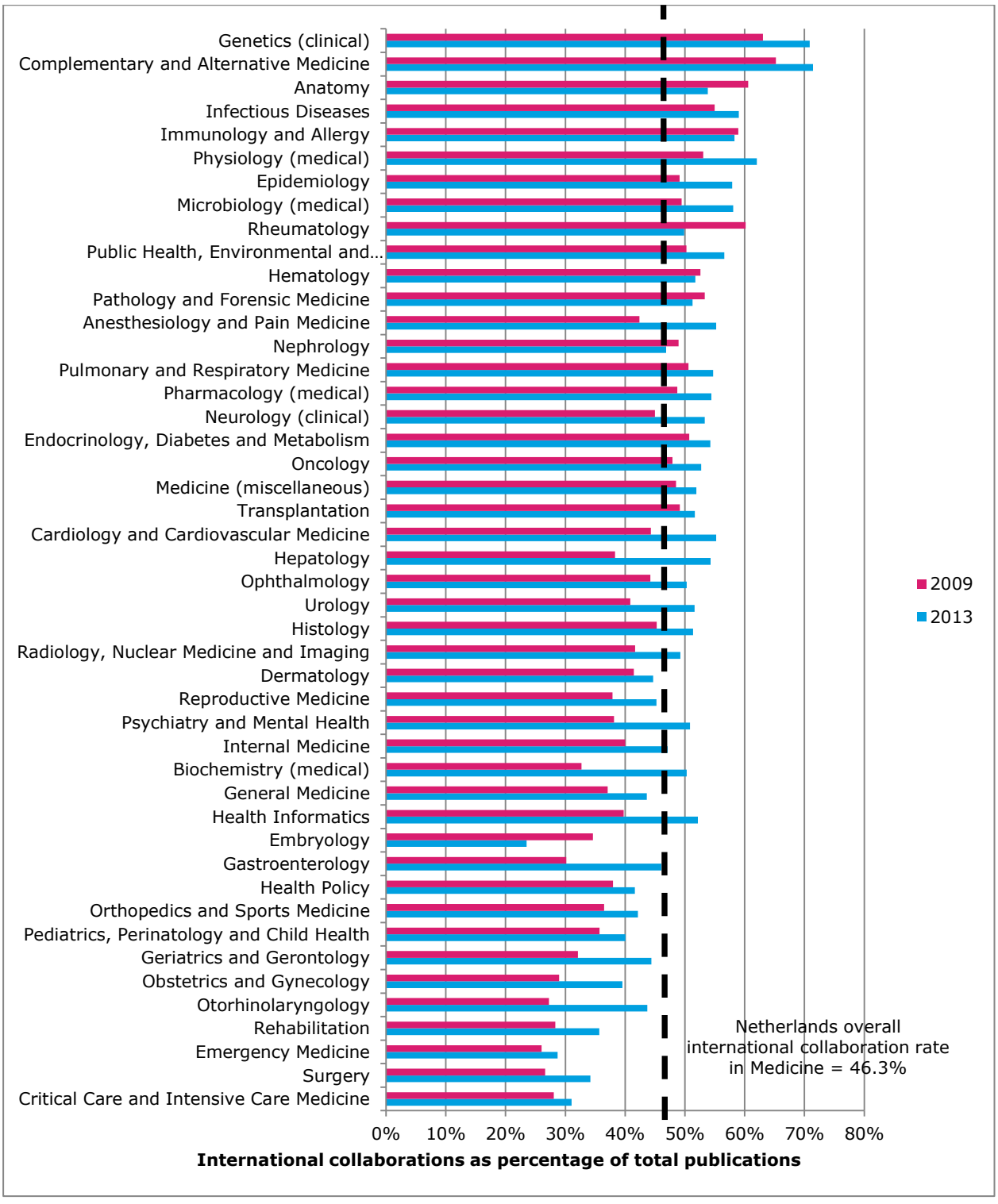


Figure 3.12— *Number of international collaborations in sub-area relative to total Netherlands' output in Medicine, per sub-area, 2009 and 2013 (Drug Guides is excluded due to low number of observations)*

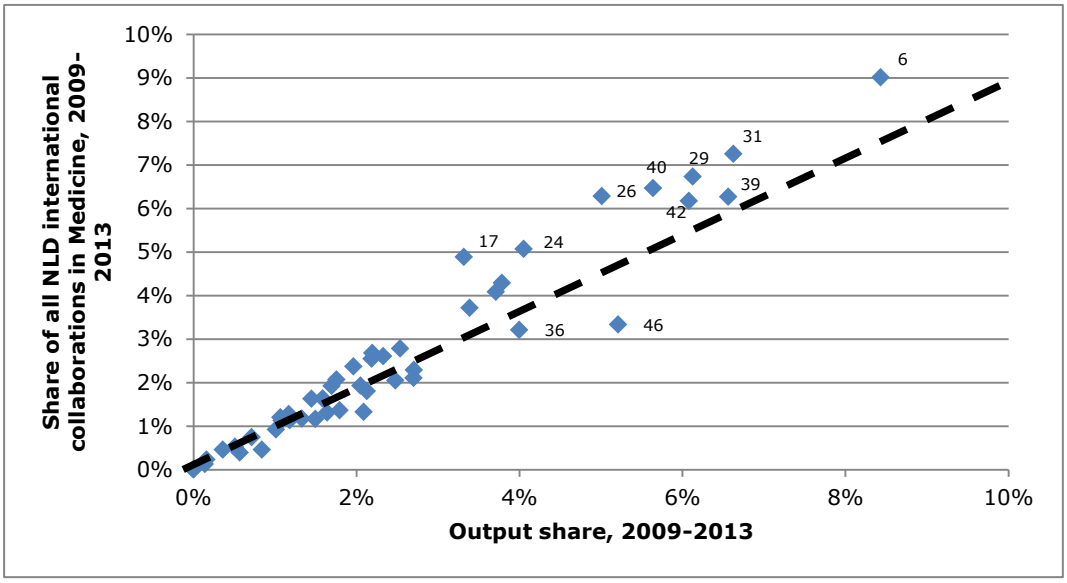


Figure 3.13— *Number of international collaborations in sub-area relative to total Netherlands' output in Medicine versus number of publications in sub-area relative to total Netherlands' output in Medicine, per sub-area, 2009-2013*

What is the citation impact of international collaborations in Medicine? **Figure *3.14*** compares a comparison for the Netherlands, the EU28, and the top two EU and non-EU countries (in terms of the FWCI of international collaborations in Medicine). As expected, although the Netherlands achieves an overall FWCI of 1.91 in Medicine, its international collaborations in Medicine achieve a FWCI of 2.63. This means that the Netherlands' international collaborations in Medicine achieve a FWCI nearly 38% (2.63/1.91 = 1.38) higher than its overall publications in Medicine. While it is difficult to draw causal inferences due to selection effects and omitted variables (researchers who conduct more impactful research may also be more likely to collaborate internationally or have the opportunity to do so), we see a strong correlation between whether an article involves an international collaborator and its FWCI, and this effect is quite pronounced for Medicine.

Given the high FWCI associated with the Netherlands' output in Medicine overall, the country's ratio of international collaboration FWCI to overall FWCI is the lowest among all comparator countries. In contrast, for example, Italy achieves a much higher multiplier (1.72). Its overall FWCI in Medicine is 1.46, while the FWCI of its international collaborations in Medicine is 2.51, yielding a multiplier of 1.72.

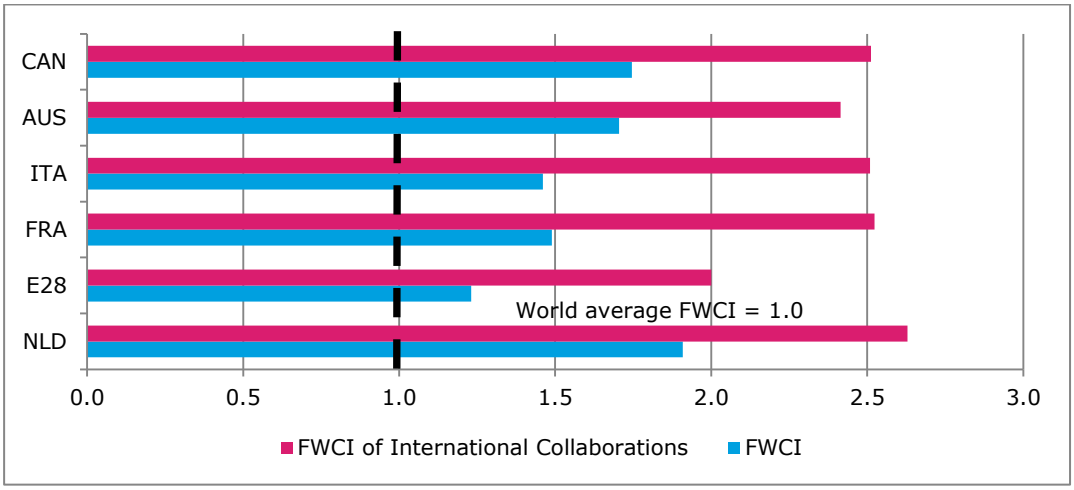


Figure 3.14— *FWCI of international collaborations versus overall FWCI for the Netherlands and top 2 EU and top 2 non-EU comparator countries, in Medicine 2009-2013*

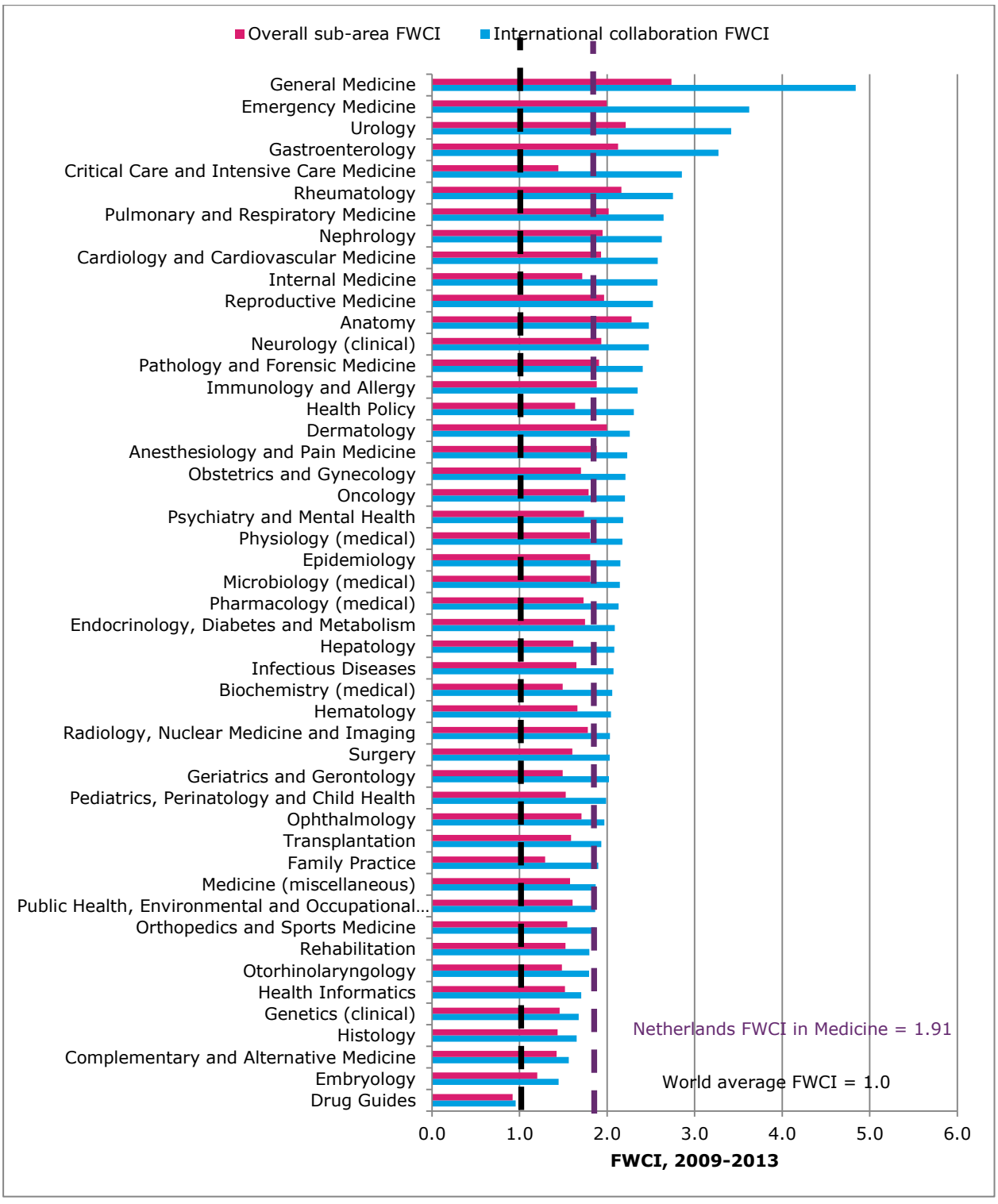


Figure 3.15— *FWCI of international collaborations versus overall FWCI of sub-area, for the Netherlands, per sub-area, 2009-2013*

Figure *3.15* provides a deeper comparison of the FWCI associated with the Netherlands' output in Medicine sub-areas and that associated with international collaborations in those sub-areas. The sub-areas with the highest FWCI in international collaborations are General Medicine (4.84); Emergency Medicine (3.62); Urology (3.42), Gastroenterology (3.27); and Critical Care and Intensive Care Medicine (2.86). Those same five sub-areas also display the highest ratios in terms of comparing international FWCI to overall FWCI, although their order shifts. The FWCI of the Netherlands' overall output in Critical Care and Intensive Care Medicine is only 1.44, while international collaborations in that sub-area achieve a FWCI that is nearly double that rate.

Among the Netherlands' top international collaborators in Medicine are some of the most prolific institutions in the world, including Harvard University (1,984 co-authored publications), Katholieke Universiteit Leuven (1,870), and University College London (1,627). More importantly, as **Figure *3.16*** shows, the FWCI associated with international collaborations with those institutions is much higher than the FWCI associated with all international collaborations in Medicine. In fact, Netherlands' institutions' international collaborations with Harvard particularly stand out (FWCI of 6.1).

Moreover, in examining the top 10 international collaborators for other countries, several Netherlands' universities appear, such as the University of Rotterdam (among the top 10 international collaborators for the USA, the UK, France, Germany, Italy), Utrecht University (the UK, Spain), and the University of Amsterdam (the UK).

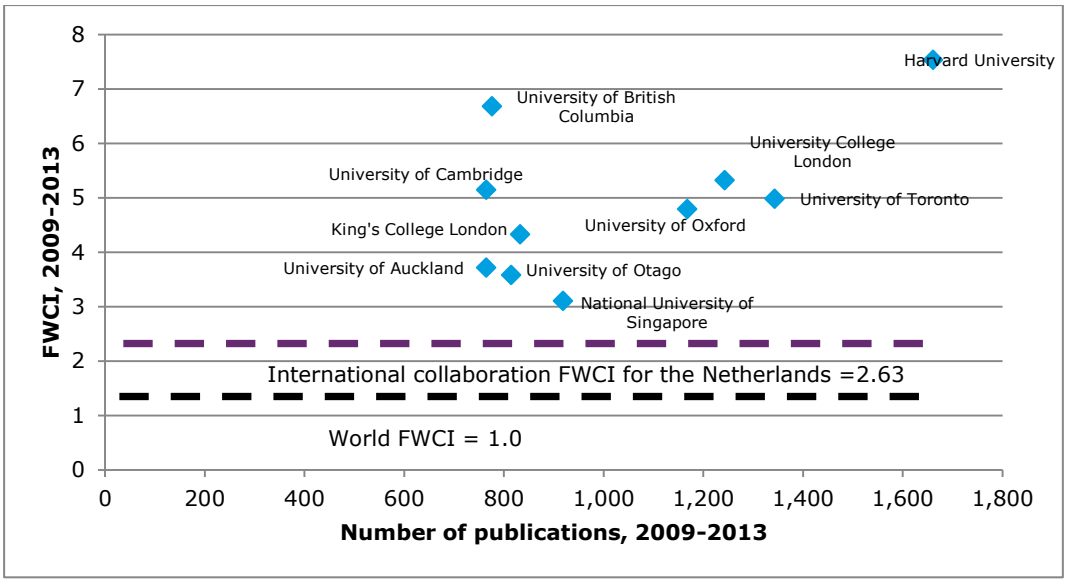


Figure 3.16— *Number and FWCI of collaborations of top 10 international institutions collaborating with Netherlands institutions in Medicine*

3.3.2 Academic-corporate collaboration

Relative to trends at the overall country level (7.1%), academic-corporate collaborations comprise an even smaller proportion of the country's overall output in Medicine (4.7%). However, the proportion of academic-corporate collaborations in Medicine in general is quite low, as EU28 (2.9%) and other comparator countries' benchmarks reveal in **Figure *3.17***. Trends have largely stayed constant, though the USA has seen a slight decline in the relative share of its output in Medicine that are academic-corporate collaborations (-3.1% CAGR).

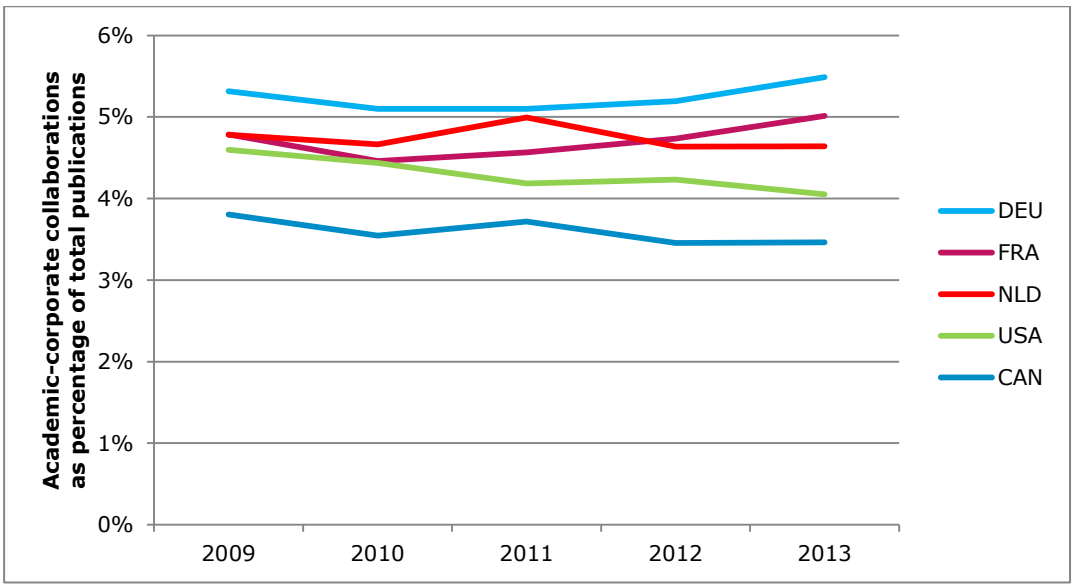


Figure 3.17— *Number of academic-corporate collaborations relative to total country output in Medicine for the Netherlands and top 2 EU and top 2 non-EU comparator countries, per year, 2009-2013*

Figure *3.18* provides a deeper breakdown of academic-corporate collaboration rates for each of the sub-areas within Medicine. In particular, the sub-areas with the highest levels of academic-corporate collaboration are: Pharmacology (medical) (at 10.2%); Radiology, Nuclear Medicine and Imaging (at 9.5%); and Rheumatology (at 9.1%).

Analogous to **Figure *3.13***, **Figure *3.19*** displays the performance of each sub-area in terms of its share of all Netherlands' academic-corporate collaborations in Medicine versus its share of all Netherlands' publications in Medicine. If a sub-area is located above the dotted line, that means that a higher-than-expected proportion of publications in that sub-area were academic-corporate collaborations, given its overall publication output share. Here, we see again that Pharmacology and Rheumatology stand out.

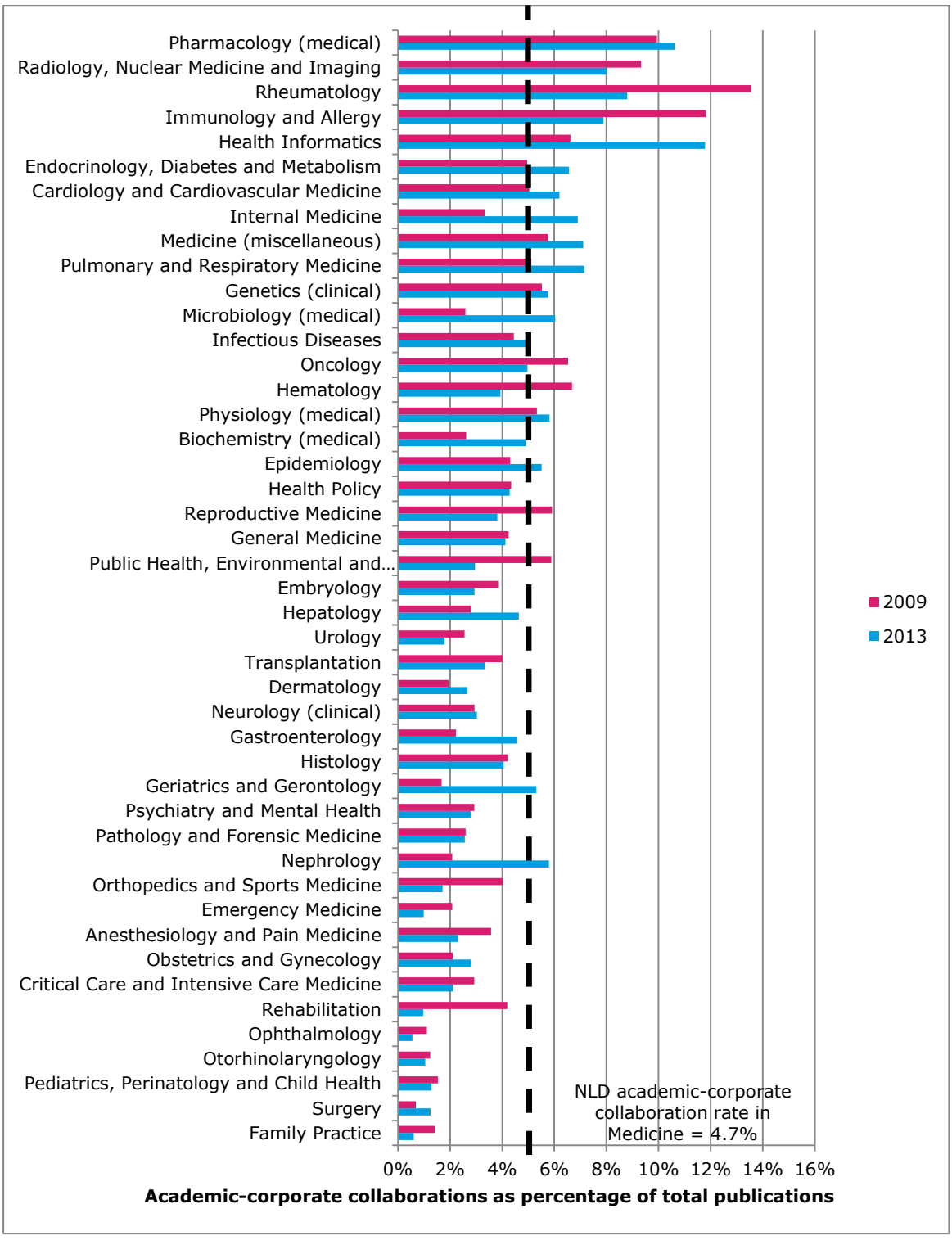


Figure 3.18— *Number of academic-corporate collaborations in sub-area relative to total Netherlands' output in Medicine, per sub-area, 2009 and 2013*

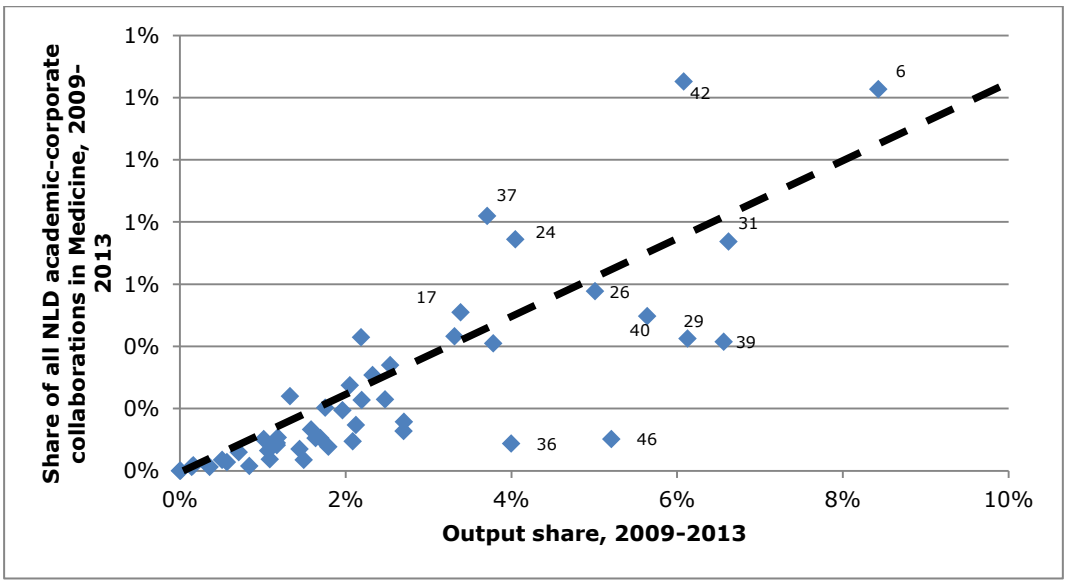


Figure 3.19— *Number of academic-corporate collaborations in sub-area relative to total Netherlands' output in Medicine versus number of publications in sub-area relative to total Netherlands' output in Medicine, per sub-area, 2009-2013 (General Medicine is excluded for ease of viewing).*

How impactful are academic-corporate collaborations in Medicine? **Figure *3.20*** compares the FWCI of academic-corporate collaborations in Medicine to that of all publications in Medicine for the Netherlands, the EU28, and the top 2 EU and top 2 non-EU comparator countries. Netherlands' academic-corporate collaborations in Medicine achieve a FWCI of 4.73, which is almost 2.5 times higher than the FWCI of its overall FWCI in Medicine. Other comparator countries see even higher multipliers – for example, the FWCI of Italy and Australia's academic-corporate collaborations are both 3.9 times more than the FWCI of those respective countries' total publications in Medicine .

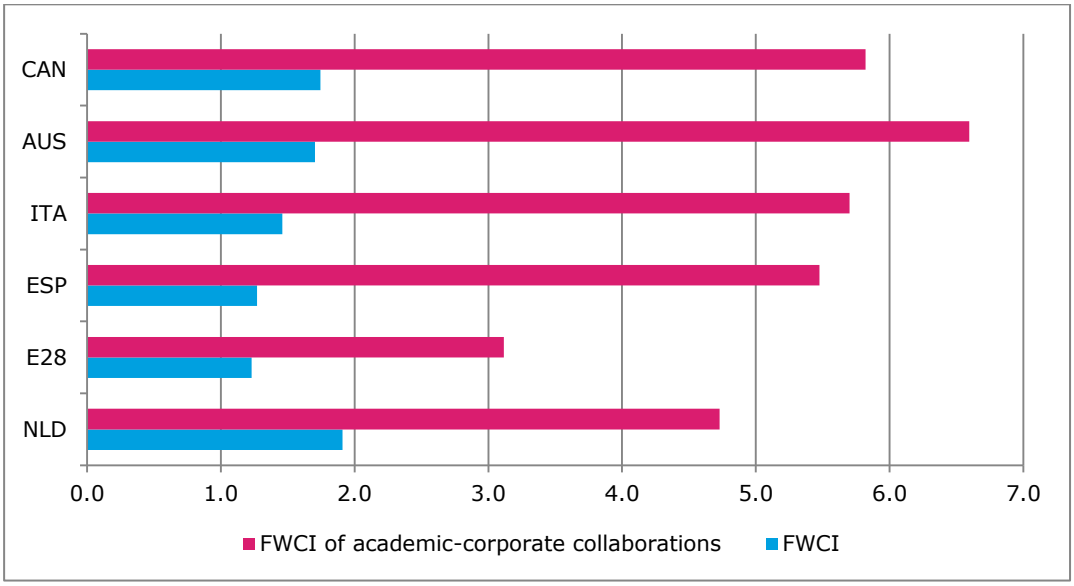


Figure 3.20— *FWCI of academic-corporate collaborations versus overall FWCI for Netherlands and top 2 EU and top 2 non-EU comparator countries, in Medicine 2009-2013*

When we analyze the FWCI of academic-corporate collaborations within specific sub-areas in Medicine, we see that the high FWCI is largely driven by academic-corporate collaborations in General Medicine. Publications in that sub-area comprise 704/4092 = 17.2% of all Netherlands' academic-corporate collaborations in Medicine, but they achieve an outsized impact (FWCI of 14.2 or nearly three times the

FWCI of all Netherlands' academic-corporate collaborations in Medicine or more than seven times the FWCI of all Netherlands' research output in Medicine).

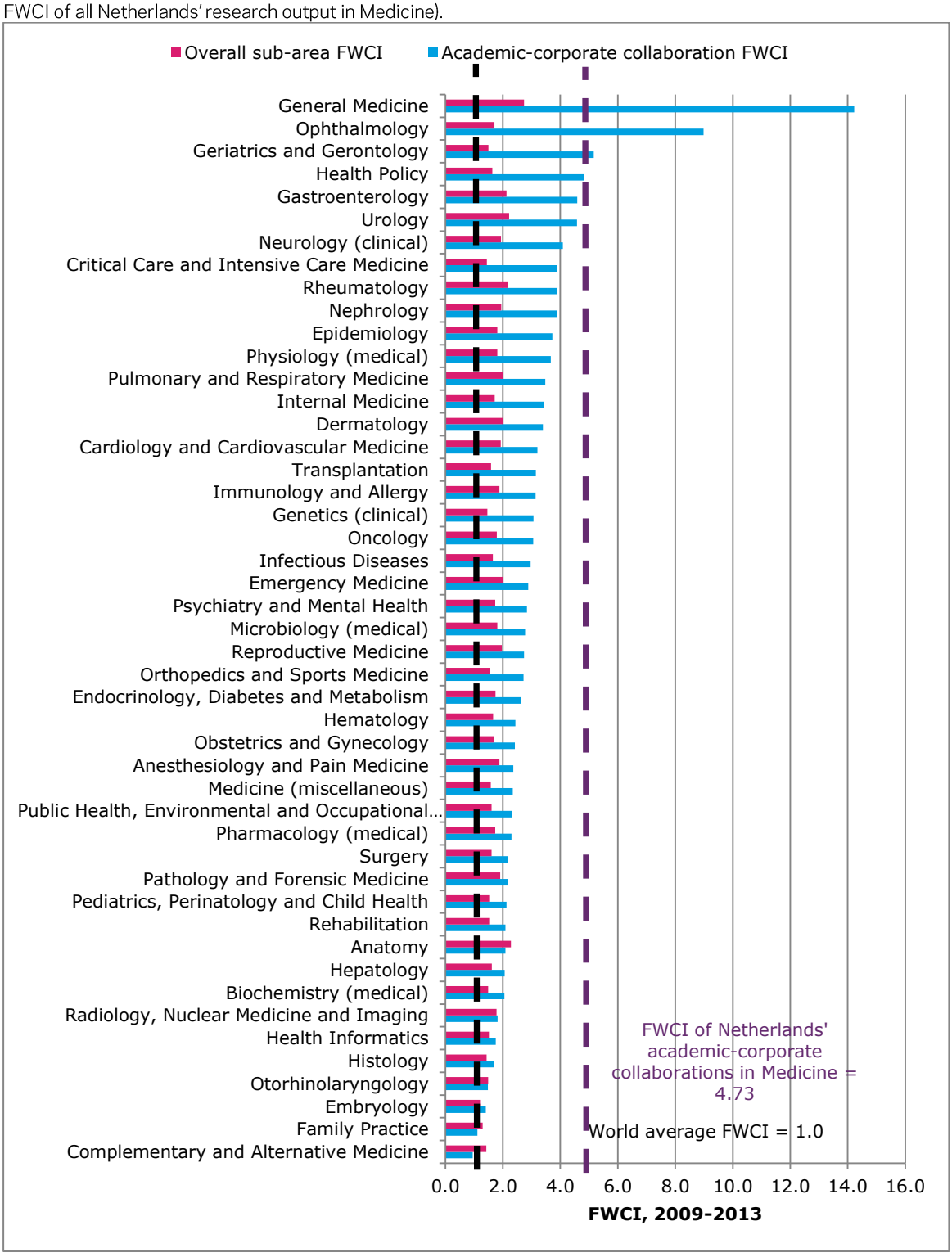


Figure 3.21 — *FWCI of academic-corporate collaborations versus overall FWCI sub-area, for Netherlands, per sub-area, 2009-2013*

The list of corporate institutions that collaborate most frequently with Netherlands institutions include several major pharmaceutical companies (GlaxoSmithKline with 299 collaborations leads all corporations; Pfizer, Eli Lilly; Novartis; Merck; Abbott Laboratories; and Bayer). As **Figure *3.22*** shows, collaborations with most of these corporations achieve a FWCI above even the high FWCI associated with all academic-corporate collaborations. Some notable exceptions include the Netherlands' collaborations with Phillips Medical Systems US and Unilever, which achieved FWCI of 1.71 and 2.37, respectively.

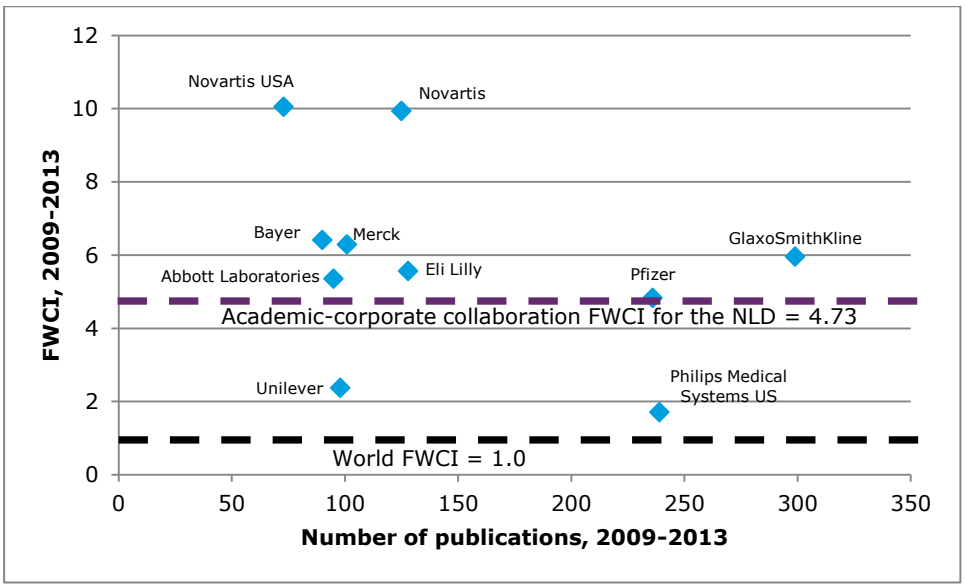


Figure 3.22—*Number and FWCI of collaborations of top 10 corporate institutions collaborating with Netherlands institutions in Medicine*

3.4 Knowledge Transfer

3.4.1 Corporate downloads

From 2009-2013, corporate downloads of Netherlands' publications in Medicine accounted for between 5.7% and 6.6% of all corporate downloads of publications in Medicine, as **Figure *3.23*** shows. While this is lower than the world corporate download shares of other comparator countries inside and outside the EU, it is still nearly twice the level of the Netherlands' world share of Medicine output (3.0%).

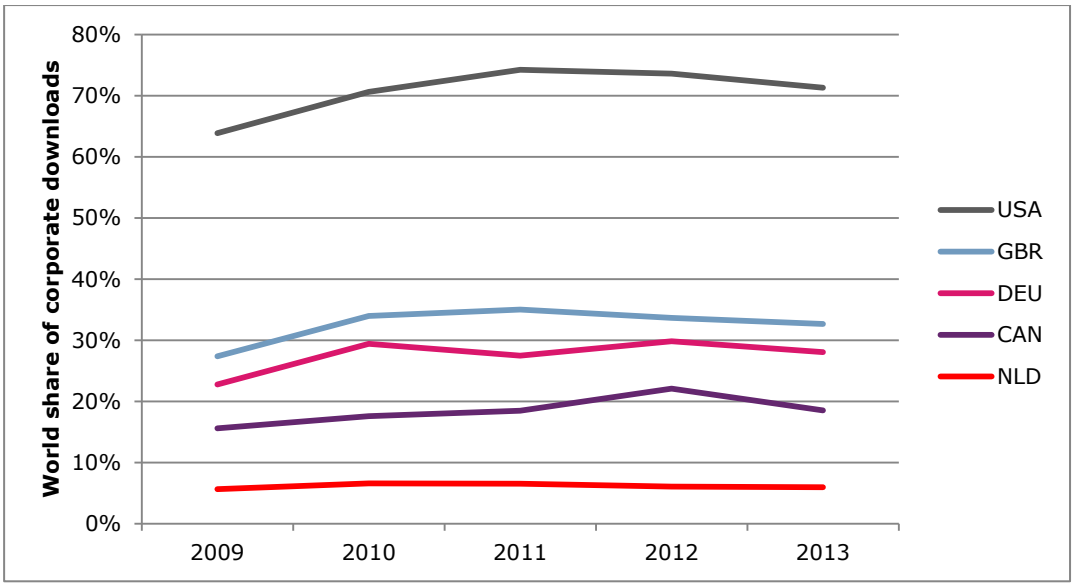


Figure 3.23— *Corporate downloads of research in Medicine by the Netherlands' and top 2 EU and top 2 non-EU comparator countries relative to that of the world, per year, 2009-2013*

Figure *3.24* provides a more in-depth breakdown of corporate downloads of the Netherlands' output across sub-areas of Medicine. Sub-areas such as Oncology and Cardiology and Cardiovascular Medicine garner a higher-than-expected proportion of all corporate downloads of Netherlands' research in Medicine, especially given the relative size of Netherlands' output in those sub-areas. On the other hand, sub-areas such as General Medicine; Radiology, Nuclear Medicine, and Imaging; and Psychiatry and Mental Health receive a lower-than-expected proportion of all corporate downloads.

Whereas **Figure *3.24*** offers a Netherlands-centric perspective of the relative popularity of its Medicine sub-areas among corporate users, **Figure *3.25*** provides a global perspective. For each sub-area, it compares Netherlands' world publication output share to its world corporate download share. For example, Netherlands' research in Critical Care and Intensive Care have garnered 11,180 corporate downloads, while all research in that sub-area have garnered 103,219 corporate downloads. That means the world corporate download share of the Netherlands in that sub-area is 11,180/103,219 = 10.8%. Considering that the Netherlands accounts for only 5.3% of all publications in the world in that sub-area, it is noteworthy that the country's world corporate download share statistic is nearly twice that of its world output share. In additional to Critical Care and Intensive Care, other sub-areas that have receive d a much higher-than-expected amount of corporate downloads include Genetics (clinical) and Urology.

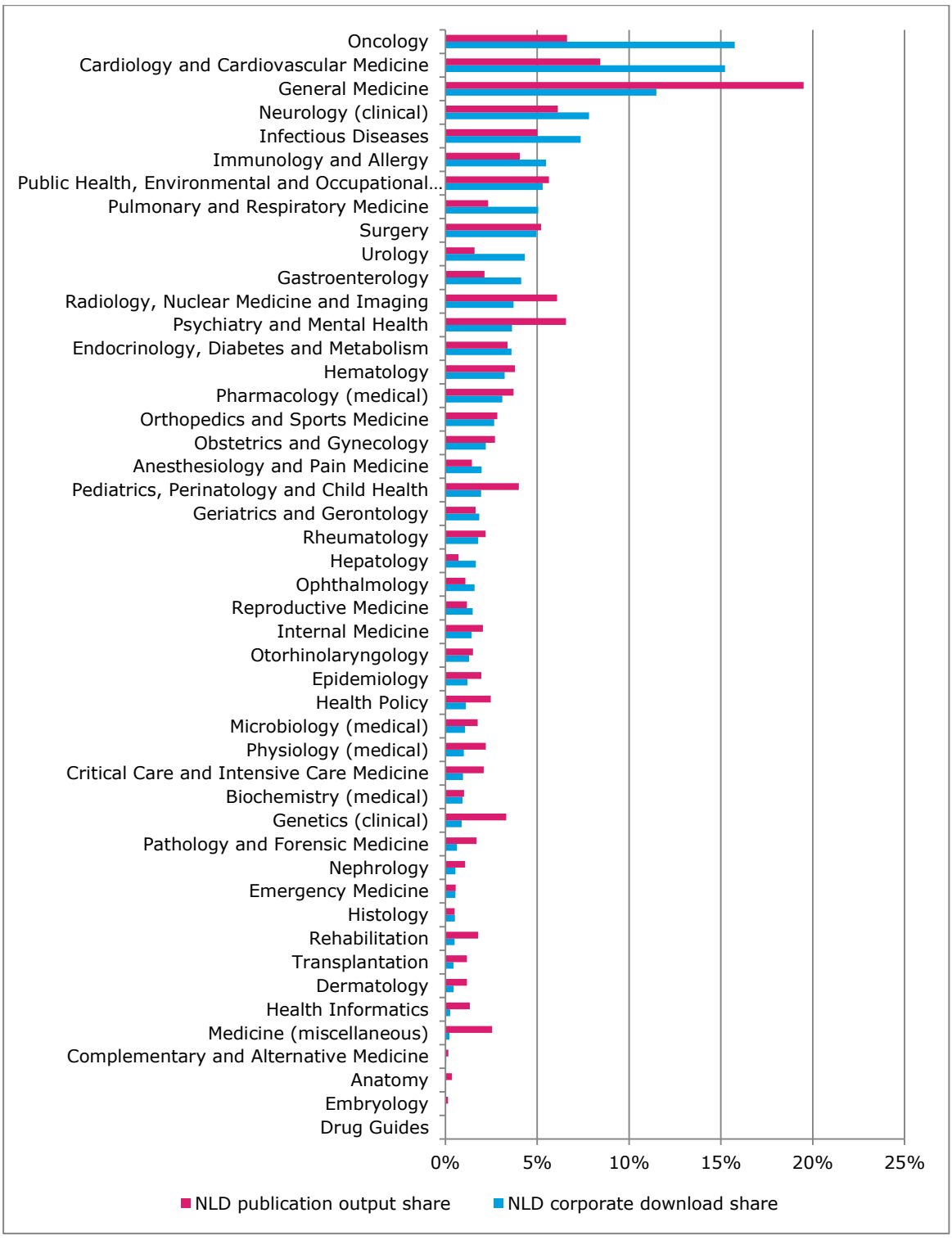


Figure 3.24— *Publication output share in Medicine by the Netherlands versus corporate downloads share, per sub-area, 2009 and 2013*

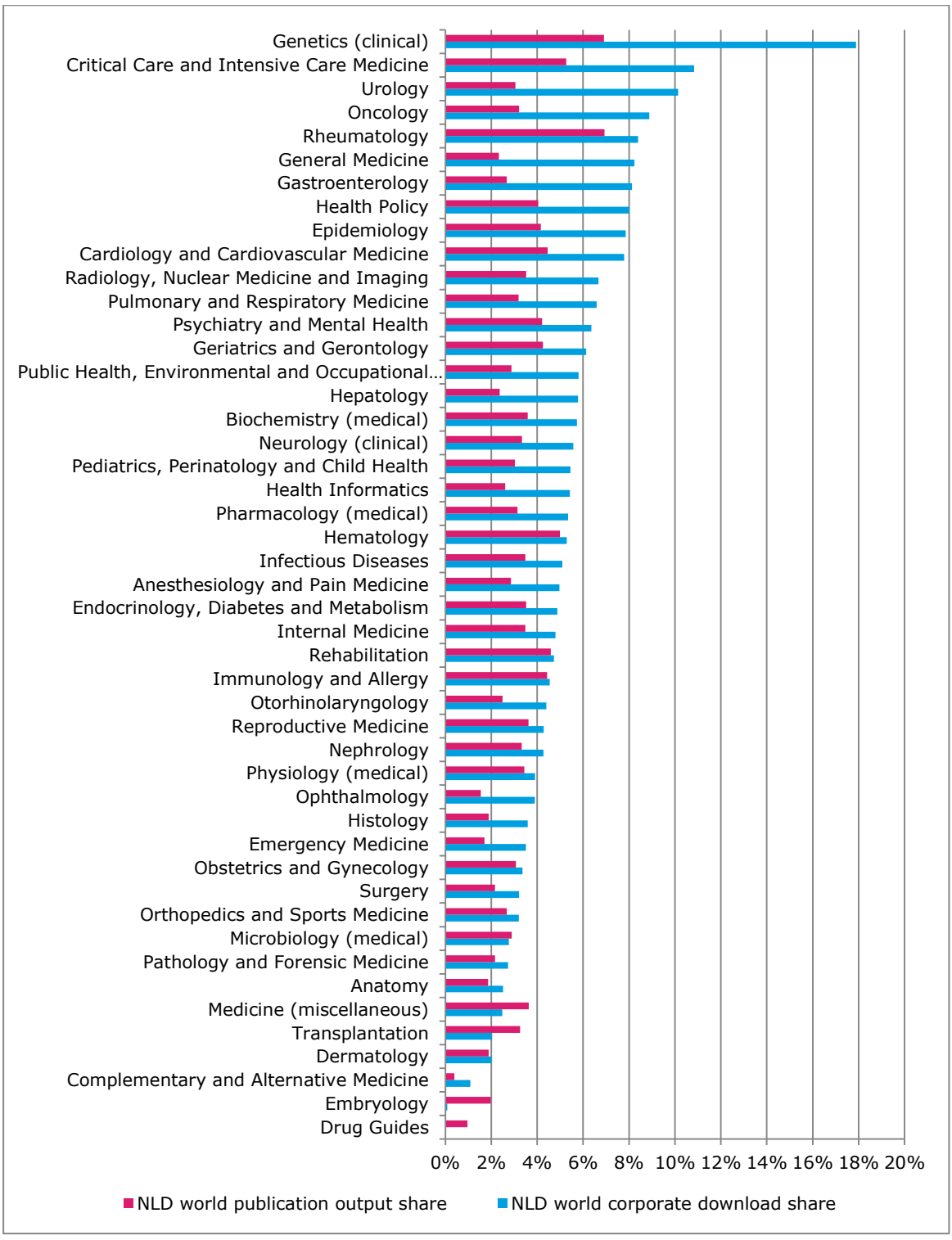


Figure 3.25— *World publication output share in Medicine by the Netherlands versus world corporate downloads share, per sub-area, 2009 and 2013*

3.4.2 Patent citations

Relative to the Netherlands' world patent citation share across all subjects (4.0%), it achieves a slightly higher world patent citation share in Medicine (5.5%). As **Figure *3.26*** demonstrates, that relative share has declined from 2009-2013 (-3.8% CAGR), while that of especially China has grown steadily (6.5% CAGR).

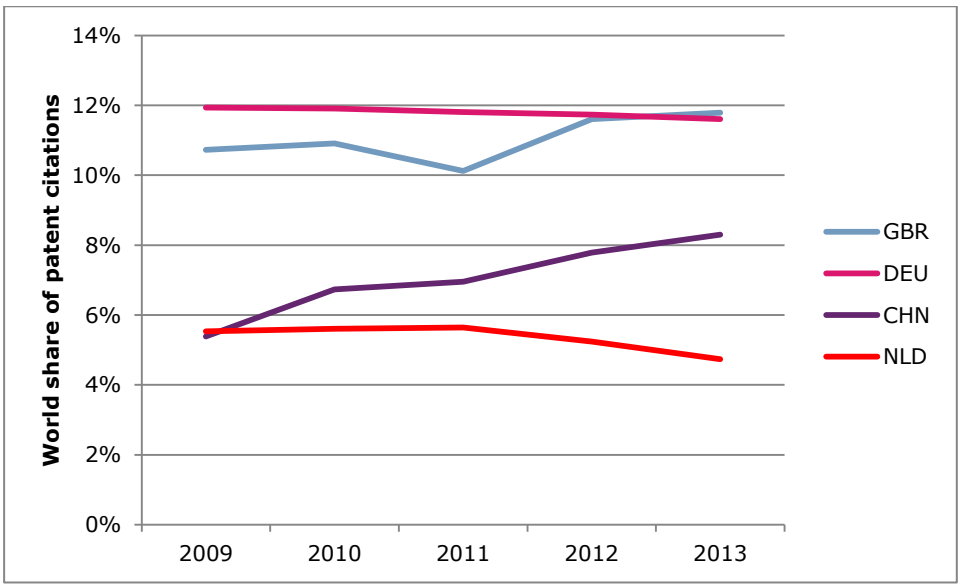


Figure 3.26— *The number of patent citations to publications in Medicine from the Netherlands' and top 2 EU and top 2 non-EU comparator countries relative to that of the world, per year, 2009-2013 (USA is excluded for ease of viewing)*

Across all Medicine sub-areas, **Table *3.1*** lists those whose academic publications have received the highest number of patent citations. Such sub-areas may tend to receive more patent citations in general because they are larger, and/or trends in patent citations for these sub-areas may closely follow world trends. When we compare world patent citation share to world publication share, we see that the Netherlands stands out in a few non-obvious sub-areas. For example, the Netherlands' research in Health Policy over the period has already received 8 patent citations, but those 8 patent citations account for20% of all patent citations in the world in this subject area. Likewise, the country's research in Rheumatology has been cited 44 cited in patents, but all publications in the world in Rheumatology have been downloaded by a corporate user only 436 times.

Sub-area	Number of patent citations to publications from 2009-2013
General Medicine	329
Oncology	249
Hematology	134
Immunology and Allergy	133
Cardiology and Cardiovascular Medicine	125
Radiology, Nuclear Medicine and Imaging	109
Genetics (clinical)	102
Infectious Diseases	97
Neurology (clinical)	79
Pharmacology (medical)	62

Table 3.1— *Number of patent citations, per sub-area for top 10 sub-areas in Medicine, 2009-2013*

3.5 Overview of the Netherlands' research performance in Medicine

In **Table *3.2***, we provide an overview of the main indicators we used in this chapter to summarize the Netherlands' research performance in the 49 sub-areas of Medicine.

Sub-area Name	Publications	FWCI	Top 1%/Total output	International collaboration/Total output	Academic-corporate collaboration/Total output	World corporate download share/World publication share	World patent citation share/World publication share
General Medicine	16841	2.73	8.37%	40.76%	4.18%	3.53	2.22
Medicine (miscellaneous)	2191	1.58	5.11%	50.71%	6.21%	0.68	1.57
Anatomy	312	2.28	9.09%	58.97%	1.60%	1.35	2.58
Anesthesiology and Pain Medicine	1250	1.88	8.43%	52.08%	2.24%	1.74	1.83
Biochemistry (medical)	876	1.49	9.34%	42.01%	4.68%	1.60	1.41
Cardiology and Cardiovascular Medicine	7280	1.93	12.73%	49.51%	6.74%	1.75	1.94
Critical Care and Intensive Care Medicine	1803	1.44	9.51%	29.40%	2.11%	2.06	1.35
Complementary and Alternative Medicine	140	1.42	1.07%	64.29%	5.00%	2.75	0.97
Dermatology	1012	2.00	7.32%	46.05%	3.26%	1.07	1.98
Drug Guides	7	0.92	0.00%	85.71%	0.00%	0.00	0.00
Embryology	123	1.20	5.71%	39.84%	4.07%	0.04	0.63
Emergency Medicine	490	2.00	6.95%	31.84%	2.24%	2.05	3.58
Endocrinology, Diabetes and Metabolism	2925	1.75	7.49%	50.80%	6.97%	1.39	0.96
Epidemiology	1696	1.81	11.68%	55.96%	4.60%	1.89	1.13
Family Practice	724	1.29	6.45%	25.28%	0.83%	0.00	1.35
Gastroenterology	1836	2.13	10.97%	39.27%	3.21%	3.04	2.08
Genetics (clinical)	2864	1.46	10.87%	68.23%	6.04%	2.59	1.41
Geriatrics and Gerontology	1416	1.49	8.31%	37.01%	2.97%	1.44	0.94
Health Informatics	1149	1.52	10.00%	40.73%	8.36%	2.08	2.83
Health Policy	2140	1.63	9.78%	38.18%	4.30%	1.98	4.94
Hematology	3268	1.66	11.39%	52.48%	5.02%	1.06	1.47
Hepatology	616	1.61	2.93%	48.38%	3.90%	2.44	1.61
Histology	440	1.43	6.61%	47.50%	3.18%	1.91	3.08
Immunology and Allergy	3498	1.88	12.09%	57.95%	8.52%	1.03	1.10
Internal Medicine	1771	1.72	8.02%	43.59%	6.21%	1.37	1.10
Infectious Diseases	4326	1.65	8.63%	58.07%	5.34%	1.46	1.25
Microbiology (medical)	1515	1.81	9.26%	54.65%	5.35%	0.96	1.55
Nephrology	923	1.95	10.10%	52.00%	2.82%	1.28	1.42
Neurology (clinical)	5290	1.93	11.50%	50.91%	3.21%	1.67	1.86
Obstetrics and Gynecology	2334	1.70	7.70%	36.08%	2.19%	1.09	1.52
Oncology	5720	1.79	6.43%	50.75%	5.16%	2.76	1.50
Ophthalmology	937	1.71	2.91%	48.03%	1.60%	2.53	2.39

Sub-area Name	Publications	FWCI	Top 1%/Total output	International collaboration/Total output	Academic-corporate collaboration/Total output	World corporate download share/World publication share	World patent citation share/World publication share
Orthopedics and Sports Medicine	2441	1.54	5.69%	37.53%	2.58%	1.20	2.21
Otorhinolaryngology	1292	1.49	6.30%	35.99%	1.08%	1.76	1.82
Pathology and Forensic Medicine	1465	1.91	7.22%	52.35%	2.87%	1.27	2.06
Pediatrics, Perinatology and Child Health	3453	1.53	7.08%	37.19%	1.01%	1.80	1.39
Pharmacology (medical)	3203	1.73	9.20%	51.01%	10.24%	1.70	1.29
Physiology (medical)	1897	1.80	7.43%	56.40%	4.80%	1.14	1.47
Psychiatry and Mental Health	5668	1.74	10.44%	44.21%	2.93%	1.51	1.13
Public Health, Environmental and Occupational Health	4870	1.61	7.15%	53.10%	4.09%	2.02	1.88
Pulmonary and Respiratory Medicine	2009	2.02	9.68%	51.87%	6.12%	2.07	2.01
Radiology, Nuclear Medicine and Imaging	5250	1.78	9.98%	47.03%	9.54%	1.90	2.35
Rehabilitation	1549	1.53	10.86%	35.12%	2.00%	1.03	1.48
Reproductive Medicine	1020	1.97	11.26%	44.51%	4.22%	1.18	1.58
Rheumatology	1890	2.16	27.86%	53.81%	9.10%	1.21	1.46
Surgery	4499	1.60	5.97%	29.61%	0.91%	1.49	2.84
Transplantation	1010	1.59	8.51%	50.40%	3.56%	0.63	1.94
Urology	1369	2.21	18.04%	47.77%	3.87%	3.32	3.08
Reviews and References (medical)	1	0.60	0.00%	0.00%	0.00%	N/A	0.00

Table 3.2— *Overview of the main indicators of the Netherlands' research performance in Medicine, per sub-area, 2009-2013. The color (from red to green) indicates the increase in value.*

Chapter 4
Subject focus: Computer Science

This section provides an in-depth analysis of Netherland's research performance in Computer Science and its sub-areas. It examines the country's total research output and impact, collaboration (international and academic-corporate) and top collaborators, and performance along novel indicators of knowledge transfer (corporate downloads and patent citations).

4.1 Key Findings

COMPOUND ANNUAL GROWTH RATE

-1.25%

The Netherlands' absolute output in Computer Science fell from 2009-2013.

FIELD-WEIGHTED CITATION IMPACT

1.64

Within Computer Science, the Netherlands achieved the highest FWCI in the sub-area of Information Systems (2.01).

HIGH RELATIVE ACTIVITY INDEX AND RESEARCH EXCELLENCE

Human-computer interaction

Netherlands' output in this sub-area is 65% higher than the world average, and although Netherlands' output comprises only 2.7% of the world publication share in this sub-area, it accounts for 6.24% of the world's top 1% most cited.

INTERNATIONAL COLLABORATION RATE

47.3%

INTERNATIONAL COLLABORATION FWCI

1.96

ACADEMIC-CORPORATE COLLABORATION FWCI

2.09

4.2 Publication output & Citation impact

4.2.1 Publication output and growth

Figure *4.1* charts the total publication count of Computer Science (CS) in the Netherlands between 2009 and 2013. The CAGR of -1.25% is lower than the EU 28 CAGR of 2.05% and the Netherlands' overall publication CAGR of 4.3% and this is due to the significant drop in output from 2012 to 2013. In absolute numbers, the output from 2012 dropped from 5,030 publications to 4,771 in 2013 – a relative decrease of just over 5%. At a world level, **Figure *4.2*** demonstrates the Netherland's overall share of worldwide CS publications. The total number of publications worldwide has remained steady at approximately 290,000 (+/- 10,000) per year since 2010 with a world CAGR of 0.24%. Each country in the chart has remained steady in their share of output except for China, whose share dropped almost 5% between 2009 and 2013. The Netherlands' share of world output remained steady at an average of 1.69%.

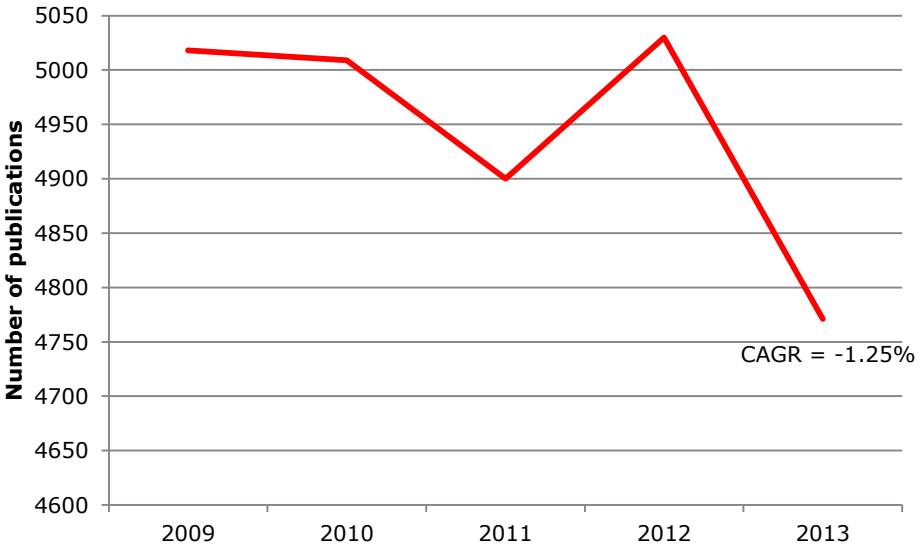


Figure 4.1— *Total number of CS publications by the Netherlands, per year, 2009-2013*

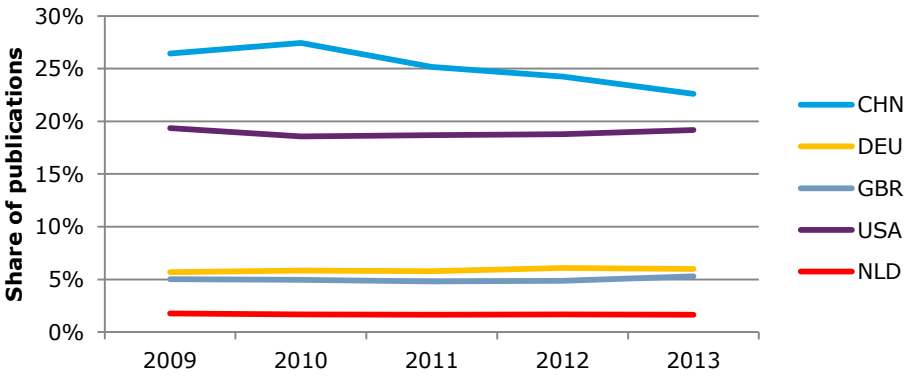


Figure 4.2— *Number of publications from the Netherlands' and top 2 EU and top 2 non-EU comparator countries in CS relative to world output, per year, 2009-2013*

This decrease in output is not only found at the larger CS subject level but also at each of the sub-area level within CS. **Figure *4.3*** shows these decreases, with the highest relative and absolute decrease

coming from Computational Theory & Mathematics. The CAGR decrease of -1.1% in Software is the least precipitous of the sub-areas.

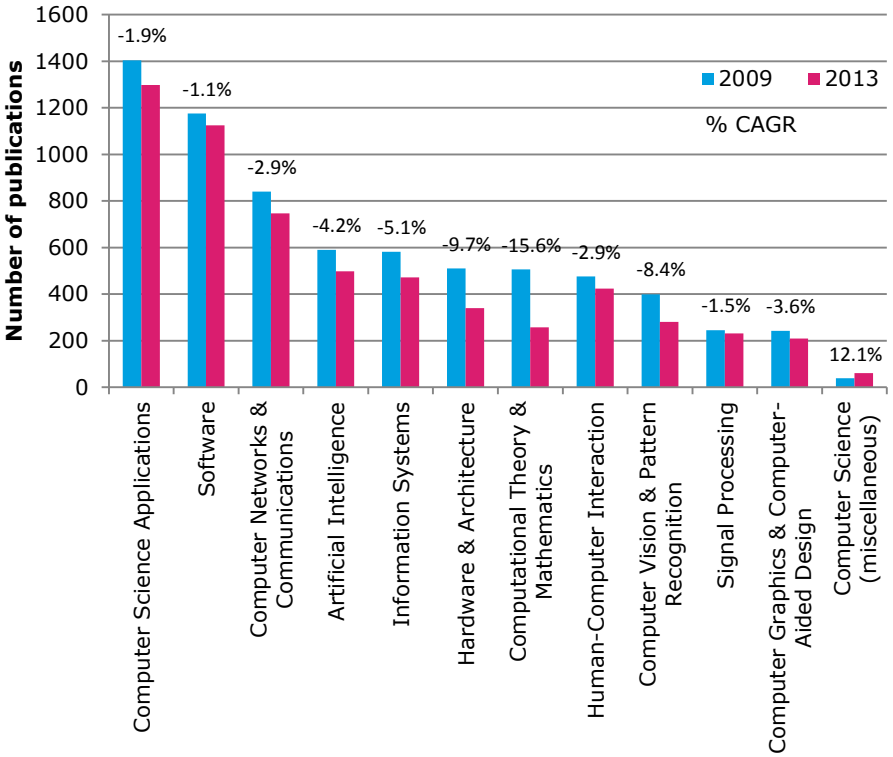


Figure 4.3— *Total number of publications in CS by the Netherlands, per sub-area, 2009 and 2013 (rank ordered by2009 values).*

Figure *4.4* charts the Relative Activity Index (RAI) of the Netherlands and EU28 as compared to world output. For an illustrative example to recap RAI, the publication output for the Netherlands in the sub-area Human-computer Interaction is 2,336 versus 24,728 publications for the whole field of Computer Science. For the world in the same sub-area and field, it is 83,779 and 1,464,862 respectively. The RAI for the Netherlands in Human-computer Interaction is therefore (2,336/24,728)/(83,779/1,464,862) = 0.09446/0.05719=1.65. This means that the Netherlands publishes 65% more than the world average in Human-computer Interaction. This sub-area is also the only sub-area to attain such a high RAI, with most others at or below 1.0. Compared to the EU28 RAI, the Netherlands relative activity is low in half the sub-areas, and only marginally higher than the EU28 in the other sub-areas with the exception of Human-computer Interaction.

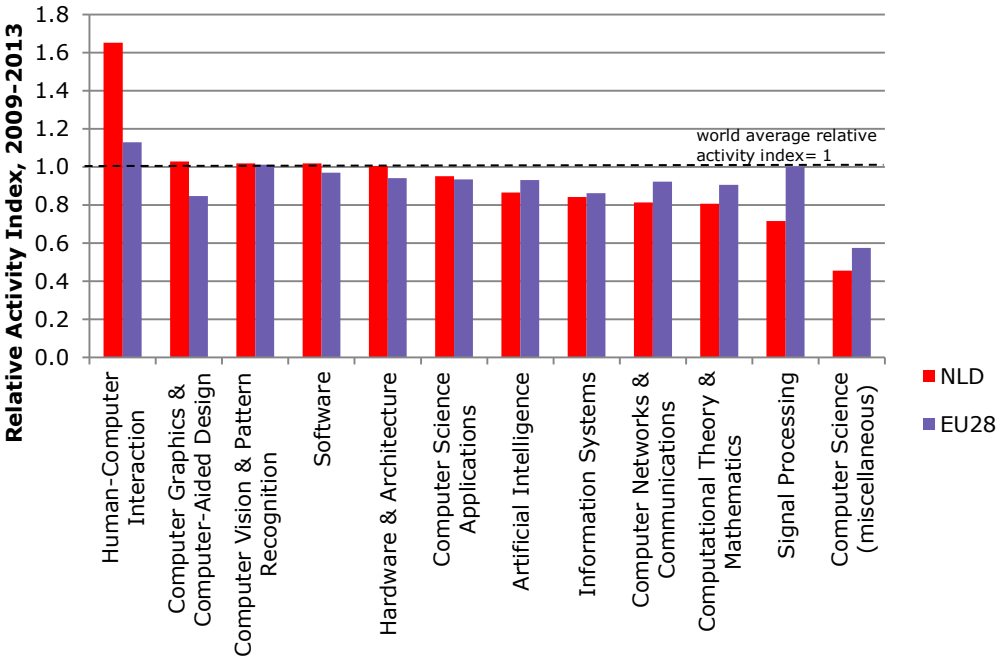


Figure 4.4— *Relative Activity Index for the Netherlands and EU28 in CS, per sub-area, 2009-2013 (rank-ordered by the Netherland's highest RAI sub-area, 2009-2013).*

Germany and the UK also exhibit relatively high activity at the world level in this sub-area with RAIs of 1.16 and 1.35 respectively.

4.2.2 Citation impact and excellence

Indicators for citation impact and excellence across Computer Science and its various sub-areas are shown in the following charts, beginning with **Figure *4.5***. To reiterate, absolute citation counts are not comparable across fields and sub-areas, therefore we use the Field Weighted Citation Impact (FWCI). The FWCI normalizes for differences in subject field, article type, and publication year, thus making the indicator more comparable across these dimensions. The world is indexed to a value of 1.00, meaning that, for example, a FWCI of 1.65 indicates an impact 1.65 times of the world average or 65% above the average.

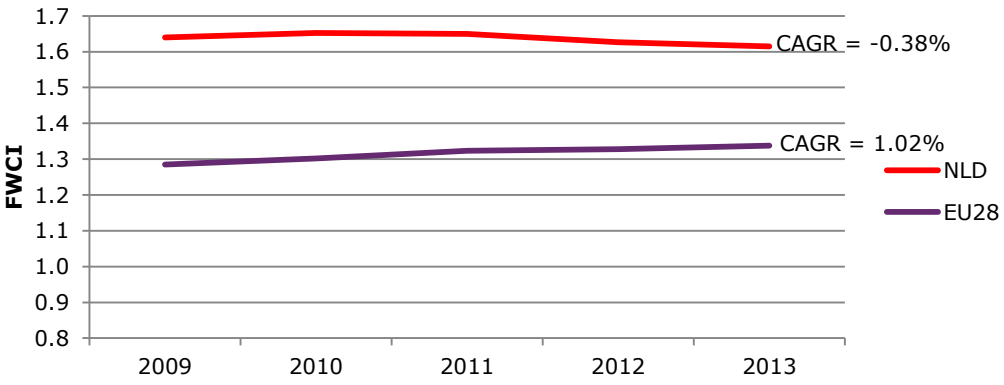


Figure 4.5— *Field-weighted citation impact for the Netherlands and EU28 in CS, 2009-2013.*

Figure *4.5* charts the FWCI of both the Netherlands and EU28 contributions to CS between 2009 and 2013. The Netherlands has remained fairly steady at a FWCI of ~1.6 with a CAGR of -0.38%, versus the EU28 at a FWCI of ~1.3 with a CAGR of 1.02%. In other words, the impact of Netherlands' research in Computer Science is 65% more than the world average and approximately 30% more than the impact of

EU28 research on the world stage. The impact over time for the EU28 is steadily increasing, whereas for the Netherlands it is decreasing at the very slow rate of -0.38%.

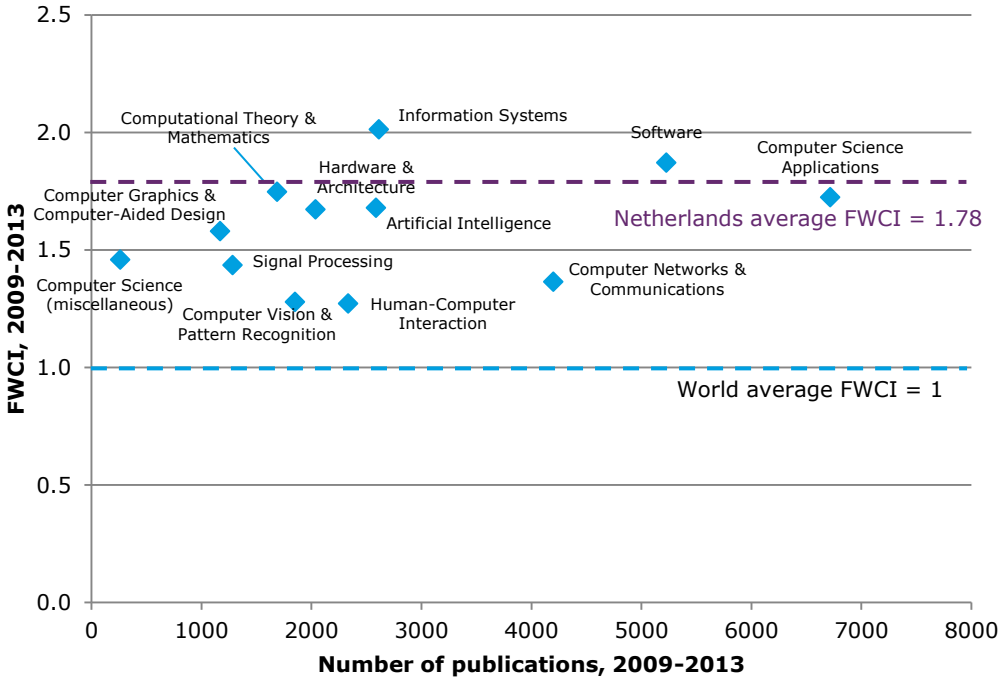


Figure 4.6— *FWCI versus number of publications in CS by the Netherlands, per sub-area, 2009-2013.*

Moving to the sub-area level, **Figure *4.6*** demonstrates that Netherlands' research across CS sub-areas exhibits high to very high FWCI values. Among all sub-areas in CS, Information systems achieves the highest FWCI with 2.01 (just over twice as much impact as the world average), and an absolute count of 2,615 publications between 2009 and 2013. Seven of the sub-areas are above the 1.5 FWCI mark, with the rest between 1.0 and 1.5. Compared to the Netherlands average FWCI across all fields, only Information Systems and Software have higher FWCI.

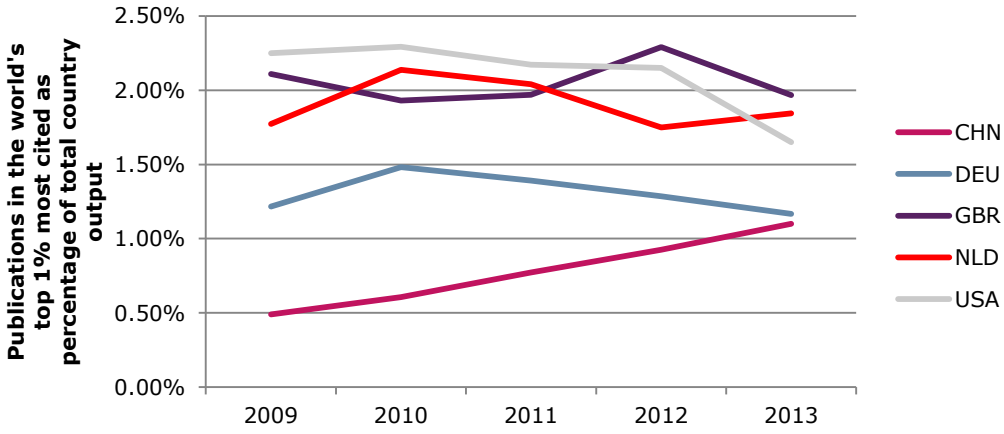


Figure 4.7— *The Netherlands and top 2 EU and top 2 non-EU comparator countries' share of the world's top 1% most cited publications in CS, per year, 2009-2013.*

Figure *4.7* provides an interesting view on the excellence aspect of Computer Science publications in the Netherlands. In 2009, 1.77% of all Netherlands' Computer Science publications were in the top 1% cited publications worldwide. This amount increased in 2010 to 2.14% and has slowly decreased to 1.84% in 2013. In absolute terms, the Netherlands publication output in the top 10% cited publications

has changed from 89 publications in CS in 2010 to 88 publications in 2013. Germany remained in a 0.25% spread and the UK within a 0.4% spread. When considering China and USA, the relative and absolute changes in the Netherlands, Germany and the UK are not large. China increased its relative share from 0.49% to 1.10% which translated to absolute numbers of 369 and 714 publications, whilst the USA decreased in share from 2.25% to 1.65%, an absolute decrease of 1237 to 908 publications.

With a focus on European research, **Figure *4.8*** shows the relative national share of the EU28's top 1% cited publications. The Netherlands has a significantly lower share compared to Germany and the UK. Over the period 2009-2013, the Netherlands share has remained fairly constant at an average of 8% whereas Germany's has been spread over a range of 17-22%. The UK has managed the highest EU28 share at an average of 26%.

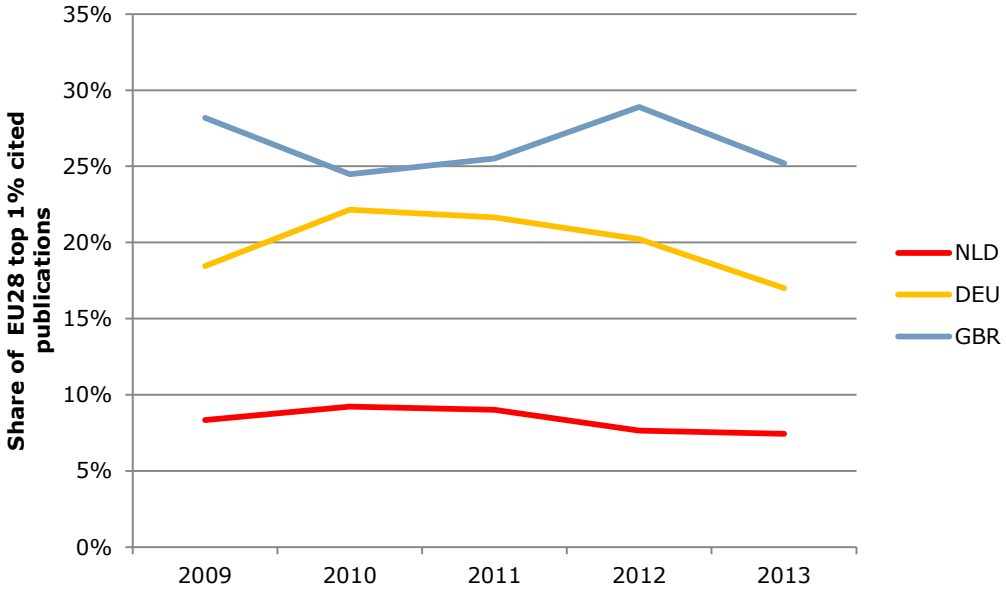


Figure 4.8— *Top 1% most cited in CS by the Netherlands and top 2 EU comparator countries relative to that of the EU28, per year, 2009-2013*

Figure *4.9* charts the relative share of the Netherlands', top 2 EU countries' and top 2 non-EU countries' publications in the top 1% cited publications worldwide. Again, the Netherlands' share has remained fairly constant at an average of 3.1% between 2009 and 2013 with a CAGR on absolute numbers of -0.28%. The biggest change in contribution has come from China, increasing at a linear rate from 13% to 24% of world share. The EU28 share, having been nearly constant between 2009 and 2012 at 37%, increased to 39%, to claim the largest share in 2013. Germany and the UK's shares have held steady at an average of 7.1% and 9.9% respectively.

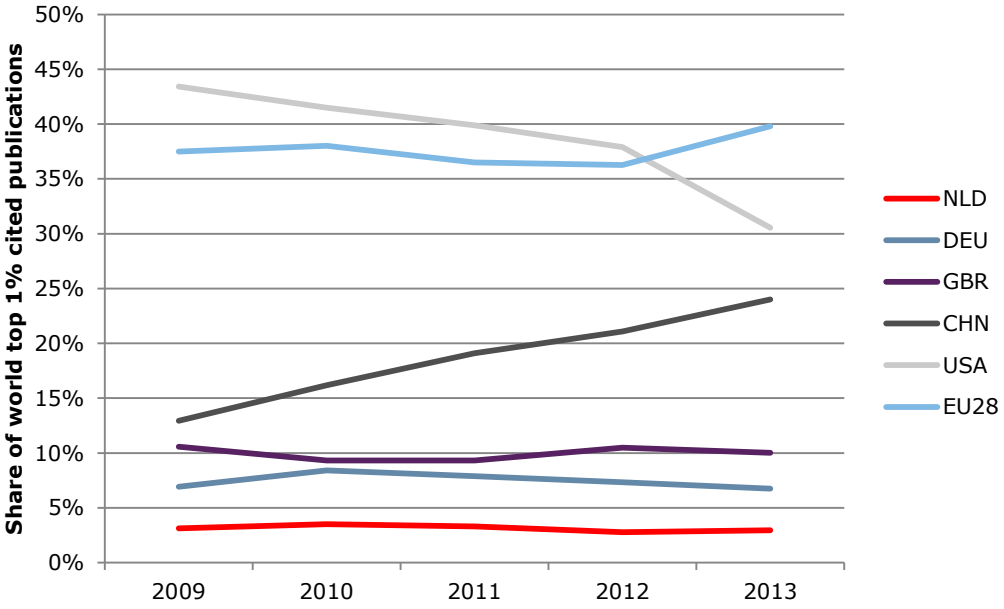


Figure 4.9— *Top 1% most cited in CS by the Netherlands and top 2 EU and top 2 non-EU comparator countries relative to that of the world, per year, 2009-2013*

Figure *4.10* examines the sub-areas in CS in more detail, specifically the share of the Netherlands' publications in the top 1% of cited papers worldwide versus the Netherlands' share of the worldwide total. Using the dashed intercept line as a reference in the chart, all the sub-areas in CS have a high share in the top 1% of cited publications relative to the world total counts in absolute terms indicating excellence in across all the sub-areas in CS. Human-computer Interaction is a high performer sub-area, with the Netherlands having 6.24% of world top 1% cited publications, but only 2.7% of world total in absolute terms.

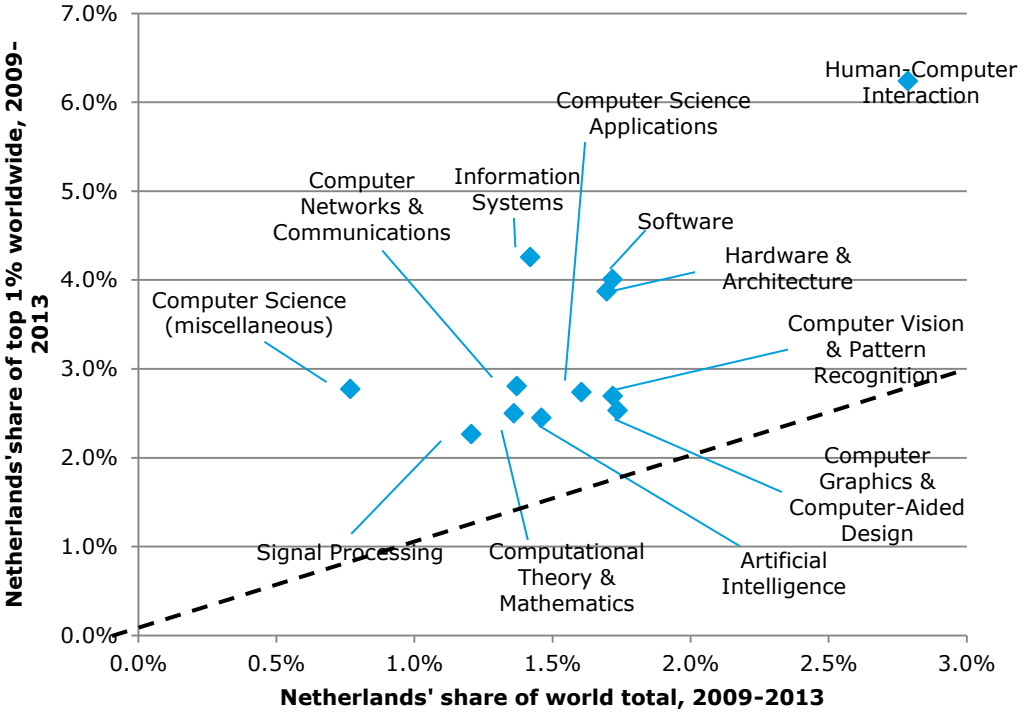


Figure 4.10— *The Netherlands top 1% most cited publications relative to that of the world versus the Netherlands publications in sub-area relative to that of the world, per sub-area, 2009-2013*

4.3 Collaboration

4.3.1 International collaboration

As specified in previous sections, international collaboration is defined as a publication with multiple authors wherein at least one co-author is from another country. Within the field of CS, international collaboration is high worldwide, and has increased from 2009-2013 for most countries. **Figure *4.11*** charts the national counts of international collaboration publications and the national shares of all CS publications that are international collaborations.

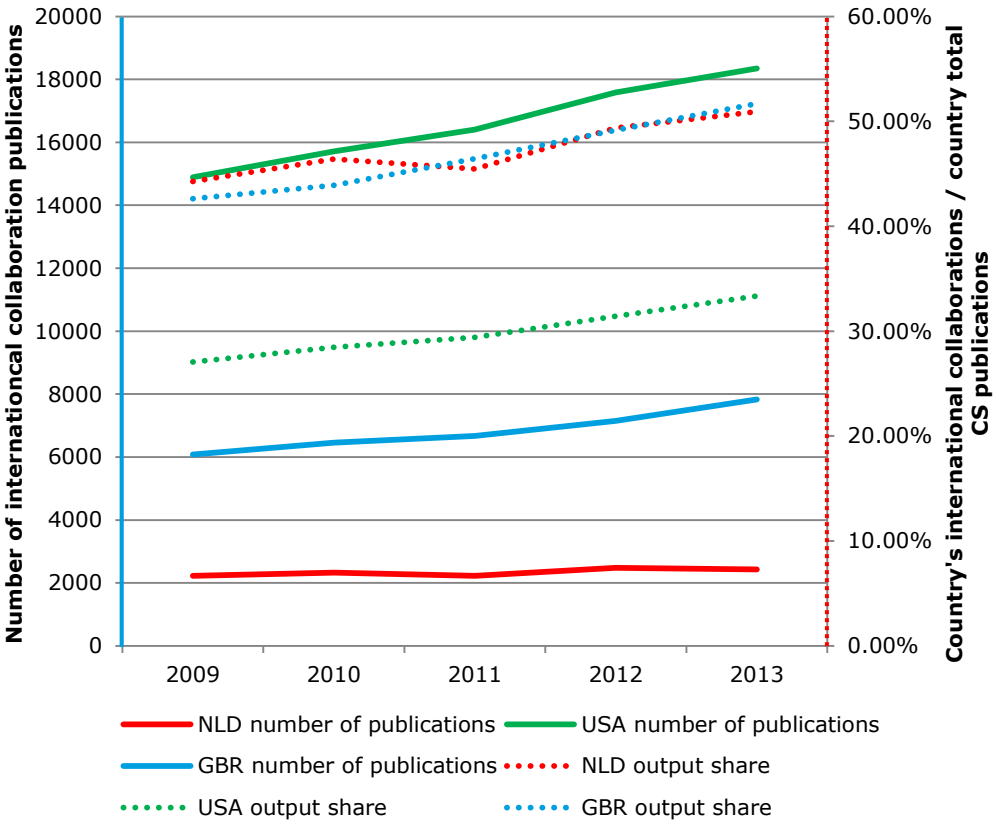


Figure 4.11 — *The Netherlands', top EU and top non-EU country's total number of international collaboration publications and each country's international collaboration share of national CS output, per year 2009-2013.*

The Netherlands' number of international collaboration has increased only slightly from 2009-2013, with a CAGR of 2.25%. The share of Netherlands' CS publications that are international collaborations has increased at a greater CAGR of 3.55% with over 50% of the Netherlands' CS publications in 2013 being international collaborations. The UK's count of international collaboration publications grew from 6084 in 2009 to 7833 in 2013, at a CAGR of 6.53%, and their national share grew from 42% in 2009 to 51% in 2013. The Netherlands and the UK shares are far higher than the USA's at 27% in 2009 and 33% in 2013. The USA's absolute number is more than double the UK's and nine times the output of the Netherlands.

Examining the Netherlands' international collaboration output in sub-areas within CS in **Figure *4.12***, Computer Science Applications has the largest share in both 2009 and 2013 with a CAGR of 1.21%. The highest CAGR for the sub-areas at 7.46% is Signal Processing, but the counts are low: 105 in 2009 and 140 in 2013. The largest drop was Computational Theory and Mathematics, with a CAGR of -14.15% and absolute numbers of 254 in 2009 and 138 in 2013.

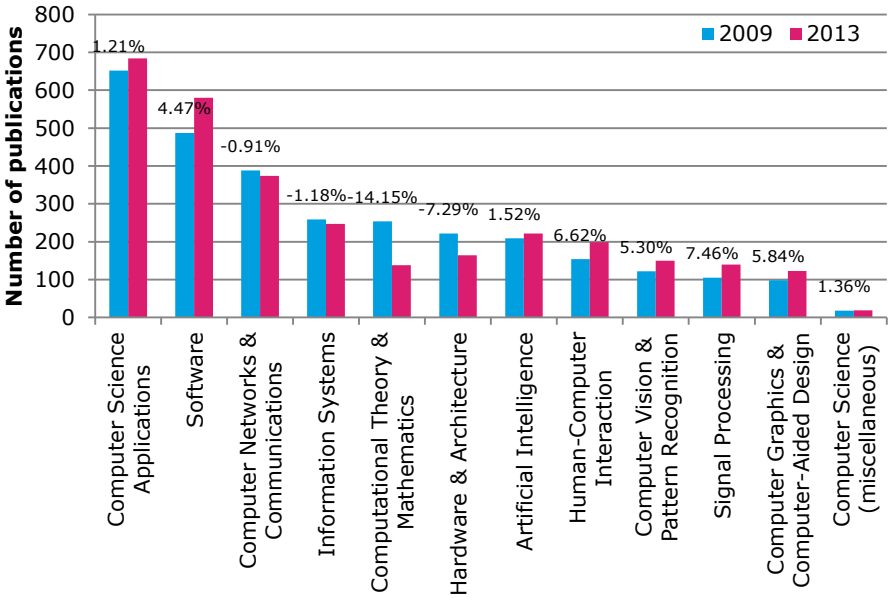


Figure 4.12— *Number of international collaborations in sub-area relative to total Netherlands' output in CS, per sub-area, 2009 and 2013*

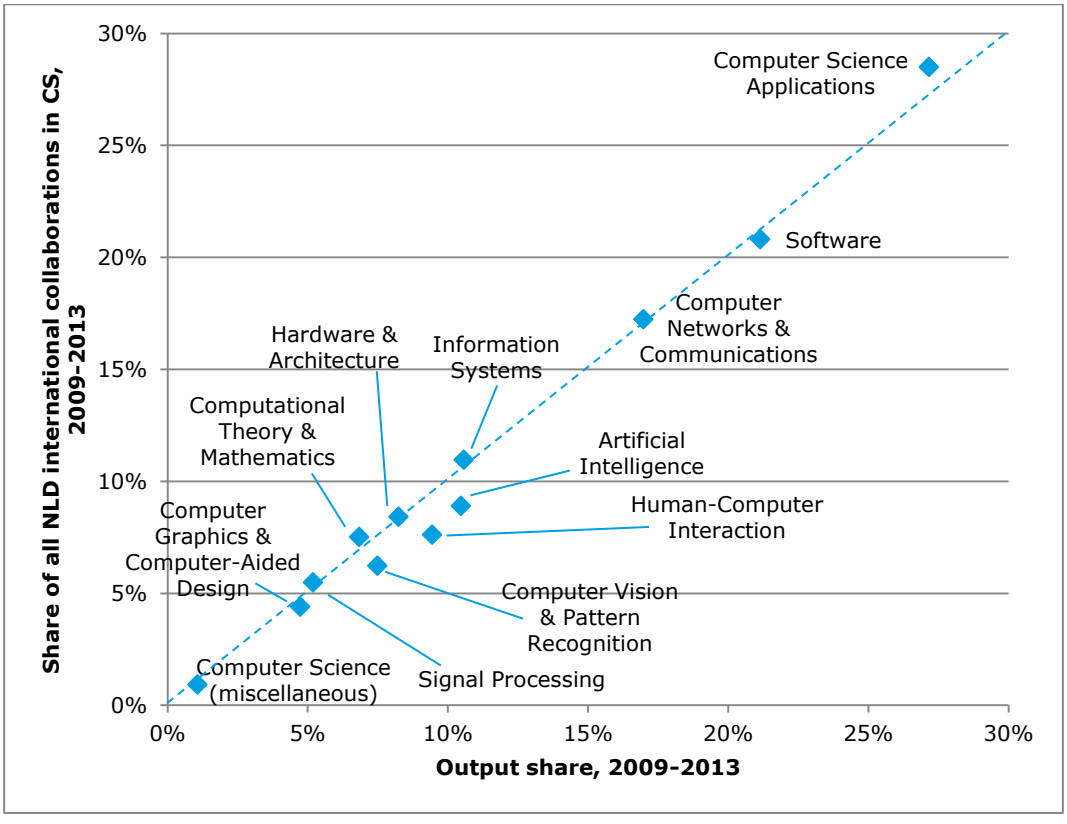


Figure 4.13— *Number of international collaborations in sub-area relative to total Netherlands' output in CS versus number of publications in sub-area relative to total Netherlands' output in CS, per sub-area, 2009-2013*

Within the sub-areas of Computer Science, the relative national share is close to the international collaboration share as seen by their proximities to the dashed intercept line, $y=x$. This indicates that no sub-area publishes relatively more with international collaborators than their corresponding total share. Computer Science Applications has the greatest share of national CS output, and also the greatest share of international collaborations in CS. Computational Theory & Mathematics experienced a sharp decline in

volume from 2009 – 2013 (See **Figure *4.12***) and the relative share in **Figure *4.13*** indicate that there was a corresponding decrease in international collaboration.

International collaboration is often a good predicator for higher quality research, and **Figure *4.14*** demonstrates just how much international collaboration has helped the impact of Netherlands' research in CS sub-areas. All sub-areas in CS except for Computer Networks and Communications are above the Netherlands' overall CS FWCI of 1.636. The total international collaborations FWCI for the Netherlands is 1.96, indicating that the Netherlands' research involving international collaborations have 95% more impact than the world average. Information Systems has the highest impact at 2.30, and Computer Networks and Communications the lowest at 1.55.

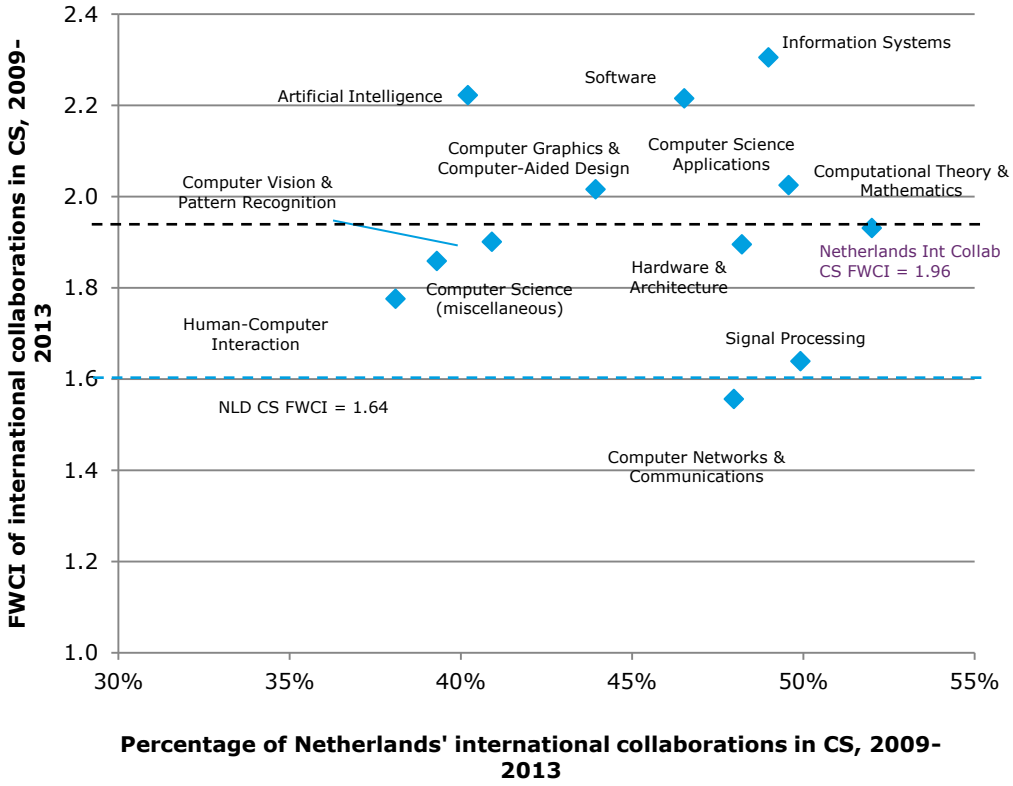


Figure 4.14— *The Netherlands' FWCI of international collaborations in CS sub-areas versus sub-area share of international collaboration in CS, 2009-2013.*

Figure *4.15* shows in more detail the comparison between international collaboration publications and all CS publications. Across all sub-areas there are large differences, with Artificial Intelligence showing the greatest difference in FWCI: 2.22 for international collaborations and 1.68 for the same sub-area in the Netherlands' overall output in the sub-area. For reference, EU28 international collaboration FWCI is 1.70, demonstrating how much more impact the Netherlands' international collaboration publications have compared to the EU28 as whole with all but two sub-areas displaying higher FWCI.

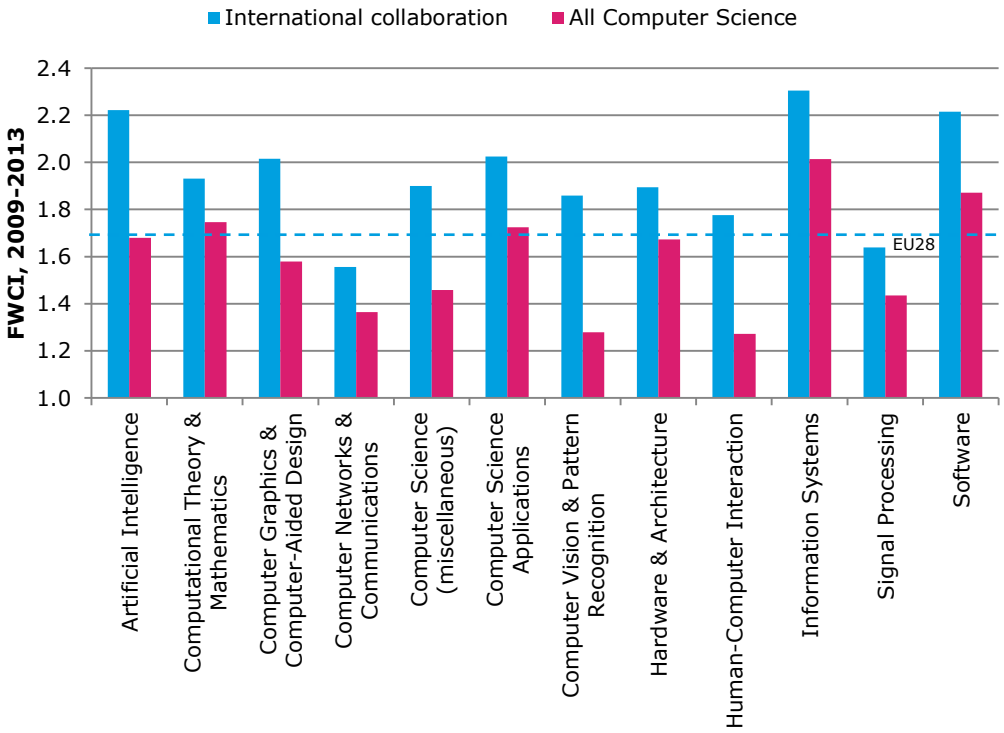


Figure 4.15— *The Netherlands' FWCI of international collaborations in CS sub-areas relative to FWCI of all Netherlands' CS publications, 2009-2013. (Includes EU28 international collaboration FWCI reference line at 1.695).*

The top international collaborators of Netherlands' researchers are shown in **Table 4.1** Katholieke Universiteit Leuven is the top collaborator in terms of publication count, with 343 publications and a FWCI of 2.854. All international collaborations with traditional research institutes have an FWCI higher than 2.00 further reinforcing earlier data regarding the impact of international collaborations. The highest FWCI international collaborator is Imperial College London, followed by Universitat Politecnica de Catalunya in Spain. The regional distribution of the top 10 international collaborators in CS implies that the Netherlands' primarily collaborates with European partners. The only Netherlands' institutions to feature in other countries' top 10 lists are TU Delft (267 publications with Germany collaborators and 144 publications with Italian collaborators) and TU Eindhoven (297 publications with German collaborators).

Rank	Collaborator	Sum of publications	FWCI
1	Katholieke Universiteit Leuven	343	2.854
2	Imperial College London	162	4.284
3	ETH Zurich	157	2.638
4	RWTH Aachen University	130	2.923
5	Thales	127	0.759
6	CNR	119	2.314
7	Universitat Politecnica de Catalunya	118	3.008
8	Ghent University	115	2.499
9	IMEC	108	3.015
10	Politecnico di Milano	100	2.44

Table 4.1— *Number and FWCI of collaborations of top 10 international institutions collaborating with Netherlands institutions in CS*

4.3.2 Academic-corporate collaboration

Academic-corporate collaborations have gained in importance as universities look for suitable application partners of their research efforts. Academic-corporate collaborations are frequently cited as indicators of knowledge exchange between fundamental and applied research efforts, with the corporate sector getting first glimpses of fundamental research and universities seeing application possibilities of their research.

Figure 4.16 charts the overall counts of academic-corporate collaborations publications for the Netherlands, and the top EU and top non-EU countries. In terms of absolute numbers, the Netherlands published 562 publications in 2009 and 435 in 2013. The CAGR over this period was quite large at -6.20%, far larger than either the USA (-1.39%) or Germany (-2.79%). Overall it appears that academic-corporate collaborations are on the decline, and the share of total CS output is either declining or only just steady.

The situation is the same at the sub-area level with declines from 2009 to 2013 across all the sub-areas, as seen in **Figure 4.17**. The biggest relative declines are in Computational Theory and Mathematics with a CAGR of -31.81% which translates into an absolute number decline from 74 publications in 2009 to 16 publications in 2013. Signal Processing was the only sub-area with a positive CAGR, 3.68%, but in absolute numbers this was an increase of only 7 publications from 45 to 52. The largest absolute decrease was in Computer Science Applications from 172 in 2009 to 121 in 2013, with a CAGR of -8.42%.

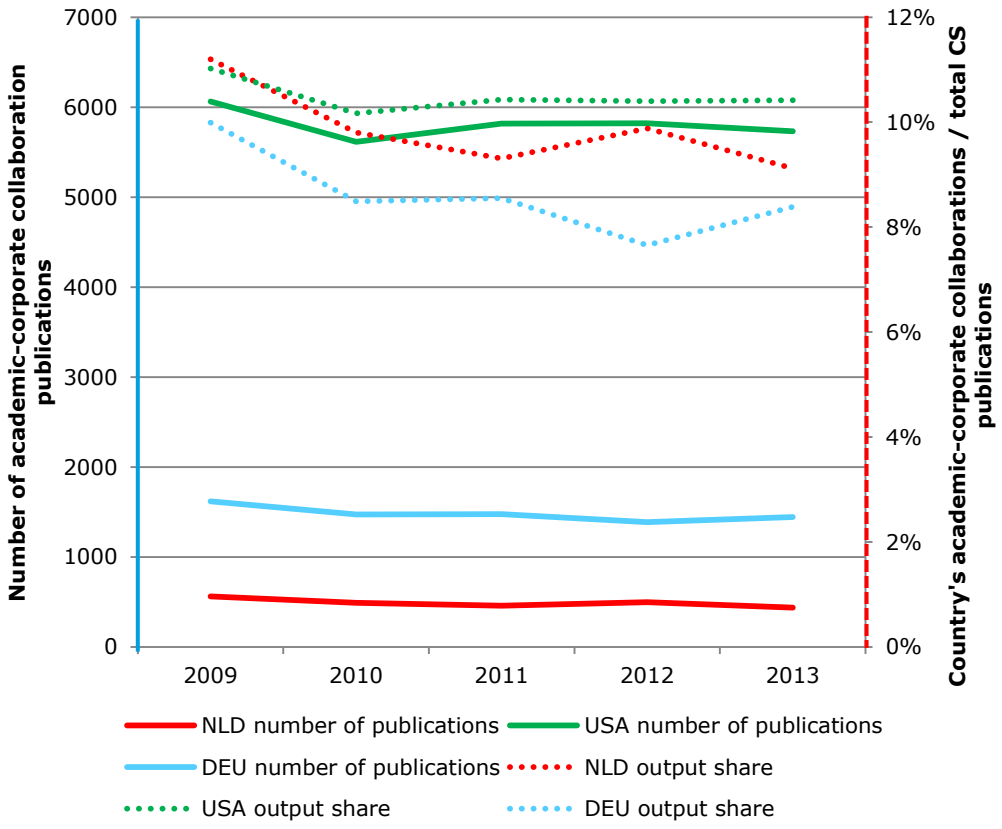


***Figure 4.16**— The Netherlands', top EU and top non-EU country's total number of academic-corporate collaboration publications and each country's academic-corporate collaboration share of national CS output, per year.*

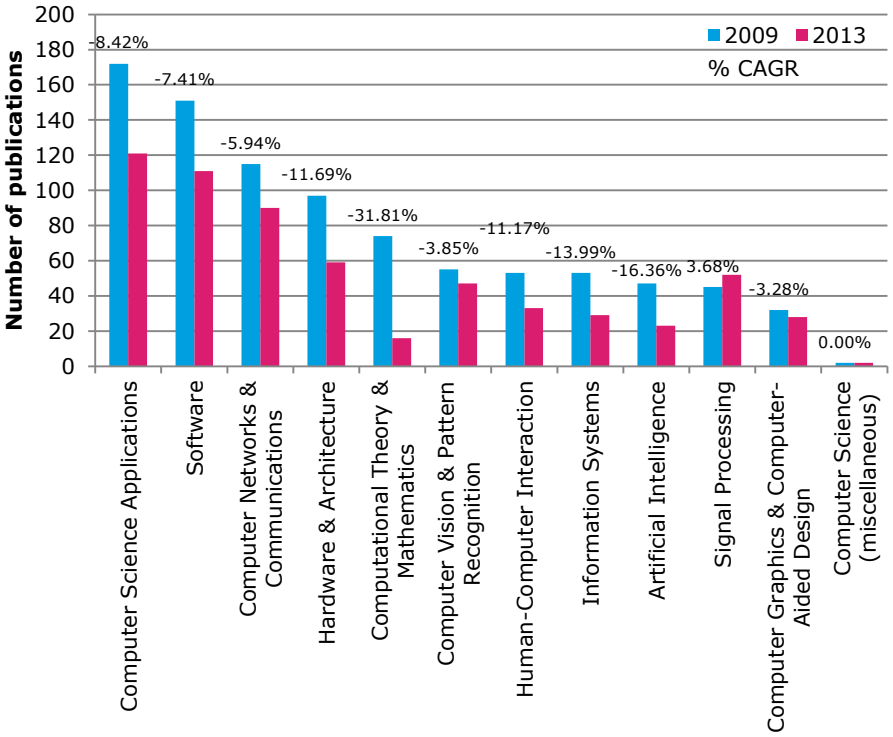


Figure 4.17 *— Number of academic-corporate collaboration publications for the Netherlands for CS sub-areas; rank-ordered by highest sub-area, 2009 & 2013.*

Figure *4.18* shows that the respective shares of academic-corporate collaborations per sub-area are not proportionally higher or lower than their overall shares in CS. There is little deviation from the reference line of y=x, with Hardware and Architecture being the sub-area showing the highest relative proportion of publications being between the academic and corporate sectors. The sub-area name does imply some cooperation between the two sectors as a corporate partner provides more opportunity or resources for the production of hardware.

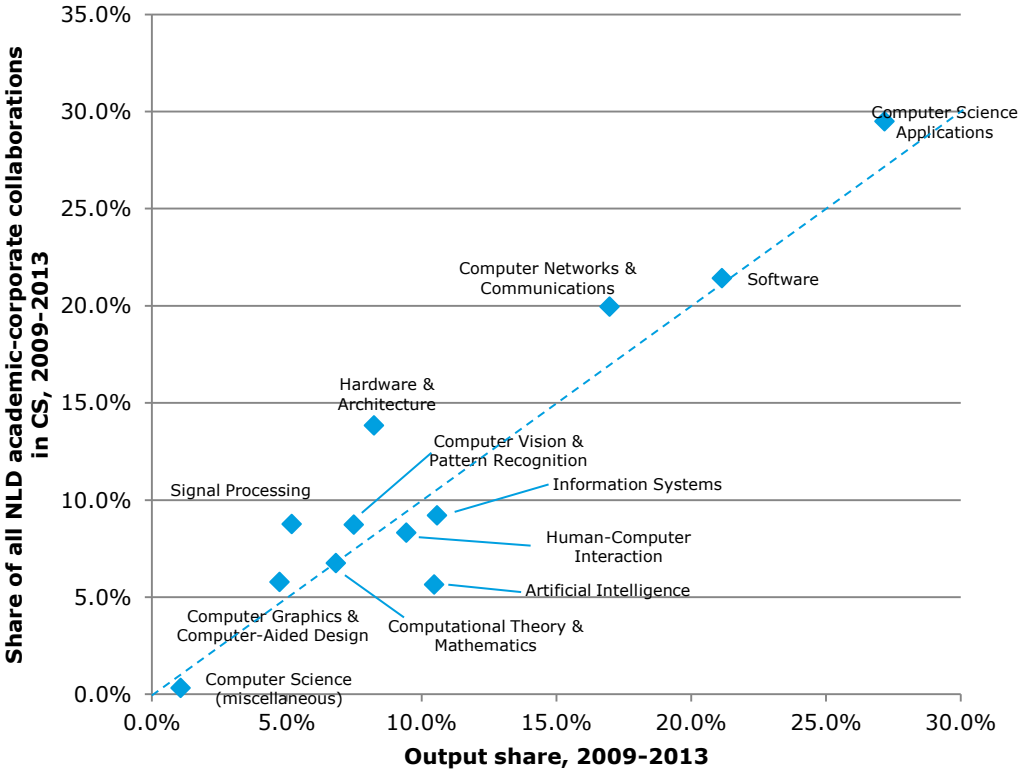


Figure 4.18— *Number of international collaborations in sub-area relative to total Netherlands' output in CS versus number of publications in sub-area relative to total Netherlands' output in CS, per sub-area, 2009-2013*

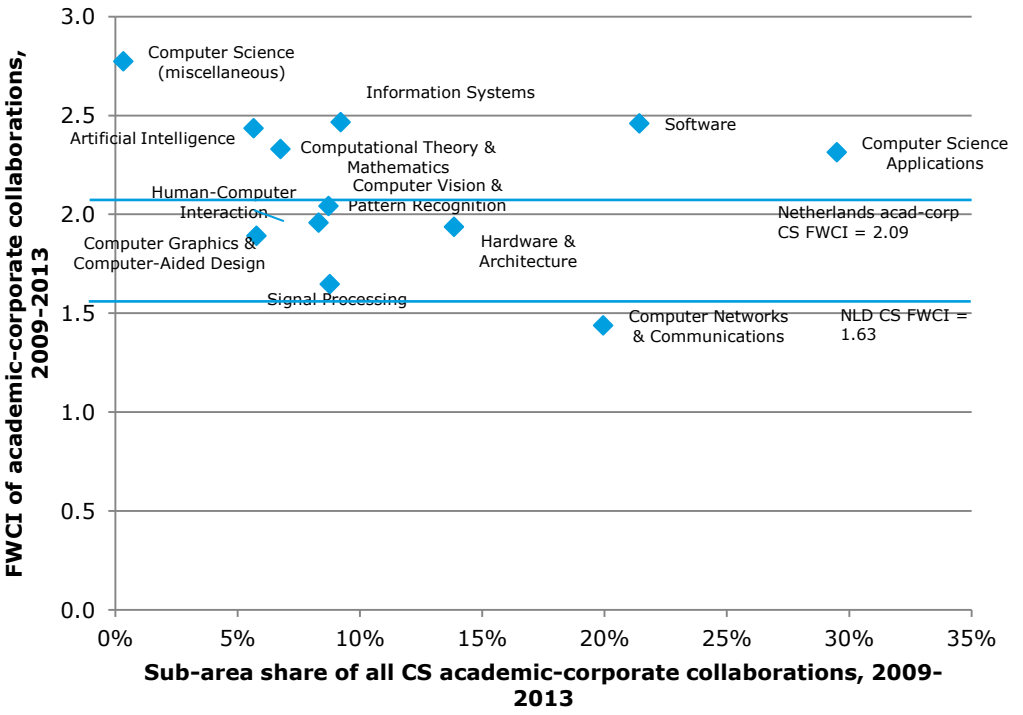


Figure 4.19— *The Netherlands' FWCI of academic-corporate collaborations in CS sub-areas versus sub-area share of all academic-corporate collaborations in CS, 2009-2013.*

Figure 4.19 shows in detail the FWCI of each sub-area regarding academic-corporate collaboration in CS in the Netherlands. Academic-corporate collaboration in CS is generally high across CS, with a FWCI of 2.09 versus 1.64 for all CS publications in the Netherlands. The highest collaboration share is Computer Science Applications with a 29% of all CS academic-corporate collaborations, and a FWCI of 2.31. The highest FWCI sub-area was Computer Science (Miscellaneous) with a FWCI of 2.77 and a share of only 0.33%. All academic-corporate collaboration sub-areas except Computer Networks and Communication have a higher FWCI than the Netherlands CS field average. **Figure 4.20** shows that across all sub-areas, academic-corporate collaborations have higher FWCIs than CS in the Netherlands in general with Computer Science (Miscellaneous) having the largest difference.

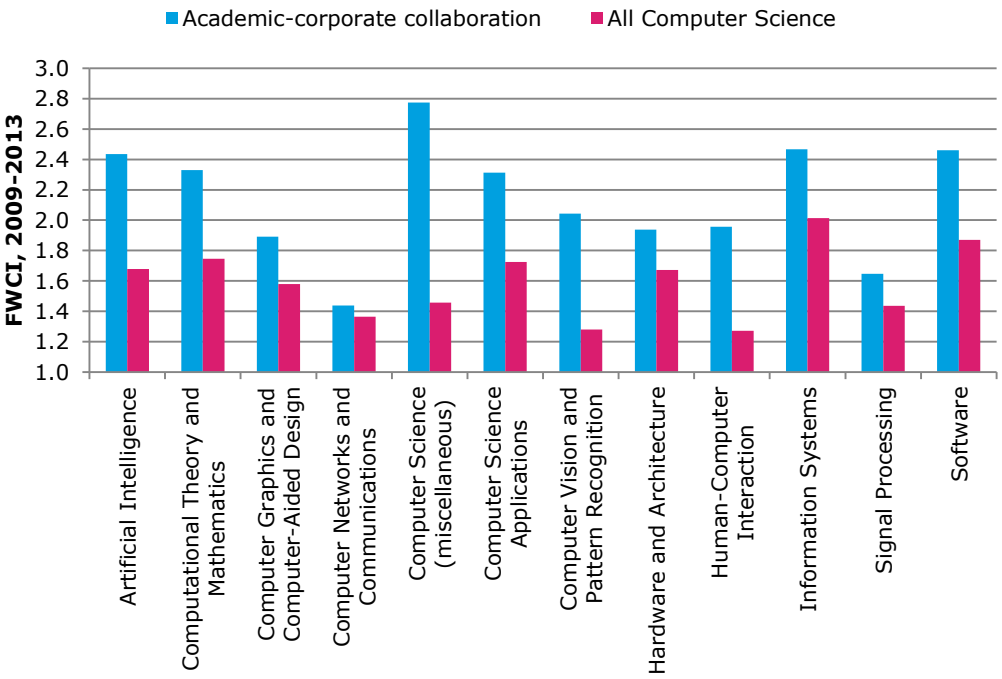


***Figure 4.20**— FWCI of academic-corporate collaborations versus overall FWCI of sub-area, for the Netherlands, per sub-area, 2009-2013*

The top corporate collaborators of Netherlands' researchers are shown in **Table 4.2**. Thales is the top collaborator in terms of publication count, but the publications receive the lowest FWCI, 0.76, of all the collaborators. An FWCI of less than 0.76 indicates the research conducted with Thales has 25 % less impact when compared to world FWCI. Publications with Carl Zeiss on the other hand, have an extremely high FWCI of 9.235.

Rank	Collaborator	Sum of publications	FWCI
1	Thales	127	0.759
2	Philips Medical Systems US	94	1.998
3	IBM	69	3.146
4	Microsoft USA	66	5.06
5	EADS Astrium	64	1.055
6	Alcatel-Lucent	50	1.35
7	Carl Zeiss SMT AG	33	9.235
8	DFKI GmbH	32	2.205
9	VTT	31	1.539
10	NICTA	30	3.236

Table 4.2— *Number and FWCI of collaborations of top 10 corporate institutions collaborating with the Netherlands academic institutions in CS*

4.4 Knowledge exchange

4.4.1 Corporate downloads

From 2009-2013, corporate downloads of Netherlands' publications in CS accounted for 3.2% of all corporate downloads of publications in CS, as **Figure *4.21*** shows. While this is lower than the world corporate download shares of other comparator countries inside and outside the EU, it is still nearly twice the level of the Netherlands' world share of CS output (1.7%).

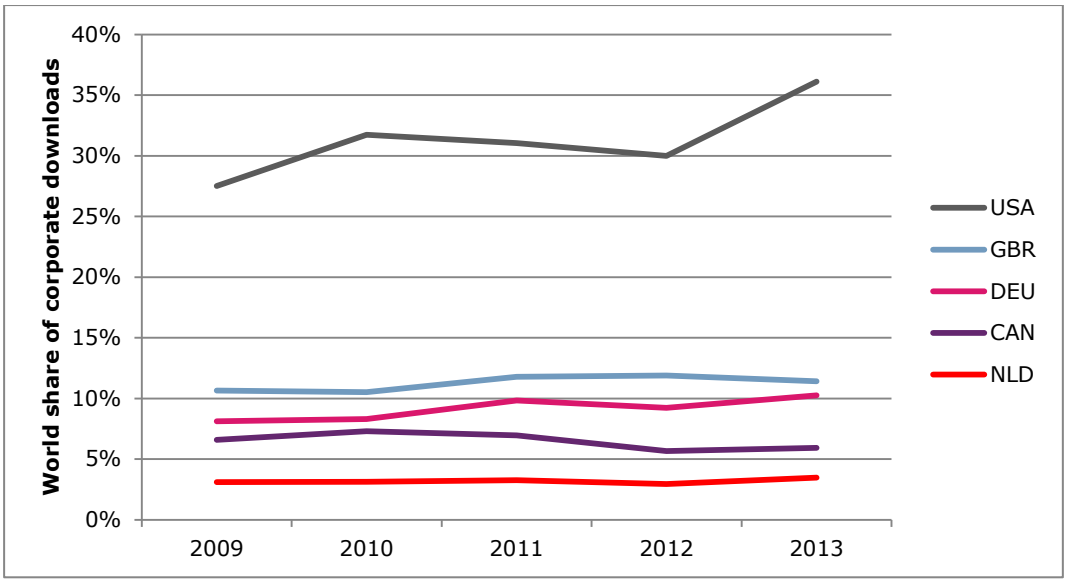


Figure 4.21— *Corporate downloads of research in CS by the Netherlands' and top 2 EU and top 2 non-EU comparator countries relative to that of the world, per year, 2009-2013*

Figure *4.22* compares Netherlands' world publication output share to its world corporate download share. For example, Netherlands' research in Information Systems have garnered 3,722 corporate downloads, while all research in that sub-area have garnered 74,960 corporate downloads. That means the world corporate download share of the Netherlands in that sub-area is 3,722/74,960 = 4.97%. Considering that the Netherlands accounts for only 1.42% of all publications in the world in that sub-area, it is noteworthy that the country's world corporate download share statistic is 3.5 times larger than its world output share. In additional to Information Systems, other sub-areas that have receive d a much higher-than-expected amount of corporate downloads include Computational Theory and Mathematics and Computer Science (miscellaneous).

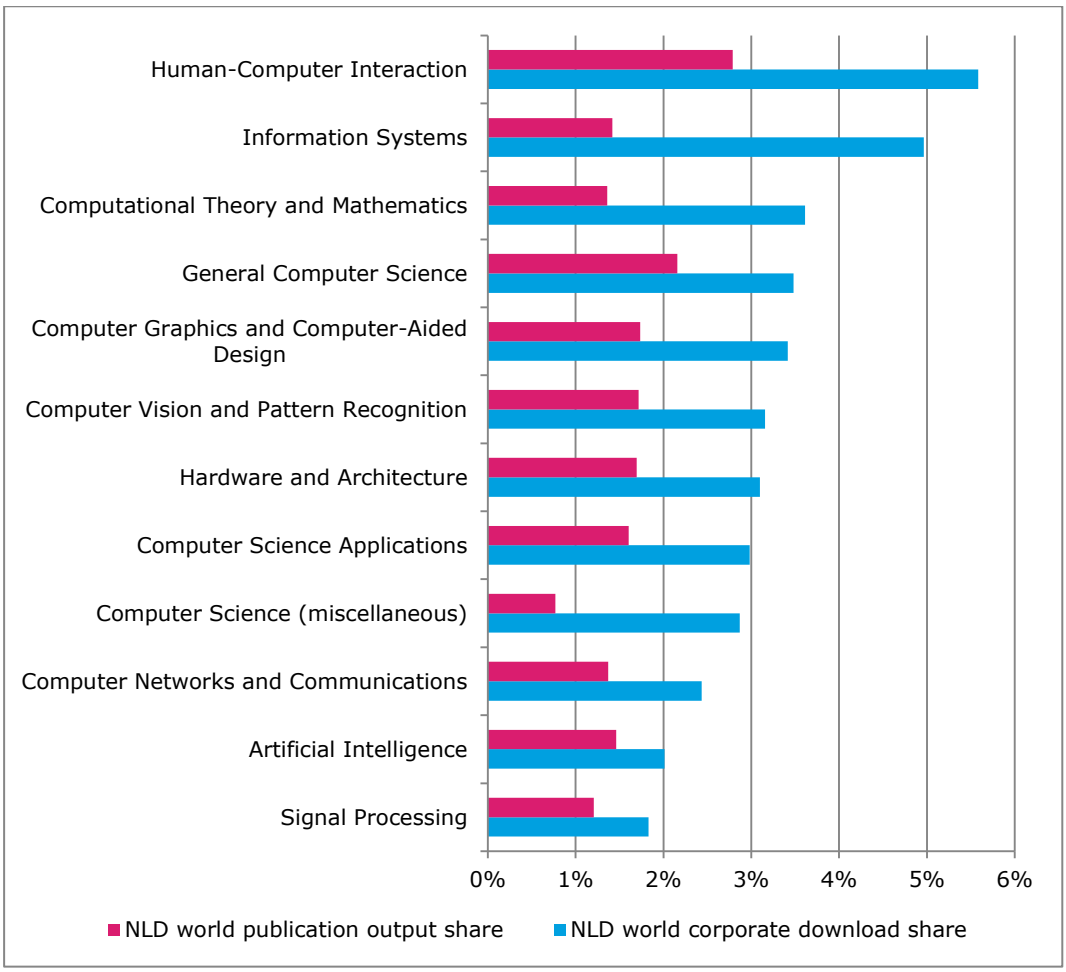


Figure 4.22— *Publication output share in CS by the Netherlands versus corporate downloads share, per sub-area, 2009 and 2013*

4.4.2 Patent citations

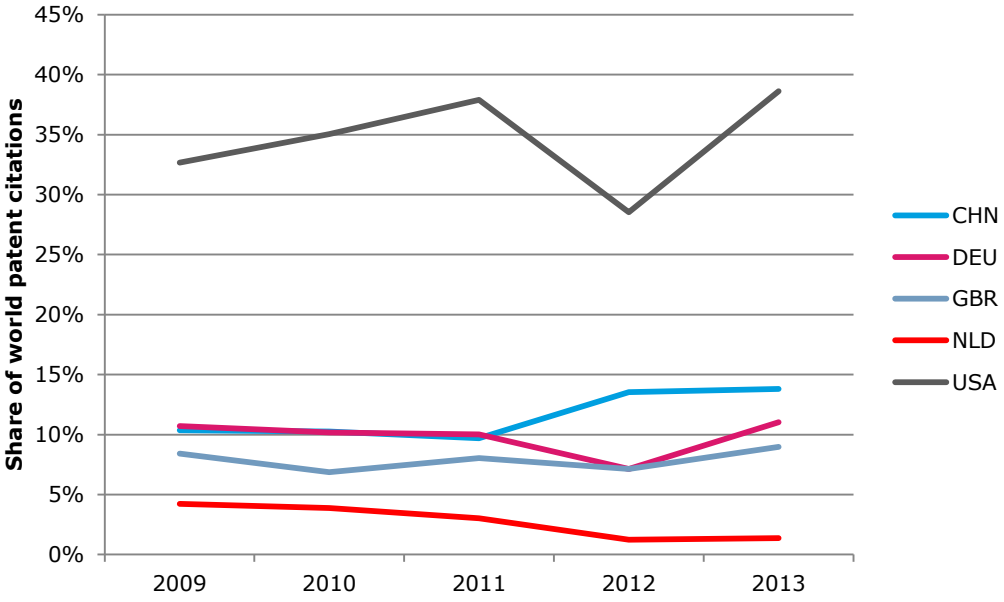


Figure 4.23— The number of patent citations to publications in CS from the Netherlands' and top 2 EU and top 2 non-EU comparator countries relative to that of the world, per year, 2009-2013

The Netherlands' share of world patent citations has decreased significantly from a high of 3.9% in 2009 to 1.4% in 2013 at a CAGR of -24.5% (**Figure *4.23***). 2013 saw major share gains on 2012 by all other countries except China whose share only grew by 0.3%. The USA's shares have varied significantly over the posted period, with its share rising steadily between 2009 and 2011, then dropping by almost 10% from 2011 to 2012. It then regained this share in 2013 to end with 38.6% of CS patent citations.

Sub-areas	Number of citations
Computer Science Applications	95
Software	40
Computer Networks and Communications	29
Signal Processing	23
Computer Vision and Pattern Recognition	21
Information Systems	16
Computational Theory and Mathematics	14
Artificial Intelligence	9
Computer Graphics and Computer-Aided Design	8
Hardware and Architecture	7
Human-Computer Interaction	2

Table 4.3— Number of patent citations, per sub-area for sub-areas in CS, 2009-2013

Absolute citations to Netherlands' sub-areas were low over the period 2009 -2013 as seen in **Table *4.3***. Computer Science Applications received 95 citations, more than double the next sub-area, Software, at 40 citations. The rest of the sub-areas received less than 30 citations each. Comparing these to the sub-area share of EU28 and World citations in **Figure *4.24***, we see that the relatively low absolute numbers translate into fairly high relative shares, Computer Science Application patents receiving just over 9% of EU28 citations and just over 4% of worldwide patent citations to the same sub-area. The sub-area with the greatest EU28 share was Information Systems with 11.27%. It also received the biggest world share of the sub-areas with 5%.

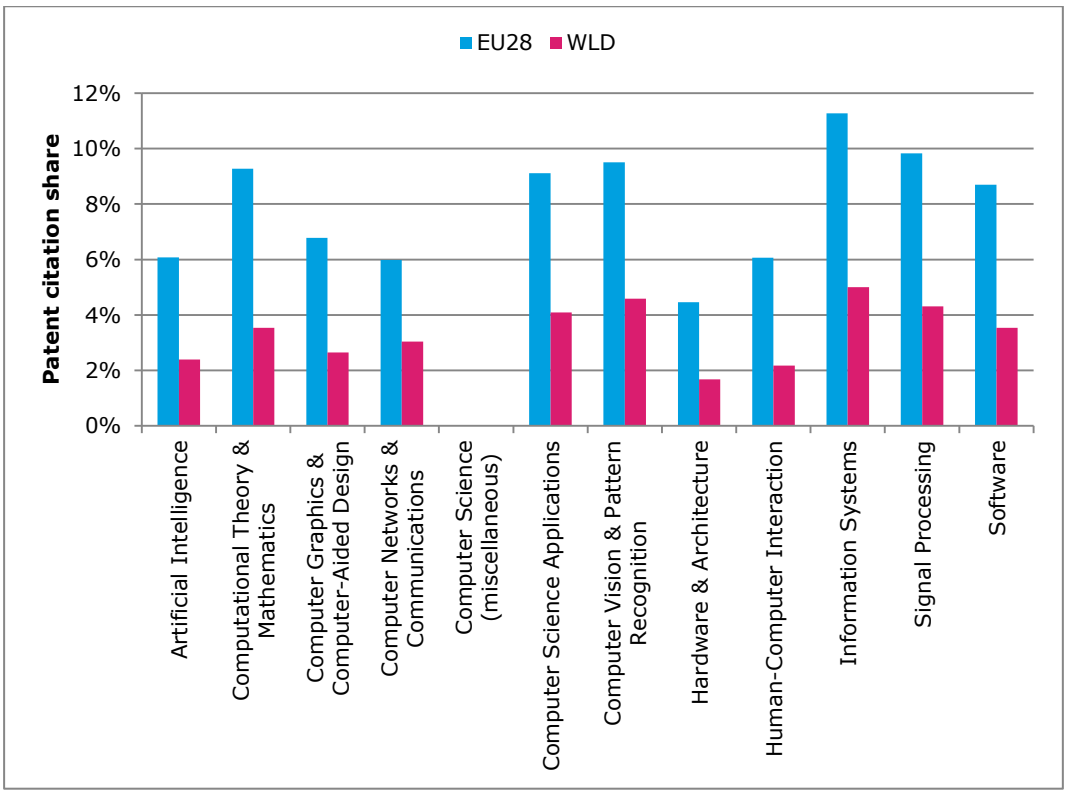


Figure 4.24— The Netherlands' share of EU28 and worldwide patent citations in CS sub-areas, 2009-2013.

4.5 Overview of the Netherlands' research performance in Computer Science

In **Table *4.4***, we provide an overview of the main indicators we used in this chapter to summarize the Netherlands' research performance in the 12 sub-areas of Computer Science.

Sub-area Name	Publications	FWCI	Top 1%/Total output	International collaboration/Total output	Academic-corporate collaboration/Total output	World corporate download share/World publication share	World patent citation share/World publication share
General Computer Science	5159	1.64	3.28%	45.90%	6.28%	1.61	1.06
Computer Science (miscellaneous)	264	1.46	2.77%	40.91%	3.03%	3.74	0
Artificial Intelligence	2589	1.68	2.45%	40.21%	5.33%	1.38	1.64
Computational Theory and Mathematics	1690	1.75	2.50%	52.01%	9.76%	2.65	2.6
Computer Graphics and Computer-Aided Design	1172	1.58	2.53%	43.94%	12.03%	1.97	1.53
Computer Networks and Communications	4200	1.36	2.80%	47.98%	11.60%	1.78	2.22
Computer Science Applications	6719	1.72	2.73%	49.58%	10.72%	1.86	2.55
Computer Vision and Pattern Recognition	1852	1.28	2.69%	39.31%	11.50%	1.84	2.67
Hardware and Architecture	2039	1.67	3.87%	48.21%	16.58%	1.83	0.99
Human-Computer Interaction	2336	1.27	6.24%	38.10%	8.69%	2	0.78
Information Systems	2615	2.01	4.26%	48.99%	8.60%	3.5	3.52
Signal Processing	1284	1.44	2.26%	49.92%	16.67%	1.52	3.57

Table 4.4— *Overview of the main indicators of the Netherlands' research performance in Computer Science, per sub-area, 2009-2013. The color (from red to green) indicates the increase in value.*

Chapter 5
Researcher mobility

This chapter uses Elsevier's researcher mobility model to analyse to what extent Netherlands' researchers are mobile, how mobility is associated with their research performance, and whether the Netherlands attracts talents.

5.1 Key Findings

MOBILE RESEARCHERS

66.5%

About two third of the active Netherlands' researchers have published at least one article with a foreign affiliation.

RESEARCHERS IN THE TRSNITORY GROUP

47.8%

Close to half of the active Netherlands' researchers belong to the highly mobile transitory group.

INFLOW AND OUTFLOW OF RESEARCHERS

The Netherlands is a net outflow country in terms of research mobility: 10.0% and 8.7% of its active researchers belong to the inflow and outflow groups, respectively. Despite the small net outflow, the inflow researchers tend to be more senior, more productive and their publications are with higher FWCI.

5.2 Measuring researcher mobility

The approach presented here uses Scopus author profile data to derive a history of affiliations of active researchers in the Netherlands (hereafter 'NLD researcher'). These researchers are then assigned to mobility classes based on the type and duration of observed moves between affiliations.

How are individual researchers unambiguously identified in Scopus?
Scopus uses a sophisticated author-matching algorithm to precisely identify articles by the same author. The Scopus Author Identifier gives each author a unique ID and groups together all the documents published by that author, matching alternate spellings and variations of the author's last name. Authors with the same surname are differentiated based on data elements associated with the article (such as affiliation, subject area, co-authors, and so on). This is enriched with manual, author-supplied feedback, both directly through Scopus and also via Scopus' direct links with ORCID (Open Researcher & Contributor ID[17]). Gender is not captured in Scopus author profiles.

What is a 'NLD researcher'?
To define the initial population for this study, NLD researchers were identified as those that had listed an affiliation in the Netherlands on at least one publication (articles, reviews and conference papers) included in Scopus during the period 1996-2013.

What is an 'active researcher'?
The nearly 296,000 NLD researchers identified include a large proportion with relatively few articles over the entire 18-year period of analysis. As such, it was assumed that they are not likely to represent career researchers, but individuals who have left the research system. A productivity filter was therefore implemented to restrict the analysis to those authors with at least 1 article in the 5-year period 2009–2013 and at least 10 articles in the entire 18-year period of 1996 to 2013, or those with fewer than 10 articles in 1996– 2013, but at least 4 articles in 2009–2013. After applying the productivity filter, a set of 93,600 active NLD researchers was defined and formed the basis of the study.

How are mobility classes defined?
In this study, stays abroad of 2 years or more were considered migratory and were further subdivided into those where the researcher remained abroad or where they subsequently returned to their original country. Stays abroad of less than 2 years were deemed transitory, and were also further subdivided into those who mostly published under a NLD or a non-NLD affiliation. Researchers without any apparent mobility based on their published affiliations were considered sedentary.

Migratory

- Total Outflow: the sum of Outflow and Returnee Outflow groups.
    - Outflow: active NLD researchers whose Scopus author data for the period 1996-2013 indicates that they have migrated from NLD to another country (or countries) for at least 2 years without returning to the NLD.
    - Returnees Outflow: active NLD researchers whose Scopus author profile data for the period 1996-2013 indicates that they have migrated to the NLD from another country (or countries) for at least 2 years, and then subsequently migrated to another country (or countries) for at least 2 years.

- Total Inflow: the sum of Inflow and Returnee Inflow groups.

[17] See http://orcid.org/ for more information

- Inflow: active NLD researchers whose Scopus author data for the period 1996-2013. indicates that they have migrated to the NLD from another country (or countries) for at least 2 years without leaving the NLD.
- Returnees Inflow: active NLD researchers whose Scopus author data for the period 1996-2013 indicates that they have migrated from the NLD to another country (or countries) for at least 2 years, and then subsequently migrated back to the NLD for at least 2 years.

Transitory

- Total Transitory: the sum of Transitory (mainly non-NLD) and Transitory (mainly NLD) groups.
  - Transitory (mainly non-NLD): active NLD researchers whose Scopus author data for the period 1996-2013 indicates that they are based in the NLD for less than 2 years at a time but are predominantly based in another country (or countries).
  - Transitory (mainly NLD): active NLD researchers whose Scopus author data for the period 1996-2013 indicates that they are based in another country (or countries) for less than 2 years at a time but are predominantly based in the NLD.

Sedentary

- Sedentary: active NLD researchers whose Scopus author data for the period 1996-2013 indicates that they have not published outside the NLD.

The measurement of international researcher mobility by co-authorship in the published literature is complicated by the difficulties involved in teasing out long-term mobility from short-term mobility (such as doctoral research visits, sabbaticals, secondments, etc.), which might be deemed instead to reflect a form of collaboration. Author nationality is not captured in article or author data. Instead, migration patterns are based on the country where an author first published (for migratory mobility) or the country where they published the majority of their articles (for transitory mobility). In individual cases, these criteria may result in authors being assigned migratory patterns that may not accurately reflect the real situation, but such errors may be assumed to be evenly distributed across the groups and so the overall pattern remains valid.

What indicators are used to characterize each mobility group?

To better understand the composition of each group defined on the map, three aggregate indicators are calculated for each to represent the productivity and seniority of the researchers they contain, and the FWCI of their articles.

- Relative Productivity represents a measure of the articles per year since the first appearance of each researcher as an author during the period 1996–2013, relative to all NLD researchers in the same period.
- Relative Seniority represents years since the first appearance of each researcher as an author during the period 1996–2013, relative to all NLD researchers in the same period.
- FWCI is calculated for all articles in each mobility class.

All three indicators are calculated for each author's entire output in the period (i.e., not just those articles listing a NLD address for that author).

5.3 Researcher mobility of the Netherlands

Looking at **Figure 5.1**, one can see that researchers in the Netherlands are fairly mobile: two-third shows mobility in one form or another between 1996 and 2013. The 33.5% of NLD researchers that have not published with affiliations outside of the Netherlands is relatively 'young', meaning they began to show up as authors in Scopus more recently than the average NLD researcher. This sedentary group of researchers is also less productive than the groups with mobility, and achieves a lower FWCI, though it is still 69% above the world average.

The largest mobility group, taking up 33.5% of the Netherlands' researchers, is mainly non-NLD researchers with transitory mobility. These are researchers coming from abroad to spend two years or less in the Netherlands, after which they move to another country. Such researchers are also by far the most productive, publishing over 50% more articles than the average NLD researcher. They are somewhat older and achieve the second highest FWCI of NLD mobility groups. At 2.17 they are cited well over twice as often as the world average. The second largest group is also one with transitory mobility, but this time the mainly NLD one. However, researchers in this group are relatively younger, less productive and their publications are less impactful than those in the mainly non-NLD group. The highest citation impact is achieved by the 'returnees inflow': NLD researchers who have spent more than two years abroad before returning to the Netherlands. Taking up only 3.2% of the Netherlands' researchers, it is the smallest of the mobility groups, but their publications are cited 125% more often than the world average publication. These returnees have the highest relative age (23% older than the average NLD researcher) and show the second highest productivity among the NLD mobility groups.

Merging the different outflow, transitory and inflow groups, it becomes clear that all NLD researchers showing mobility are on average of about the same 'age' (as measured by their publishing history). Accounting for close to half of all NLD researchers, the group of transitory mobility is naturally the largest, but also the most productive, with a relative productivity of 1.32. While there is a slightly higher outflow of researchers than inflow, the latter group is both more productive and more impactful, suggesting the Netherlands benefits from bringing in knowledge from abroad.

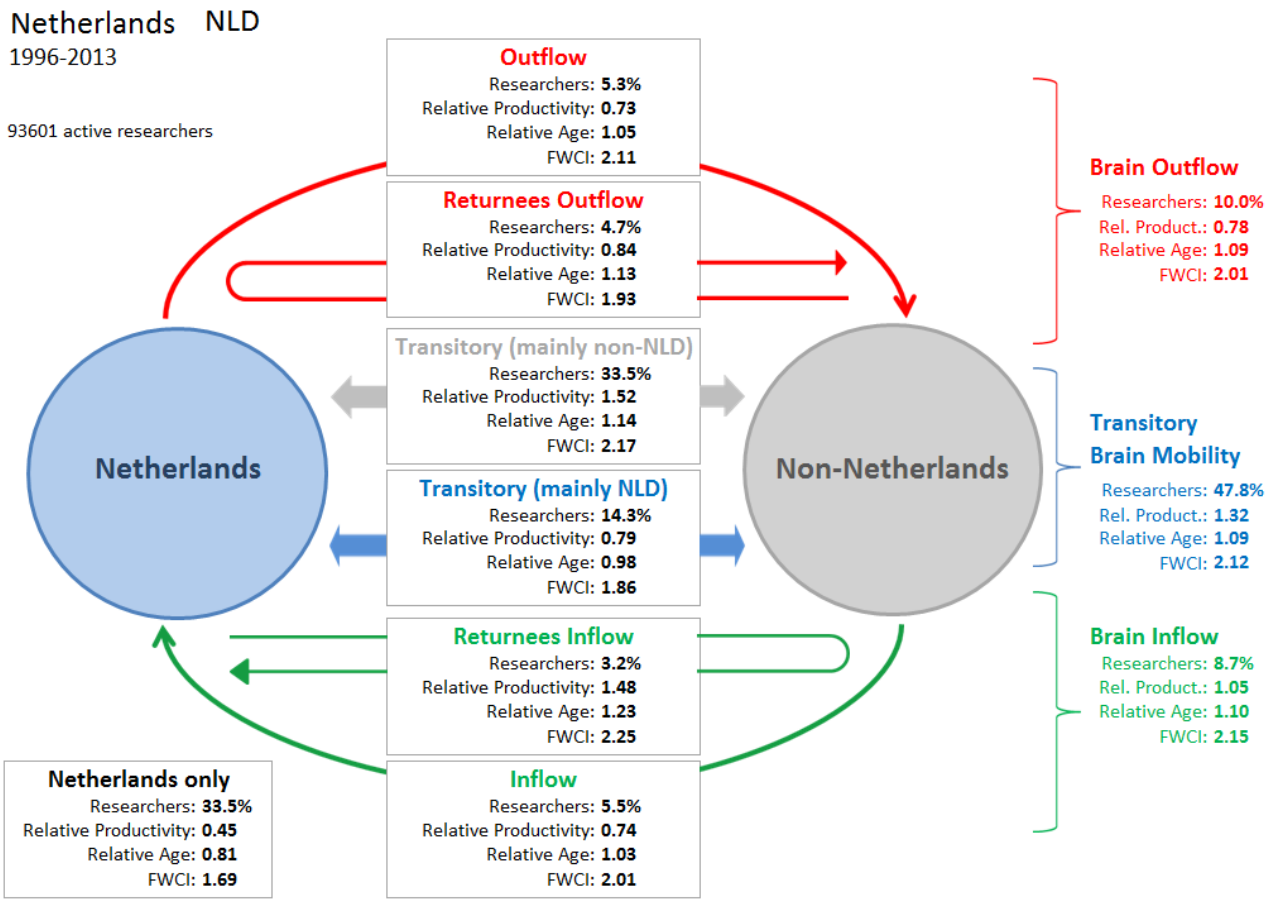


Figure 5.1 — *Researcher mobility for the Netherlands, 1996-2013*

Appendix A
Data sources and terms

Methodology and rationale

Our methodology is based on the theoretical principles and best practices developed in the field of quantitative science and technology studies, particularly in science and technology indicators research. The Handbook of Quantitative Science and Technology Research: The Use of Publication and Patent Statistics in Studies of S&T Systems (Moed, Glänzel and Schmoch, 2004[18]) gives a good overview of this field and is based on the pioneering work of Derek de Solla Price (1978)[19] , Eugene Garfield (1979)[20] and Francis Narin (1976)[21] in the USA, and Christopher Freeman, Ben Martin and John Irvine in the UK (1981, 1987)[22] , and in several European institutions including the Centre for Science and Technology Studies at Leiden University, the Netherlands, and the Library of the Academy of Sciences in Budapest, Hungary.

The analyses of bibliometric data in this report are based on recognised advanced indicators (e.g., the concept of relative citation impact rates). Our base assumption is that such indicators are useful and valid, though imperfect and partial measures, in the sense that their numerical values are determined by research performance and related concepts, but also by other, influencing factors that may cause systematic biases. In the past decade, the field of indicators research has developed a best practices which state how indicator results should be interpreted and which influencing factors should be taken into account. Our methodology builds on these practices.

Article types

For all bibliometric analysis, only the following document types are considered:

- Article (ar)
- Review (re)
- Conference Proceeding (cp)

Counting

All analyses make use of whole counting rather than fractional counting. For example, if a paper has been co-authored by one author from the UK and one author from the Netherlands, then that paper counts towards both the publication count of the UK, as well as the publication count of the Netherlands. Total counts for each country are the unique count of publications.

We acknowledge that "there is no fair method to determine how much money, effort, equipment and expertise each researcher, institute or country contributes to a paper and the underlying research effort. Dividing up a paper between the participating units is therefore to some extent arbitrary. Our basic assumption is that each author, main institution and country listed in the affiliated addresses made a nonnegligible contribution. Each paper is therefore assigned in the full to all unique authors, institutions and countries listed in the address heading." Extended technical annex to chapter 5 of the 'Third European Report on S&T Indicators '; "Bibliometric Analyses of World Science" by Robert Tijssen and Thed van Leeuwen, CWTS, Leiden University.[23]

Data sources

Scopus is Elsevier's abstract and citation database of peer-reviewed literature, covering 57 million documents published in over 22,000 journals, book series and conference proceedings by some 5,000 international publishers. Reference lists are captured for 35+ million records published from 1996 onwards, and the additional 21+

[18] Moed, H.F., Glänzel, W., & Schmoch, U. (eds.) (2004). Handbook of Quantitative Science and Technology Research. The Use of Publication and Patent Statistics in Studies of S&T Systems. Dordrecht, the Netherlands: Kluwer Academic Publishers.

[19] de Solla Price, D.J. (1978). Foreword. Essays of an Information Scientist, 3: v–ix.

[20] Garfield, E. (1979). Is Citation Analysis a Legitimate Evaluation Tool? Scientometrics 1(4): 359–375.

[21] Pinski, G., & Narin, F. (1976). Citation Influence for Journal Aggregates of Scientific Publications: Theory, with Application to the Literature of Physics. Information Processing & Management 12(5): 297–312.

[22] Irvine, J., Martin, B. R., Abraham, J., & Peacock, T. (1987). Assessing Basic Research: Reappraisal and Update of an Evaluation of Four Radio Astronomy Observatories. Research Policy 16(2–4): 213–227.

[23] ftp://ftp.cordis.europa.eu/pub/indicators/docs/3rd_report_biblio_ext_methodology.pdf.

million pre-1996 records reach as far back as the publication year 1823.

Scopus coverage is multi-lingual and global: approximately 15% of titles in Scopus are published in languages other than English (or published in both English and another language). The database contains titles from more than 120 different countries and over 50 languages in all geographic regions. Scopus covers approximately 18,000 titles from Europe, 10,500 from North-America, 3,300 from Asia-Pacific, 900 from Central and South America, and 400 titles from Africa.

Scopus coverage is also inclusive across all major research fields, with 11,500 titles in the Physical Sciences, 12,800 in the Health Sciences, 6,200 in the Life Sciences, and 9,500 in the Social Sciences. Titles which are covered are predominantly serial publications (journals, trade journals, book series, and conference material), but considerable numbers of conference papers are also covered from stand-alone proceedings volumes (a major dissemination mechanism, particularly in the computer sciences). Acknowledging that a great deal of important literature in all fields (but especially in the Social Sciences and Arts & Humanities) is published in books, Scopus has begun to increase book coverage in 2013 (89,000 books in June 2015). Currently, Scopus already covers books published by Elsevier, Springer, Wiley, Brill, De Gruyter, Woodhead, Karger, Oxford University Press, Edward Elgar, Maney, Intellect, IOS Press, Pan Stanford, University of California Press, Princeton University Press, Edinburgh University Press, Delft University Press, Duke University Press, McGill Queens University Press, Project Muse (60+ UPs), OECD, and other publishers.

A body of literature is available on the limitations and caveats in the use of such 'bibliometric' data, such as the accumulation of citations over time, the skewed distribution of citations across articles, and differences in publication and citation practices between fields of research, different languages, and applicability to social sciences and humanities research. In social sciences and humanities, the bibliometric indicators presented in this book for these fields must be interpreted with caution because a reasonable proportion of research outputs in such fields take the form of books, monographs and non-textual media. As such, analyses of journal articles, their usage and citation, provides a less comprehensive view than in other fields, where journal article comprise the vast majority of research outputs. More information can be found on www.elsevier.com/solutions/scopus.

ScienceDirect is Elsevier's leading full-text journal articles platform. With an invaluable and incomparable customer base, the use of scientific research on ScienceDirect.com provides a different look at performance measurement. ScienceDirect.com is used by more than 12,000 institutes worldwide, with more than 15 million active users. The average click through to full-text per month is 67 million. ScienceDirect contains more than 13 million content pieces, 2,500 journals, and 33,000 books. More info can be found on www.elsevier.com/solutions/sciencedirect.

World Intellectual Property Office (WIPO) is a specialized agency of the United Nations that administers the intellectual property and provides the world's largest database of 30 million patent documents, including 2.2 million published international patent applications. More info can be found on www.wipo.int.

CAGR: Compound Annual Growth Rate

The Compound Annual Growth Rate is defined as the year-over-year constant growth rate over a specified period of time. Starting with the first value in any series and applying this rate for each of the time intervals yields the amount in the final value of the series.

$$CAGR(t_0, t_n) = \left(\frac{V(t_n)}{V(t_0)}\right)^{\frac{1}{t_n - t_0}}$$

Where $V(t_0)$ is the starting value, $V(t_n)$ is the finishing value, and $t_n - t_0$ is the number of the years.

Indicators

Publication output

The number of publications per country, which have at least one author affiliated to the institute. A publication which is co-authored by authors from different countries, thus counts towards the publication output of each country.

Publication share

Publication share is the global share of publications for a specific country expressed as a percentage of the total output. Using a global share in addition to absolute numbers of publications provides insight by normalizing for increases in world publication growth and expansion of the field in question or the whole Scopus database.

Activity index

Activity index is defined as a country's share of its total article output across subject field(s) relative to the global share of articles in the same subject field(s). A value of 1.0 indicates that a country's research activity in a field corresponds exactly with the global activity in that field; higher than 1.0 implies a greater emphasis while lower than 1.0 suggests a lesser focus.

Field-Weighted Citation Impact

Citations accrue to published articles over time, as articles are first read and subsequently cited by other authors in their own published articles. Citation practices, such as the

number, type and age of articles cited in the reference list, may also differ by research field. As such, in comparative assessments of research outputs citations must be counted over consistent time windows, and publication and field-specific differences in citation frequencies must be accounted for.

Field-weighted citation impact is an indicator of mean citation impact, and compares the actual number of citations received by an article with the expected number of citations for articles of the same document type (article, review or conference proceeding paper), publication year and subject field. Where the article is classified in two or more subject fields, the harmonic mean of the actual and expected citation rates is used. The indicator is therefore always defined with reference to a global baseline of 1.0 and intrinsically accounts for differences in citation accrual over time, differences in citation rates for different document types (reviews typically attract more citations than research articles, for example) as well as subject-specific differences in citation frequencies overall and over time and document types. It is one of the most sophisticated indicators in the modern bibliometric toolkit.

Highly cited articles

Highly cited articles (unless otherwise indicated) are those in the top-cited X% of all articles published and cited in a given period.

Downloads

A download is defined as the event where a user views the full-text HTML of an article or downloads the full-text PDF of an article from ScienceDirect, Elsevier's full-text journal article platform; views of an article abstract alone, and multiple full-text HTML views or PDF downloads of the same article during the same user session, are not included in accordance with the COUNTER Code of Practice 35. ScienceDirect provides download data for approximately 16% of the articles indexed in Scopus; it is assumed that user downloading behaviour across countries does not systematically differ between online platforms. Field-weighted download impact is calculated from these data according to the same principles applied to the calculation of field-weighted citation impact.

Patent citations

The patenting process can be divided into three distinct phases; filing an application for a patent and its examination; the registration of a decision (granted or not); and the on-going payment of maintenance fees to keep the patent in force. Data indicating the volume of patenting activity in each of these phases are available: patent applications, patents granted and patents in force.

It is tempting to attempt to calculate the patenting "efficiency" of a given country by dividing the number of patents granted by the number of patent applications, for example. However, given the variable length of time taken for the examination of a patent application, phasing issues mean that any indicator derived in such a way could be somewhat misleading.

It is important to note that these counts for patent applications, patents granted and patents in force are totals, aggregated across all fields of research and all sectors of R&D performance. However, not all research fields and sectors have the same propensity to patent, and so national patenting activities may reflect national research field specialisation and industry focus.[24]

International Collaboration

International collaboration in this report is indicated by articles with at least two different countries listed in the authorship byline.

Academic-corporate collaboration

At least one author of the article is affiliated with an academic institution and also at one author affiliated with the corporate sector.

Sectors

Academic

▶ University: universities and other institutions that grant undergraduate, graduate, and/or Ph.D. degrees as well as engage in research. Examples: the University of Oxford, the University of Cambridge.

▶ College: institutions that grant undergraduate degrees as well as engage in research to some extent. Examples of colleges: Trinity Valley Community College (http://www.tvcc.edu/), Scottish Agricultural College (http://www.sruc.ac.uk)

▶ Research institute: organizations whose primary function is to conduct research and may include some educational activities but which are not universities. Example: Salk Institute, members of the Max-Planck Society (MPI of Biochemistry and others). Charity-funded research centres are also included in this category, e.g., the UK's National Eye Research Centre, Wellcome Trust and Cancer Research UK.

Medical

▶Medical school: organizations that offer medical degrees as well as engage in research. Examples: Queen's Medical Centre, Harvard Medical School, Brown Medical School. We do not designate dental schools and providers of other health-related degrees as Medical schools.

[24] van Pottelsberghe de la Potterie, B. (2008) "Europe's R&D: Missing the wrong targets?" Intereconomics 43 (4) pp. 220-225.

► Hospital: organizations whose primary function is to provide health care, although they may also do research. Example: All Saints Hospital, St Mary's Hospital London, and Royal Brompton Hospital.

Corporate

► Company: commercial entities primarily operating with a profit motive, although some non-profit organizations could potentially be classified as companies. Examples: Unilever, British Broadcasting Corporation, Microsoft Research Cambridge, Royal Bank of Scotland, IBM, Hewlett-Packard.
► Law firm: business entities formed by one or more lawyers to engage in the practice of law. Examples: Baker and McKenzie (http://www.bakermckenzie.com/)

Government

► Government: includes all levels of government as well as United Nations. Example: US Department of Energy, Department for Business, Innovation & Skills, UK.
► Military organization: Example: UK Defence Science and Technology Laboratory, US Army Research Laboratory, Weapons and Materials Research Directorate.

Appendix B
Data Tables

Legend for Scatterplots in Chapter 3, Subject Deep Dive: Medicine

Number	Subject Code	Sub-area
1	2700	General Medicine
2	2701	Medicine (miscellaneous)
3	2702	Anatomy
4	2703	Anesthesiology and Pain Medicine
5	2704	Biochemistry (medical)
6	2705	Cardiology and Cardiovascular Medicine
7	2706	Critical Care and Intensive Care Medicine
8	2707	Complementary and Alternative Medicine
9	2708	Dermatology
10	2709	Drug Guides
11	2710	Embryology
12	2711	Emergency Medicine
13	2712	Endocrinology, Diabetes and Metabolism
14	2713	Epidemiology
15	2714	Family Practice
16	2715	Gastroenterology
17	2716	Genetics (clinical)
18	2717	Geriatrics and Gerontology
19	2718	Health Informatics
20	2719	Health Policy
21	2720	Hematology
22	2721	Hepatology
23	2722	Histology
24	2723	Immunology and Allergy
25	2724	Internal Medicine
26	2725	Infectious Diseases
27	2726	Microbiology (medical)
28	2727	Nephrology
29	2728	Neurology (clinical)
30	2729	Obstetrics and Gynecology
31	2730	Oncology
32	2731	Ophthalmology
33	2732	Orthopedics and Sports Medicine

34	2733	Otorhinolaryngology
35	2734	Pathology and Forensic Medicine
36	2735	Pediatrics, Perinatology and Child Health
37	2736	Pharmacology (medical)
38	2737	Physiology (medical)
39	2738	Psychiatry and Mental Health
40	2739	Public Health, Environmental and Occupational Health
41	2740	Pulmonary and Respiratory Medicine
42	2741	Radiology, Nuclear Medicine and Imaging
43	2742	Rehabilitation
44	2743	Reproductive Medicine
45	2745	Rheumatology
46	2746	Surgery
47	2747	Transplantation
48	2748	Urology
49	2744	Reviews and References (medical)

Authors

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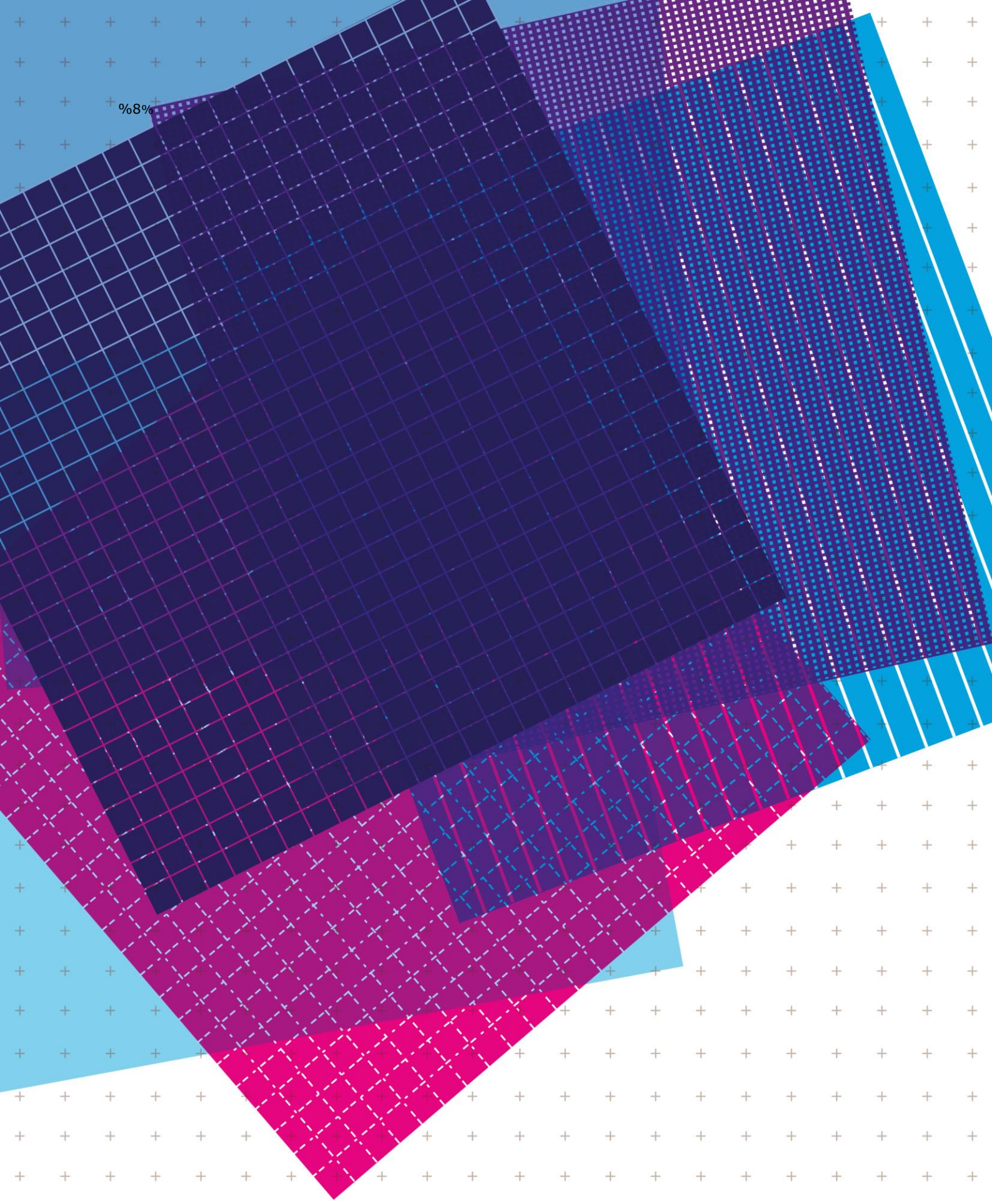
Notes



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