Quantum publications

A bibliometric analysis by the State Secretariat for Education, Research and Innovation SERI

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State Secretariat for Education,
Research and Innovation SERI

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Publication details

Published by: © 2022 State Secretariat for Education, Research and Innovation

Translation: SERI and Federal Chancellery Language Services

Languages: English and French

ISSN: 2296-3871

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Introduction

Quantum research has taken on increasing strategic importance for science, the economy and society in recent years. This trend motivated us to carry out an in-depth bibliometric analysis on the field,[1] examining publications categorised under 'quantum'.

This report presents figures on quantum publications (in peer-reviewed journals contained in the Clarivate Analytics database):

- at national level and for selected countries
- for the world's most published institutions
- for institutional sectors in Switzerland
- at regional level in Switzerland, as well as:
    - for Switzerland's most published institutions, and the analysis of:
    - the impact of publications (i.e. the relative citation indicator)
    - the rate of national/international collaboration and
    - collaboration with other countries.

Our bibliometric analysis covers the period from 2008–2012 to 2016–2020.

[1] The complete results on quantum publications are available in the 2022 SERI report 'Scientific publications in Switzerland, 2008–2020'

Key points in brief

Quantum publications

The number of quantum publications has increased significantly worldwide, particularly between 2013 and 2017 (Fig. 1).

At the beginning of the period under review (2008–2012), the countries with the greatest share of the number of publications were the United States (17.9%), China (11.7%) and Russia (6.8%), with Japan, France, Italy and Germany at around 6% each (Fig. 2). China's share has grown the most, from almost 6,000 quantum publications for 2008–2012 to 18,000 for 2016–2020, putting it in first place. The number of US publications also increased but at a slower pace, going from 8,000 for 2008–2012 to 12,000 for 2016–2020, which ranked second for 2016–2020.

Switzerland increased its share of global quantum publications slightly from 0.9% in 2008–2012 to 1% in 2016–2020. It thus ranks 18th among the countries producing quantum publications for 2016–2020. Switzerland's number of quantum publications has been increasing steadily since the 2008–2012 period, although the pace has slowed in the most recent period.

For 2016–2020, the top institutions publishing on quantum technologies are the Russian Academy of Sciences, the CNRS (France), and the University of Science and Technology of China. The leading Swiss institution is ETH Zurich, which ranks 24th.

In 2016–2020, the higher education sector in Switzerland produced the largest share of the country's quantum publications (77.9%), followed by research institutes (12.9%), private businesses (6.6%) and international organisations (2.6%).

For 2016–2020 ETH Zurich produced 31% of Switzerland's quantum publications, followed by the University of Geneva (14.2%) and EPFL (13.7%).

The Zurich and Lake Geneva regions produced the vast majority of Switzerland’s quantum publications (42% and 32% respectively) for the 2016–2020 period.

Impact of quantum publications

Switzerland has performed very well in terms of the impact of its quantum publications, taking the lead over Germany and the UK for 2016–2020, with an impact that was 33 points above the world average of 100.

Partnerships in quantum publications

The rate of international collaboration for Swiss quantum publications has consistently been very high: 85% for 2008–2012, increasing to 89% for 2016–2020.

In 2008–2012 Swiss quantum researchers collaborated mainly with neighbouring countries – Italy (20.5%), Germany (13.5%) and France (11.7%) – followed by the United States (10.9%). In 2016–2020, the United States became Switzerland's main partner for quantum publications (15.2%), followed by Italy (9.7%), Germany (8.5%) and France (8.0%).

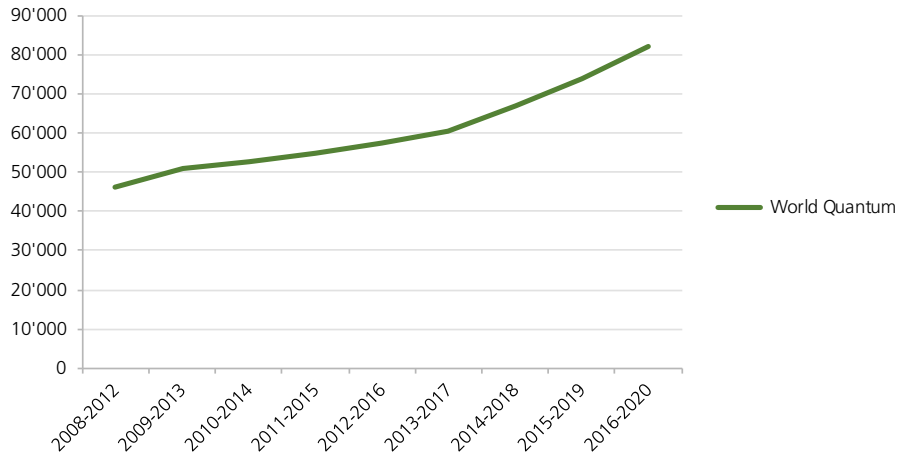
1. Quantum publications

A keyword search was conducted in the Clarivate Analytics database, including the *Science Citation Index Expanded (SCIE)*, the *Social Science Citation Index Expanded (SSCIE)*, the *Arts & Humanities Citation Index (A&HCI)* and the *Emerging Sources Citation Index (ESCI*), and publications with the word 'quantum' in their title and journals with the word 'quantum' in their name were extracted. While the term 'quantum' appears in publications from philosophy, social sciences and history, these have not been included in this study as our focus here is on the quantum sciences, quantum computing, technology and physics (i.e. what are known as the 'hard sciences').

1.1 Worldwide quantum publications

The number of quantum publications worldwide is steadily increasing and has almost doubled (x 1.8) since the first period under review, from 42,000 publications to some 82,200 publications for 2016–2020. The increase has accelerated since the 2013–2017 period (Fig. 1), with an increase of approximately 5% between each period until the 2013–2017 period, then about a 10% increase until 2016–2020.

Figure 1: Evolution of the number of quantum publications worldwide, from 2008–2012 to 2016–2020



Source: Clarivate Analytics (SCIE/SSCIE/A&HCI/ESCI), graphic by SERI © SERI 2022

Table 1: Number of quantum publications worldwide, from 2008–2012 to 2016–2020

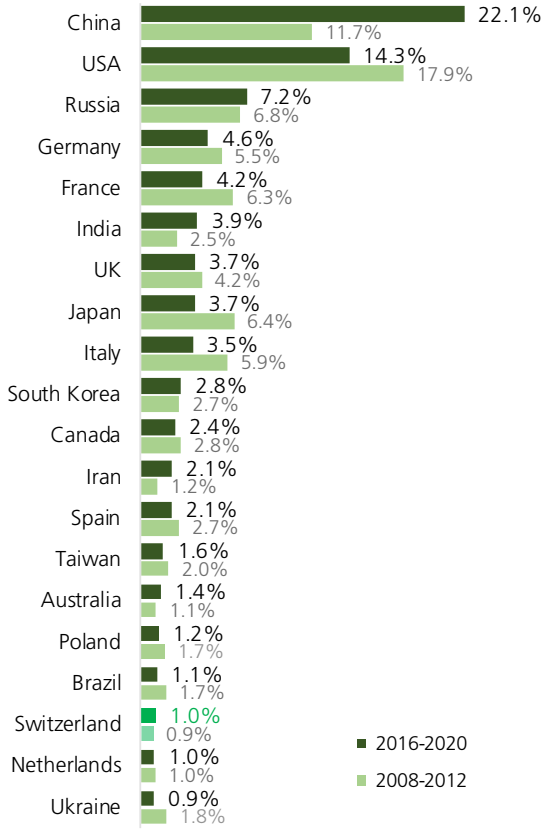
Number of publications	2008–2012	2009–2013	2010–2014	2011–2015	2012–2016	2013–2017	2014–2018	2015–2019	2016–2020
World quantum	46,020	50,801	52,438	54,732	57,336	60,569	66,952	73,906	82,217

1.2 Switzerland in the world ranking of quantum publications by country

During the 2008–2012 period, the United States was the largest producer of quantum publications (17.9% of world share) but since then has been overtaken by China with a share of 22.1% for 2016–2020 (Fig. 2).

Switzerland increased its world share of quantum publications slightly from 0.9% in 2008–2012 to 1% in 2016–2020. It thus ranked 18th among the countries producing quantum publications in 2016–2020.

Figure 2: World share of quantum publications by country for 2008–2012 and 2016–2020, top 20 countries in 2016–2020



Source: Clarivate Analytics (SCIE/SSCIE/A&HCI/ESCI), graphic by SERI © SERI 2022

As of 2016–2020 at the global level, Switzerland was producing 1% of the world's scientific publications (see section 1.3, SERI 2022 bibliometric analysis '[Scientific publications in Switzerland, 2008–2020]'), meaning that its share in the production of quantum publications is proportionate. On the other hand, while the United States is the main producer of total scientific publications, followed by China, the situation is the opposite for quantum publications.

Annex A contains information on the 20 most productive countries during the 2016–2020 period, with a figure illustrating the evolution over time of the number of quantum publications for each of these countries.

1.3 Leading institutions producing quantum publications

Our database shows at least 2,000 institutions publishing on quantum, but many produce only a few publications. Only 100 institutions had more than 100 publications in one of the reporting periods. For 2006–2020 the most active institutions were the Russian Academy of Sciences, the CNRS (France), and the University of Science & Technology of China.

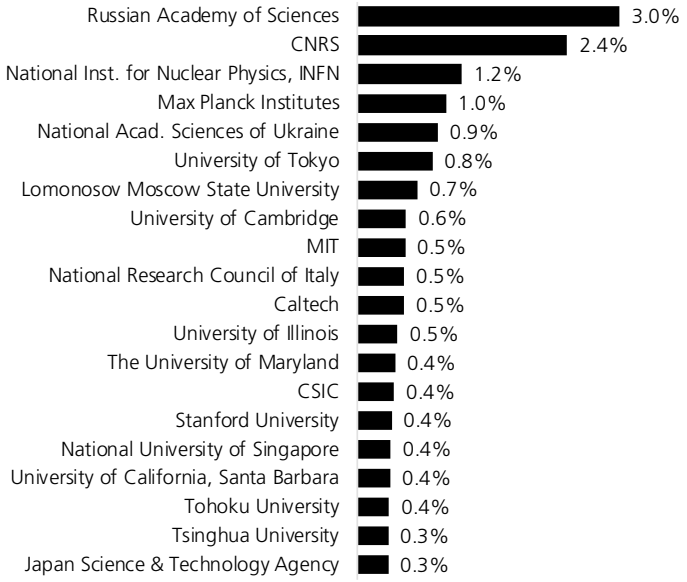
The leading Swiss institution is ETH Zurich, which ranks 24th among institutions producing quantum publications.

Figure 3: Global share of quantum publications for the top 20 institutions, 2016–2020 period

Source: Clarivate Analytics (SCIE/SSCIE/A&HCI/ESCI), graphic by SERI

The Russian Academy of Sciences and the CNRS were the two most prolific institutions for 2008–2012. The National Institute for Nuclear Physics (INFN, Italy) was in third place.

Figure 4: Global share of quantum publications for the top 20 institutions, 2008–2012 period

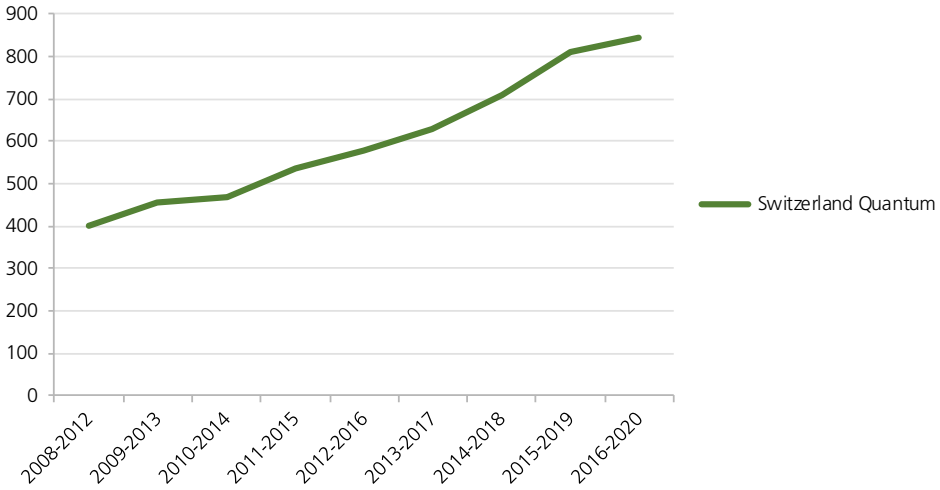


Source: Clarivate Analytics (SCIE/SSCIE/A&HCI/ESCI), graphic by SERI

1.4 Quantum publications in Switzerland

As at the worldwide level (Fig. 1), the number of quantum publications from Switzerland has also been rising steadily since the beginning of the overall period under review, from 399 publications for 2008–2012 to 845 publications for 2016–2020 (x 2.1). The number nevertheless stabilised in the most recent period (Fig. 5).

Figure 5: Evolution of the number of quantum publications in Switzerland, from 2008–2012 to 2016–2020



Source: Clarivate Analytics (SCIE/SSCIE/A&HCI/ESCI), graphic by SERI © SERI 2022

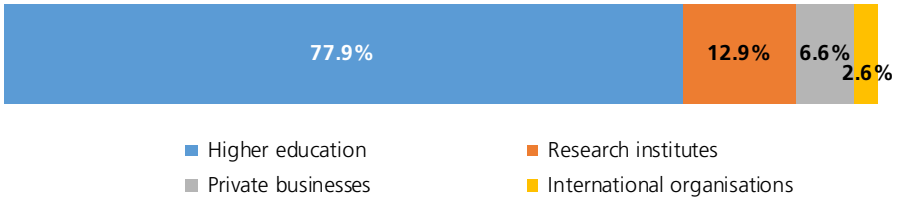
Table 2: Number of quantum publications in Switzerland, from 2008–2012 to 2016–2020

Number of publications	2008–2012	2009–2013	2010–2014	2011–2015	2012–2016	2013–2017	2014–2018	2015–2019	2016–2020
Switzerland quantum	399	454	468	535	578	629	709	810	845

1.5 Switzerland's quantum publications by institutional sector

For 2016–2020, the higher education sector produced the largest share of Switzerland's quantum publications (77.9%), followed by research institutes (12.9%), private businesses (6.6%) and international organisations (2.6%) (Fig. 6).

Figure 6: Breakdown of Swiss quantum publications by institutional sector, 2016–2020



Source: Clarivate Analytics (SCIE/SSCIE/A&HCI/ESCI), graphic by SERI

The higher education sector's share of this type of publication in Switzerland is larger than its share at the global level, where it was producing 70.8% of the world's scientific publications (see section 1.8, SERI 2022 bibliometric analysis 'Scientific publications in Switzerland, 2008–2020').

Institutional sectors

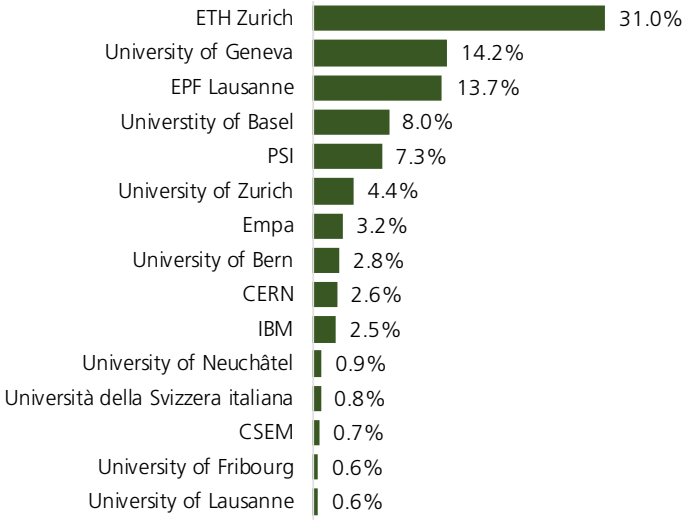
The breakdown of research institutions into institutional sectors has been done only for those located in Switzerland. Four institutional sectors have been defined:

- Higher education: cantonal universities, Swiss federal institutes of technology, universities of applied sciences, private colleges and universities, and teaching hospitals
- Private businesses: private companies in Switzerland, as well as private clinics and hospitals
- Research institutes: research institutes of the ETH Domain, federal research institutes, foundations, as well as public hospitals that are not teaching hospitals
- International organisations

1.6 Switzerland's quantum publications by institution

For 2016–2020, 47 institutions in Switzerland had at least one publication meeting the quantum criteria. ETH Zurich produces 31% of Switzerland's quantum publications, followed by the University of Geneva (14.2%) and EPF Lausanne (13.7%) (Fig. 7). These three institutions already dominated the ranking during the 2008–2012 period. CERN, on the other hand, is seeing its share fall as its absolute number of publications has not increased (Fig. 9).

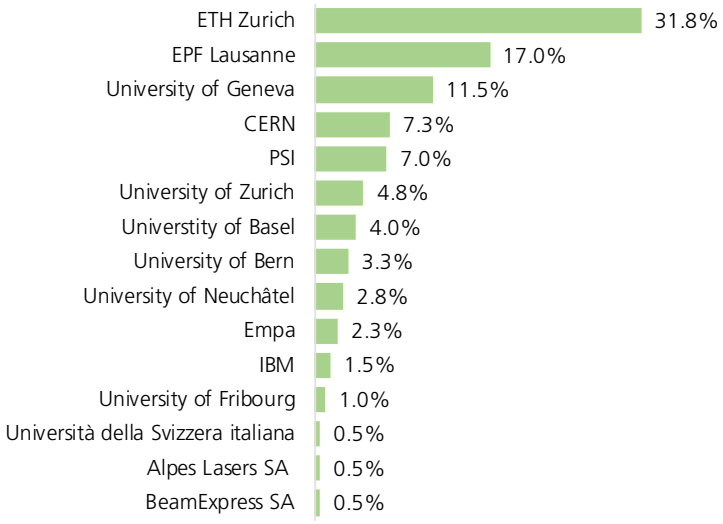
Figure 7: Share of quantum publications for the top 15 institutions in Switzerland, 2016–2020



Source: Clarivate Analytics (SCIE/SSCIE/A&HCI/ESCI), graphic by SERI © SERI 2022

For 2008–2012, 29 institutions in Switzerland had at least one publication meeting the quantum criteria. ETH Zurich produces 31.8% of Switzerland's quantum publications, followed by EPF Lausanne (17%) and the University of Geneva (11.5%) (Fig. 8).

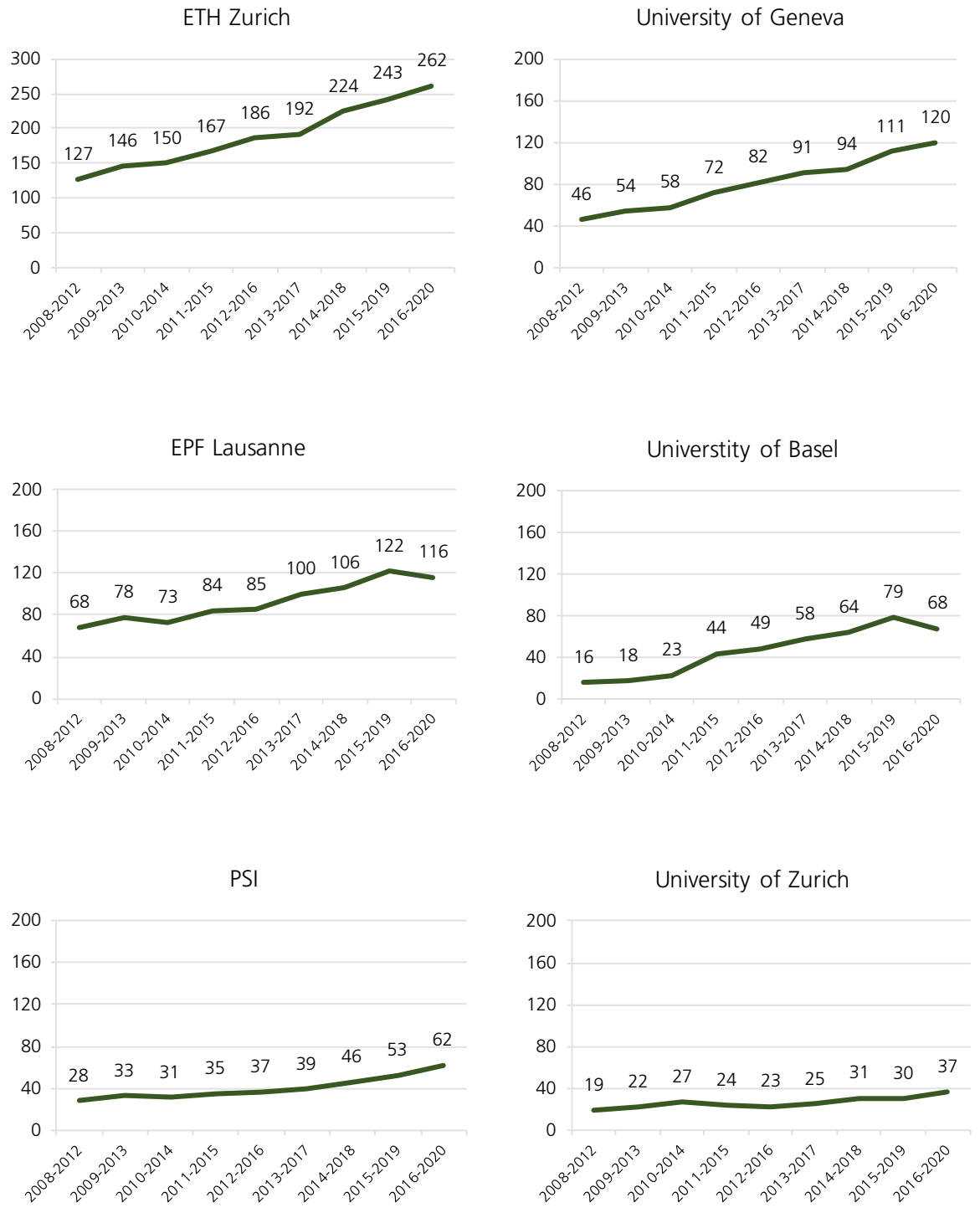
Figure 8: Share of quantum publications for the top 15 institutions in Switzerland, 2008–2012



Source: Clarivate Analytics (SCIE/SSCIE/A&HCI/ESCI), graphic by SERI © SERI 2022

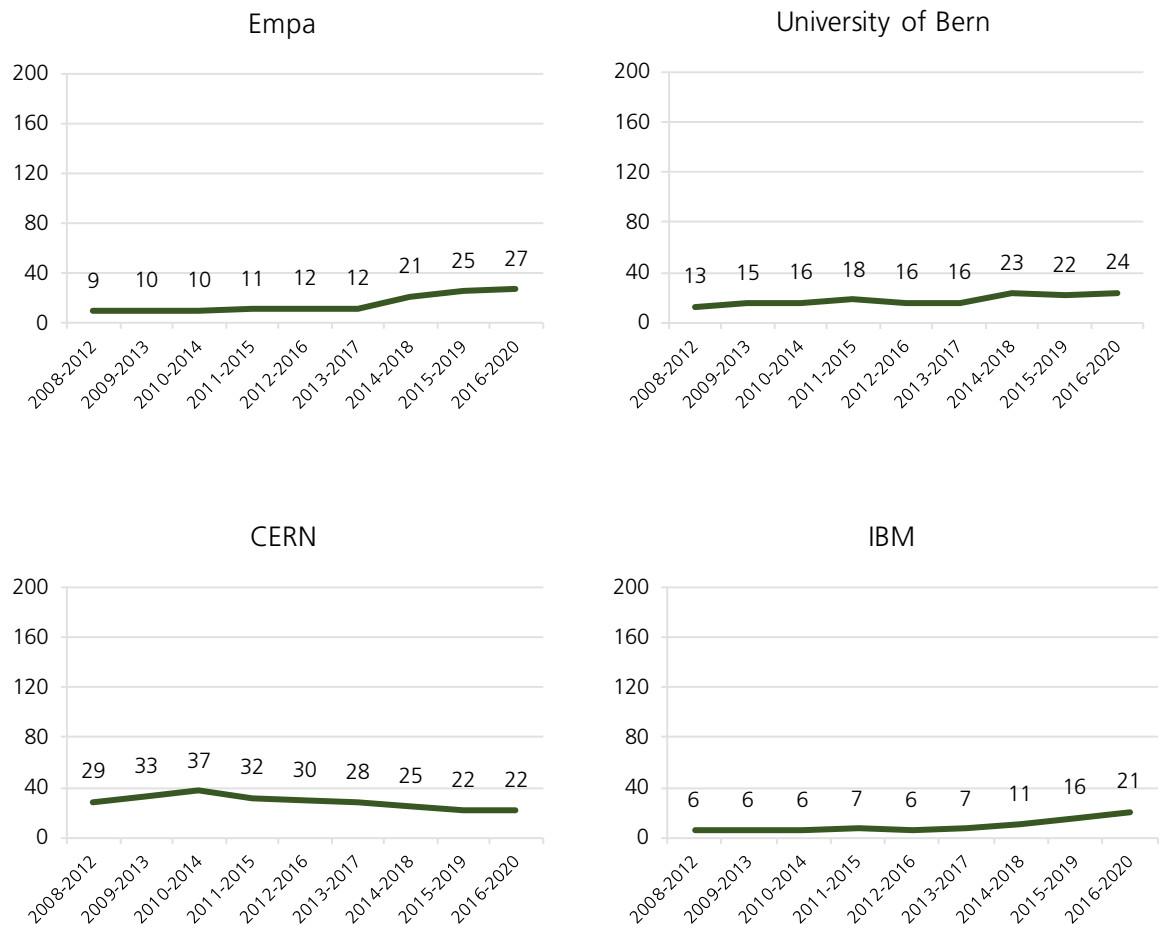
Overall, the number of quantum publications by the largest institutions in Switzerland rose throughout the entire periods studied, except for EPFL and the University of Basel, whose numbers dropped slightly for 2016–2020 (Fig. 9).

Figure 9: Evolution of the number of quantum publications by institution, from 2008–2012 to 2016–2020



Source: Clarivate Analytics (SCIE/SSCIE/A&HCI/ESCI), graphic by SERI © SERI 2022

Figure 9 (cont.): Evolution of the number of quantum publications by institution, from 2008–2012 to 2016–2020



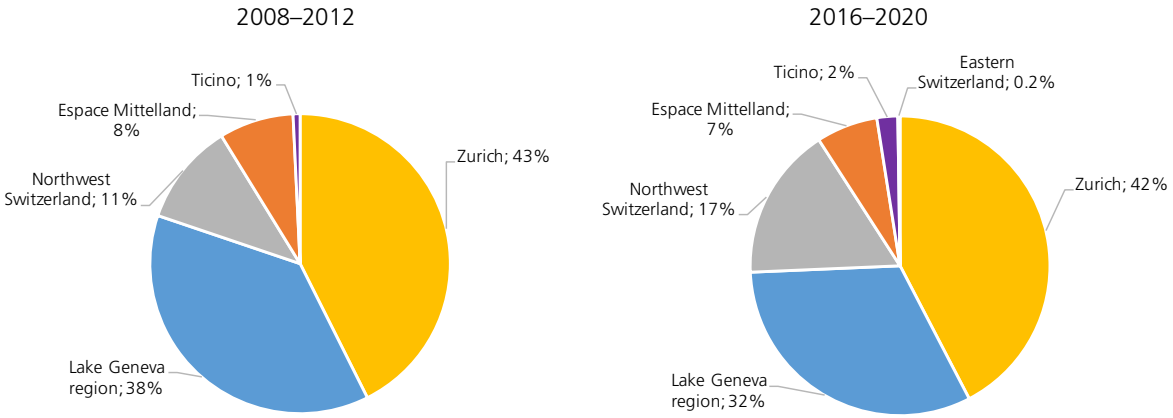
Source: Clarivate Analytics (SCIE/SSCIE/A&HCI/ESCI), graphic by SERI

NB: Figures are presented for Swiss institutions with more than 20 quantum publications for 2016–2020.

1.7 Switzerland's quantum publications by region

The Zurich and Lake Geneva regions produced the vast majority of Switzerland's quantum publications, with 42% and 32% respectively for 2016–2020, and 43% and 38% respectively for 2008–2012. This reflects the fact that ETH Zurich, the University of Geneva and EPFL produce the most quantum publications, followed by Northwest Switzerland, Espace Mittelland and Ticino (Fig. 10).

Figure 10: Quantum publications of Switzerland's regions as a percentage of total Swiss publications, 2008–2012 and 2016–2020



Source: Clarivate Analytics (SCIE/SSCIE/A&HCI/ESCI), graphic by SERI © SERI 2022

Region definitions

The 26 Swiss cantons were grouped into seven regions based on the nomenclature of the Federal Statistical Office:

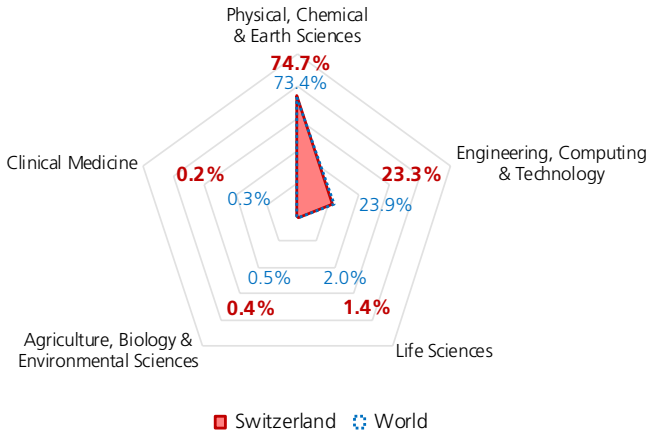
- Lake Geneva region: Geneva, Vaud and Valais
- Zurich: Zurich
- Northwest Switzerland: Aargau, Basel-Stadt and Basel-Landschaft
- Espace Mittelland: Bern, Fribourg, Jura, Neuchâtel and Solothurn
- Eastern Switzerland: Schaffhausen, Appenzell Ausserrhoden, Appenzell Innerrhoden, Thurgau, St Gallen, Glarus and Graubünden
- Ticino: Ticino
- Central Switzerland: Lucerne, Nidwalden, Obwalden, Schwyz, Uri and Zug

Source: https://www.bfs.admin.ch/bfs/fr/home/statistiques/themes-transversaux/analyses-spatiales/niveaux-geographiques/regions-analyse.html

1.8 Switzerland's quantum publications by research field

Swiss quantum publications have appeared in five major research fields, but three of those make up very small shares of the overall total: 1.4% in Life Sciences, 0.4% in Agriculture, Biology & Environmental Sciences and 0.2% in Clinical Medicine. The largest field of research is Physical, Chemical & Earth Sciences with 74.7% of quantum publications, followed by Engineering, Computing & Technology (23.3%) (Fig. 11).

Figure 11: Distribution of quantum publications by research field, Switzerland and world, 2016–2020 period



Source: Clarivate Analytics (SCIE/SSCIE/A&HCI/ESCI), graphic by SERI © SERI 2022

All countries have nearly identical research profiles, with more than 70% of quantum publications produced in the field of Physical, Chemical & Earth Sciences, except for India, Iran, Taiwan and Ukraine, which have slightly different profiles (see annex A, which presents the profiles of the 20 countries with the greatest number of publications).

Research fields are subdivided into sub-fields (see list in Annex B.2).

In Switzerland, the sub-field Physics (Physical, Chemical & Earth Sciences) alone produces 42% of quantum publications. This is followed by Electrical & Electronics Engineering (Engineering, Computing & Technology) at 18% and then three sub-fields of Physical, Chemical & Earth Sciences: Applied Physics / Condensed Matter / Materials Science (16%), Physical Chemistry / Chemical Physics (7%) and Chemistry (7%).

Research fields

The definition of research fields depends on the classification used by a database to split scientific journals into categories. Here, scientific journals are split according to their content into seven broad categories (or research fields; see *Current contents* https://mjl.clarivate.com/search-results Web of Science coverage/Current contents): Life Sciences; Physical, Chemical & Earth Sciences; Clinical Medicine; Agriculture, Biology & Environmental Sciences; Social & Behavioural Sciences; Engineering, Computing & Technology; and Arts & Humanities. The research fields themselves are split into several sub-fields. See annex B.2 for a full list of research fields and sub-fields.

2. Impact of quantum publications

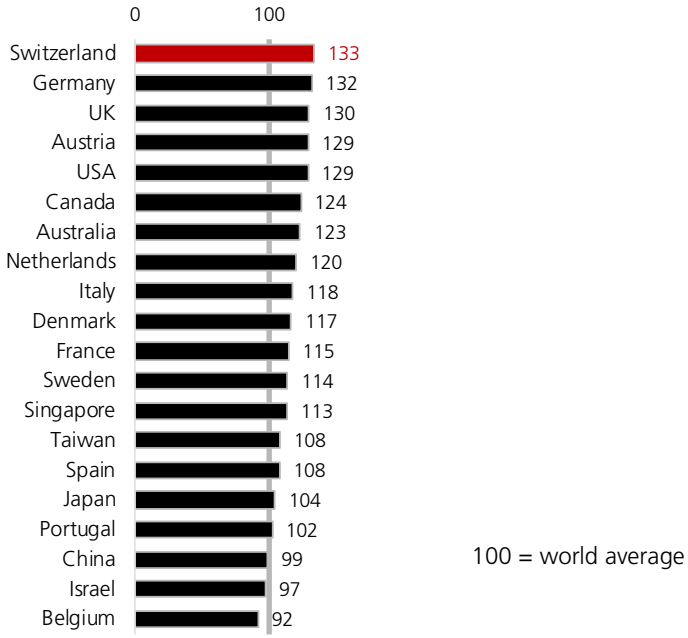
A publication's impact is measured by the number of times the publication in question is cited by researchers (see box for definition). The impact is an indicator of the level of recognition among peers.

2.1 Impact of Switzerland's quantum publications in a global comparison

Swiss publications have a very high impact, with Switzerland topping the international rankings in the 2016–2020 period, ahead of Germany and the UK with an impact that was 33 points above the world average of 100 (Fig. 12).

While China is the largest producer of quantum publications, its impact is still below the world average in 18th place.

Figure 12: Impact indicator for quantum publications, 2016–2020



Source: Clarivate Analytics (SCIE/SSCIE/A&HCI/ESCI), graphic by SERI © SERI 2022

Switzerland's impact at the global level for all publications exceeds the world average of 100 by 27 points, the third best result after the Netherlands and the UK (see section 1.5.1, SERI 2022 bibliometric analysis '[Scientific publications in Switzerland, 2008–2020]').

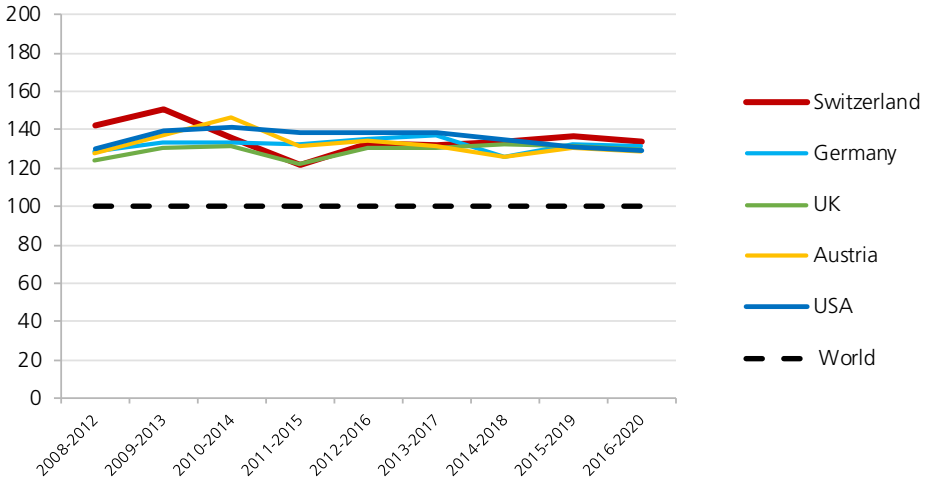
Annex A provides a profile for each country, including a figure showing the evolution of the impact of their publications.

2.2 Evolution of the impact of quantum publications for the top 5 countries

The impact of Swiss quantum publications is consistently well above the world average throughout the periods studied (Fig. 13).

The top 5 countries have had very similar impacts in recent periods.

Figure 13: Evolution of the impact of quantum publications for the top 5 countries



Source: Clarivate Analytics (SCIE/SSCIE/A&HCI/ESCI), graphic by SERI © SERI 2022

NB: Given the low numbers of quantum publications (for Switzerland and Austria), the variations in impact between periods can be significant. This applies particularly to the beginning of the period under review, when few publications on this topic were being produced.

Calculating impact (relative citation indicator)

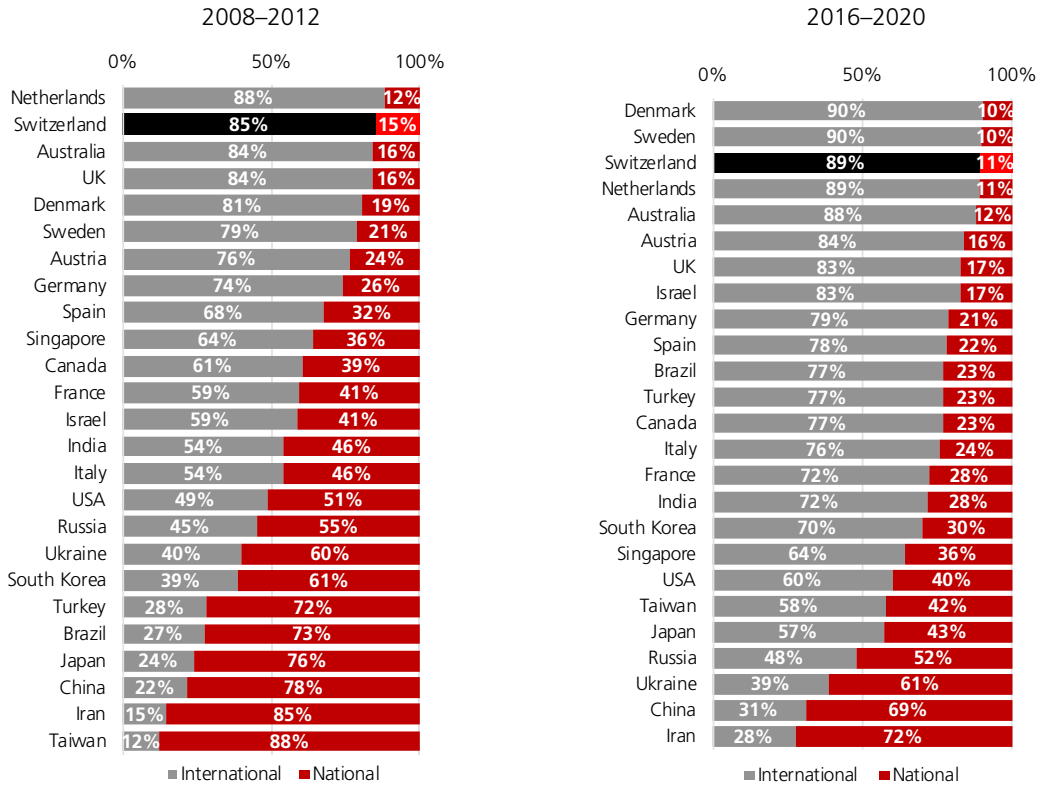
The impact of a country's publications indicates the readership that these publications reach among the research community. It is measured by the number of citations a publication receives. For each publication, the number of citations is put into context, i.e. divided by the global average citations in the research field in question, and then standardised on a scale where 100 represents the world average. The analysis window is five years, as for publication counting. See annex B.3 for more details on definition and calculation methods.

2.3 Partnerships in quantum publications

2.4 National and international partnership rates for quantum publications by country

The rate of international collaboration for Swiss quantum publications has consistently been very high: 85% for 2008–2012, increasing to 89% for 2016–2020 (Fig. 14). The rate of international collaboration is increasing for all countries. As of 2016–2020, only four countries (Russia, Ukraine, China and Iran) still have a higher rate of national than international collaboration.

Figure 14: Rate of national and international partnerships in quantum publications for a selection of 25 countries, for 2008–2012 and 2016–2020



Source: Clarivate Analytics (SCIE/SSCIE/A&HCI/ESCI), graphic by SERI © SERI 2022

Switzerland had a lower overall international partnership rate (taking all publications into account), with 79% in 2008–2012 and 84% in 2016–2020 (see section 1.6.1, SERI 2022 bibliometric analysis 'Scientific publications in Switzerland, 2008–2020').

Methods of counting publication partnerships

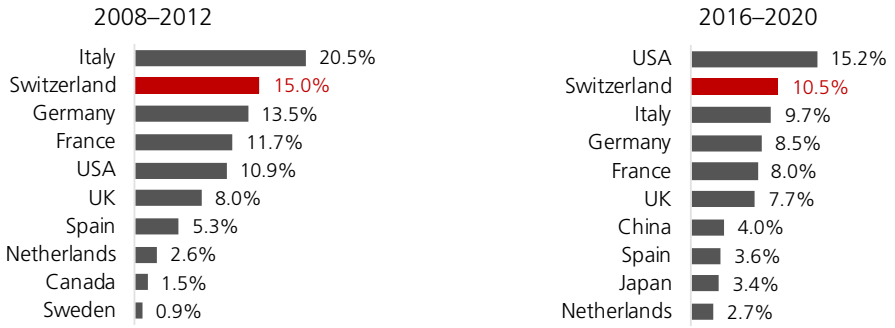
For each Swiss institution appearing on a publication, we count the other institutions involved in the publication, and classify the partnership as national or international according to the country where these institutions are located. The percentages of partnerships are calculated on the basis of the country's total partnerships. This indicator thus refers to total partnerships and not total publications.

2.5 Partnerships in Switzerland's quantum publications

For 2008–2012 Swiss quantum researchers collaborated mainly with neighbouring countries – Italy (20.5%), Germany (13.5%) and France (11.7%) – followed by the United States (10.9%) (Fig. 15).

For 2016–2020, the United States became Switzerland's main partner for quantum publications (15.2%), followed by Italy (9.7%), Germany (8.5%) and France (8.0%).

Figure 15: Origin of partners in quantum publications of Swiss-based researchers as a percentage of Switzerland's total partnerships, top 10 countries, for 2008–2012 and 2016–2020



Source: Clarivate Analytics (SCIE/SSCIE/A&HCI/ESCI), graphic by SERI © SERI 2022

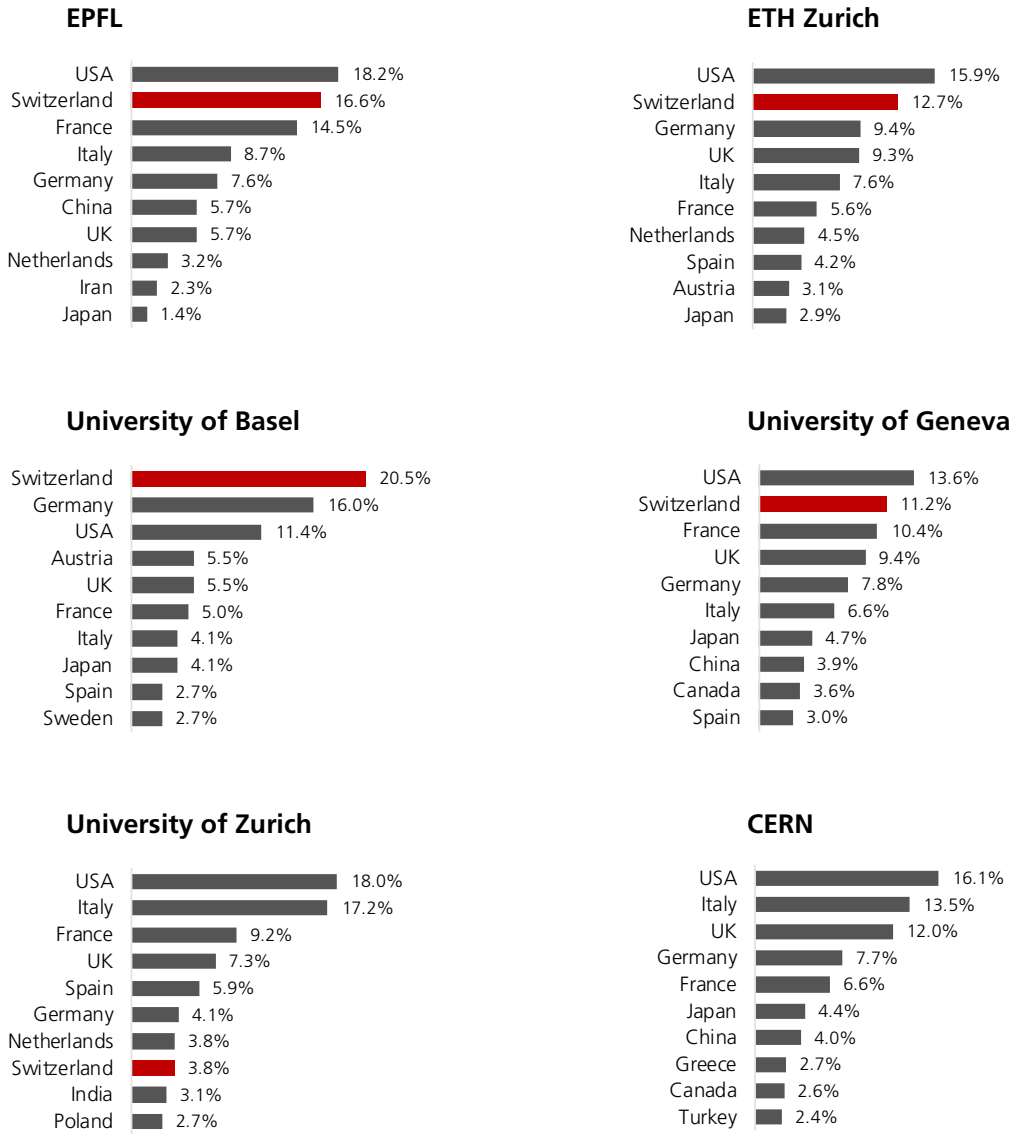
Switzerland collaborated with 43 other countries for 2008–2012, rising to 66 countries for 2016–2020.

Annex A provides figures on other countries' partnerships. Switzerland is rarely among these countries' top 10 collaboration partners; for example, the United States has a collaboration rate of 0.8% with Switzerland, which puts Switzerland in 18th place.

2.6 Partnerships in Swiss institutions' quantum publications

For 2016–2020, higher education institutions collaborated mainly with the United States, Germany, France, the United Kingdom, Italy and other institutions in Switzerland (Fig. 16). Switzerland only ranks 15th among CERN's collaboration partners.

Figure 16: Origin of partners in quantum publications, as a percentage of the institution's total partnerships, top 10 countries, for 2016–2020



Source: Clarivate Analytics (SCIE/SSCIE/A&HCI/ESCI), graphic by SERI

The collaboration rates of other Swiss institutions have also been calculated and are available on request.

Annexes

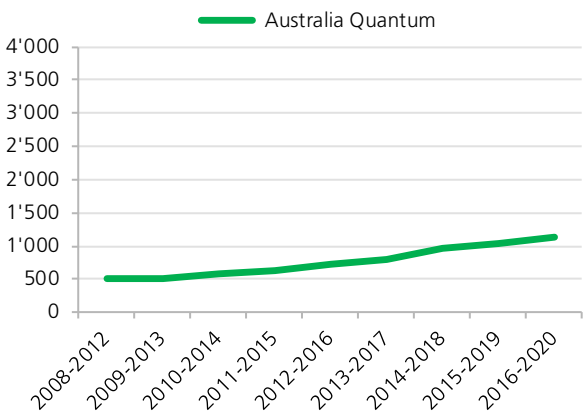
A Country factsheets

This annex provides a factsheet for each country, showing the evolution of the number of quantum publications, the profile of publications by research area for 2016–2020, the evolution of publication impact, and the country's partnerships.

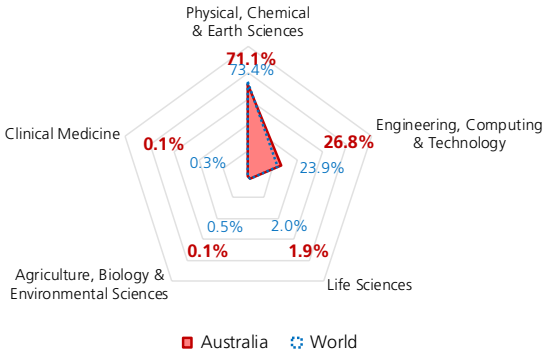
The 20 largest countries for 2016–2020 are presented in this annex in alphabetical order (Fig. 2). Other countries are available on request.

Australia

Evolution of the number of quantum publications



Research profile, 2016–2020



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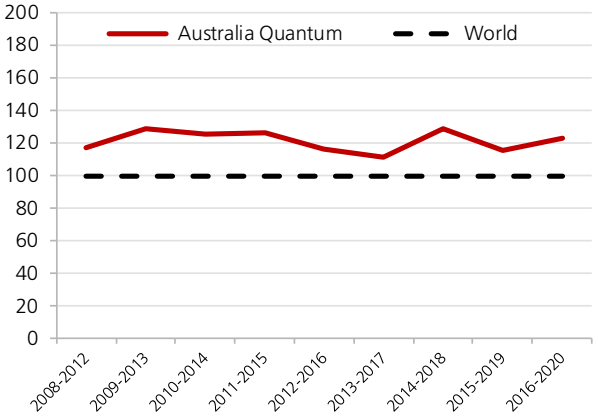
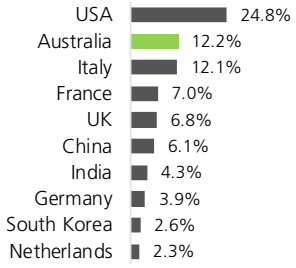


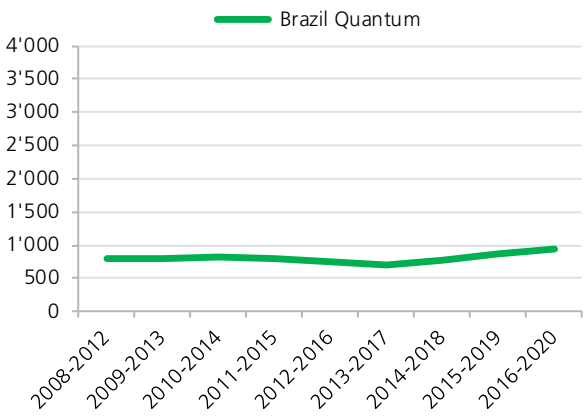
Partnerships, 2016–2020



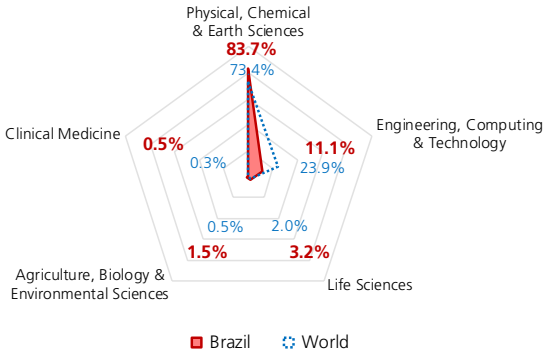
Australia collaborates the most with the United States, followed by national collaboration and collaborations with Italy and France. Its partnership rate with Switzerland is 0.6%, which places Switzerland 20th among Australia's partner countries.

Brazil

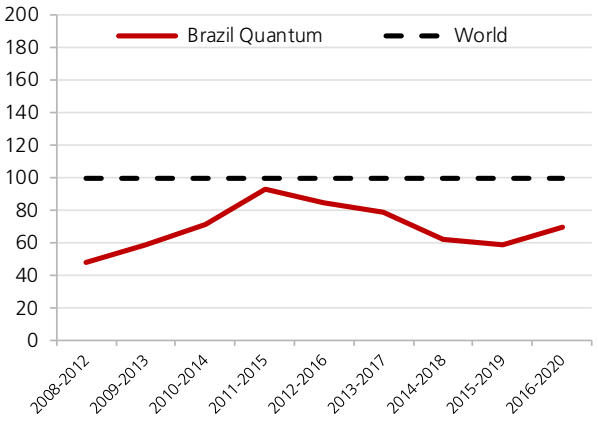
Evolution of the number of quantum publications



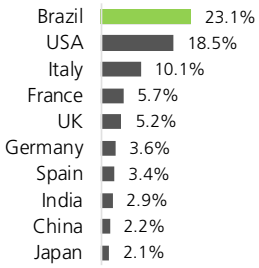
Research profile, 2016–2020



Impact



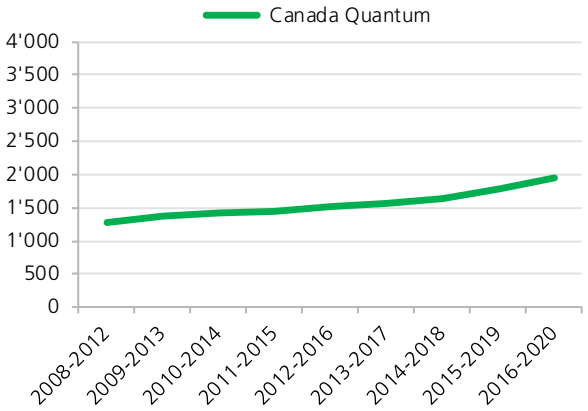
Partnerships, 2016–2020



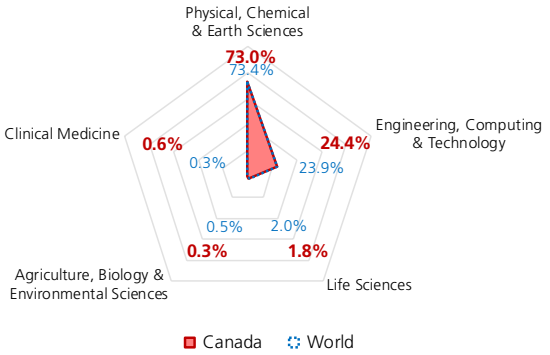
National collaboration comes in first, followed by collaborations with the United States, Italy and France. Its partnership rate with Switzerland is 0.8%, which places Switzerland 20th among Brazil's partner countries.

Canada

Evolution of the number of quantum publications



Research profile, 2016–2020



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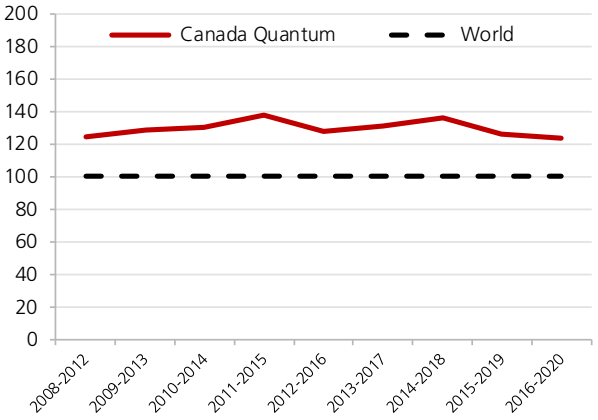
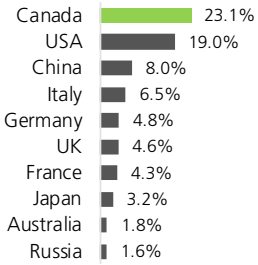


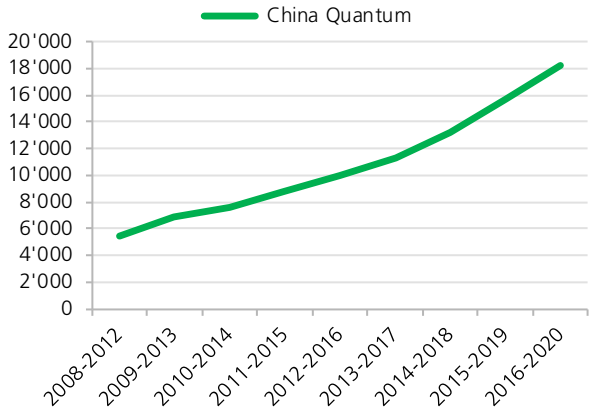
Partnerships, 2016–2020



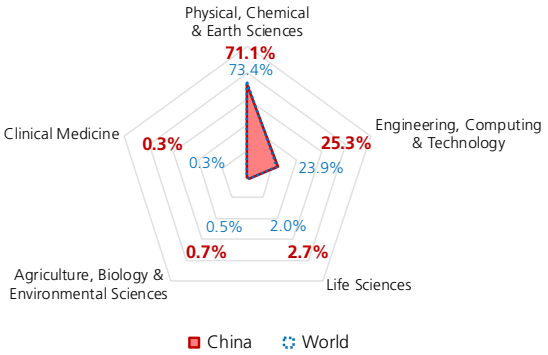
National collaboration comes in first, followed by collaborations with the United States, China and Italy. Its partnership rate with Switzerland is 1.1%, which places Switzerland 15th among Canada's partner countries.

China

Evolution of the number of quantum publications



Research profile, 2016–2020



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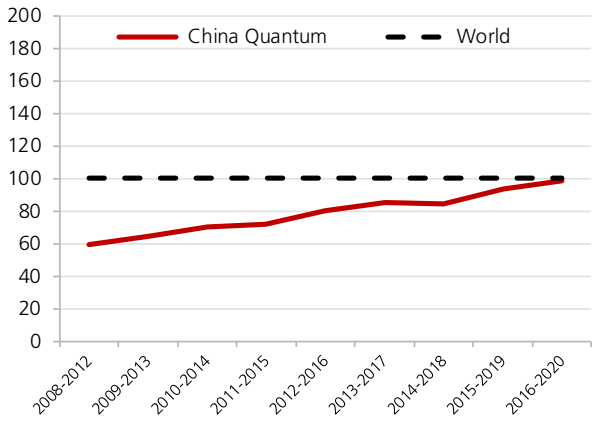
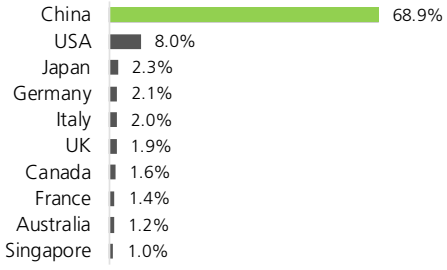


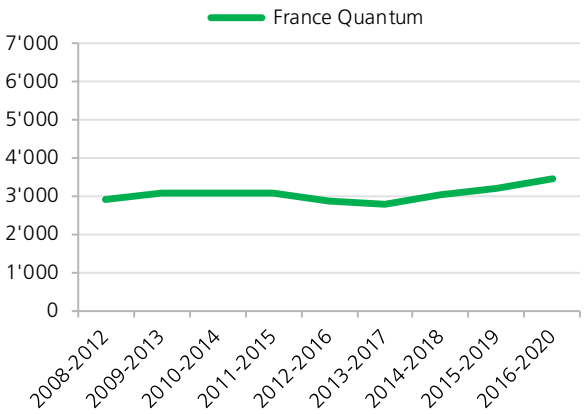
Partnerships, 2016–2020



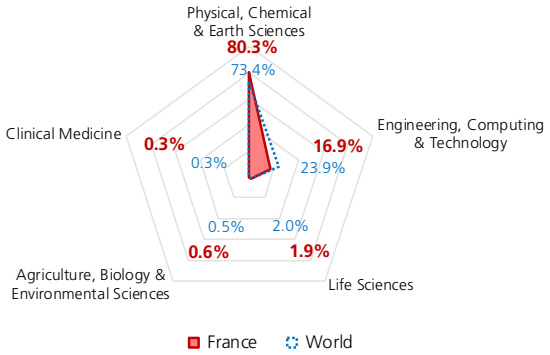
China has a very strong network of national collaboration, followed by partnerships with the US and Japan. Its partnership rate with Switzerland is 0.4%, which places Switzerland 18th among China's partner countries.

France

Evolution of the number of quantum publications



Research profile, 2016–2020



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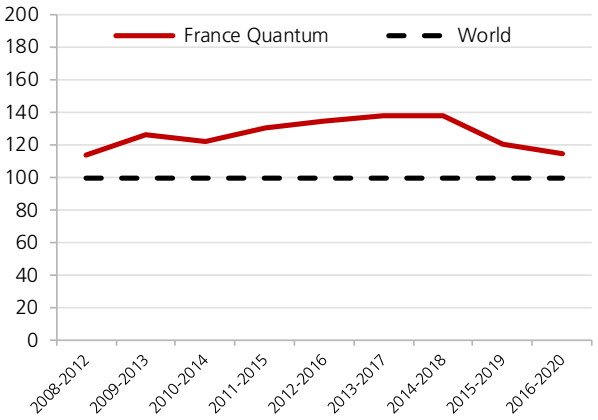
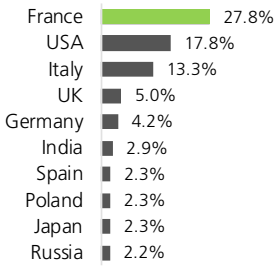


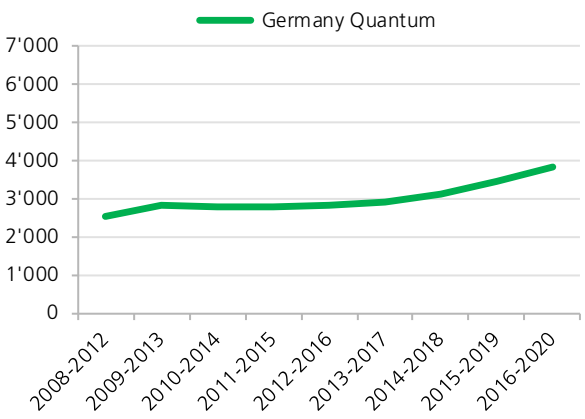
Partnerships, 2016–2020



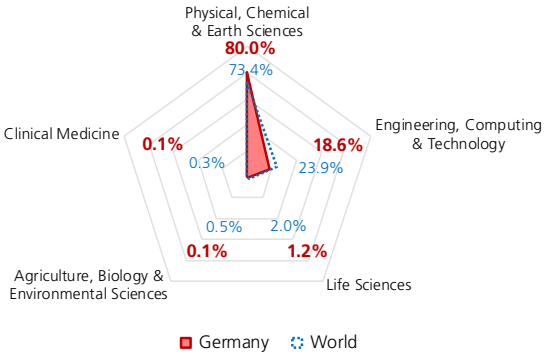
National collaboration comes in first, followed by collaborations with the United States and Italy. Its partnership rate with Switzerland is 1.1%, which places Switzerland 16th among France's partner countries.

Germany

Evolution of the number of quantum publications



Research profile, 2016–2020



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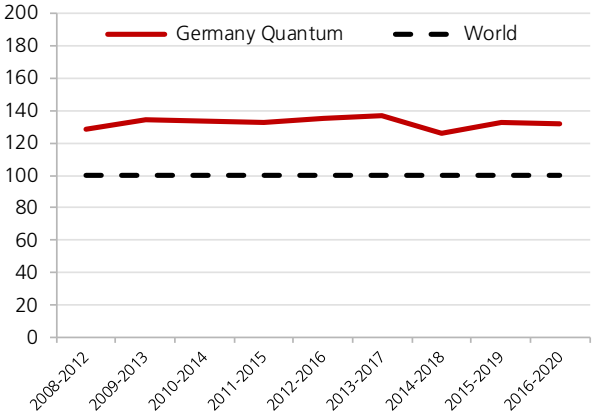
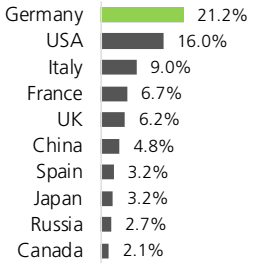


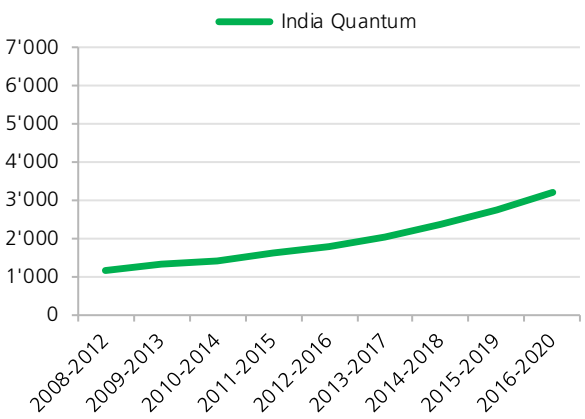
Partnerships, 2016–2020



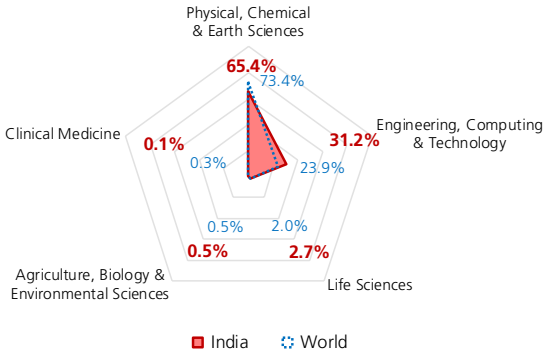
National collaboration comes in first, followed by collaborations with the United States, Italy and France. Its partnership rate with Switzerland is 1.8%, which places Switzerland 11th among Germany's partner countries.

India

Evolution of the number of quantum publications



Research profile, 2016–2020



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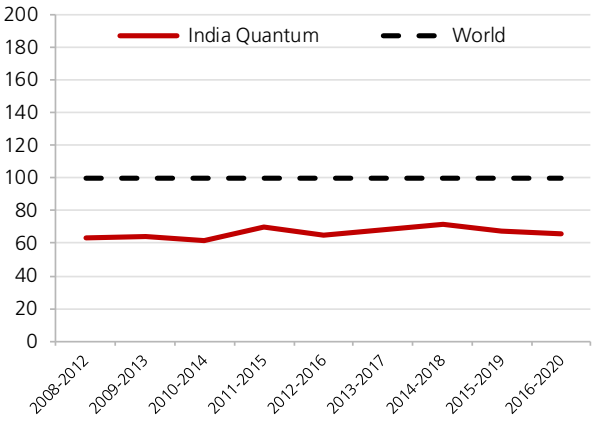
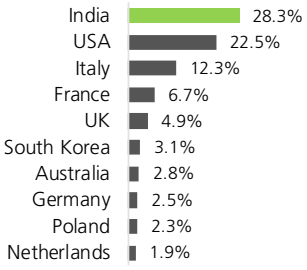


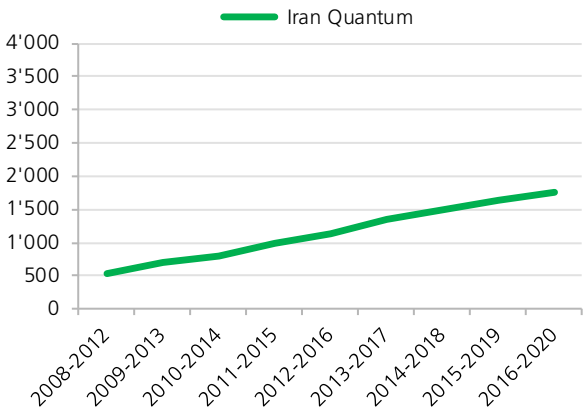
Partnerships, 2016–2020



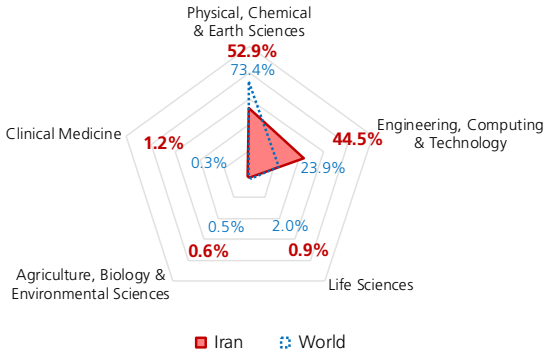
National collaboration comes in first, followed by collaborations with the United States and Italy. Its partnership rate with Switzerland is 0.2%, which places Switzerland 26th among India's partner countries.

Iran

Evolution of the number of quantum publications



Research profile, 2016–2020



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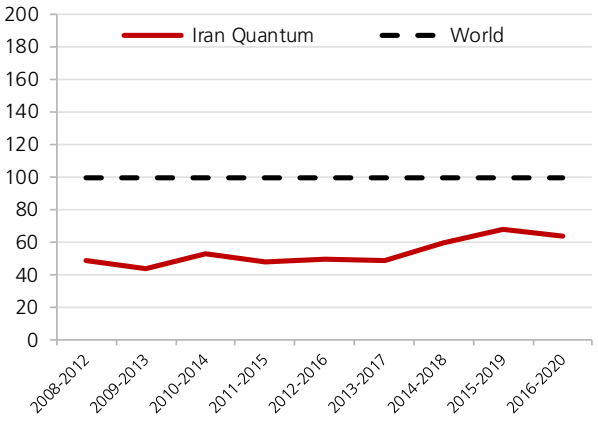
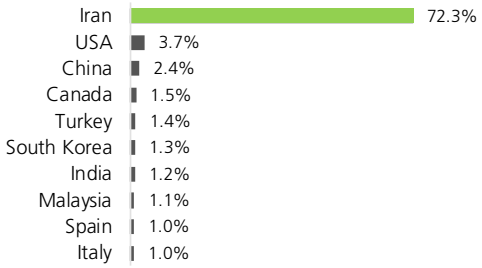


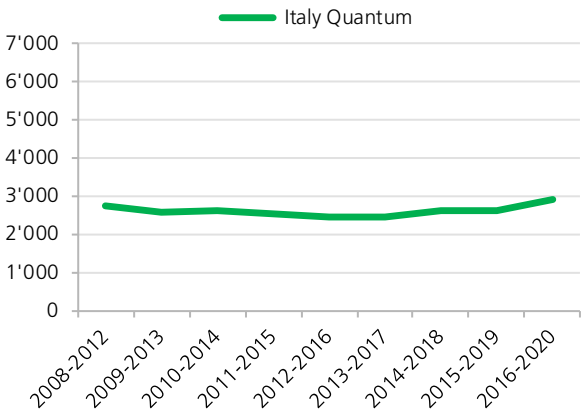
Partnerships, 2016–2020



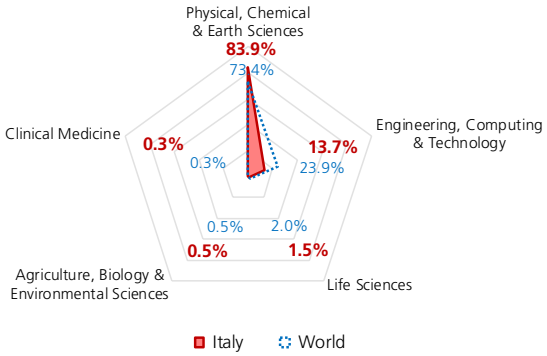
National collaboration comprises a very large share (about 73%), followed by collaborations with the United States, China and Canada. Its partnership rate with Switzerland is 0.7%, which places Switzerland 16th among Iran's partner countries.

Italy

Evolution of the number of quantum publications



Research profile, 2016–2020



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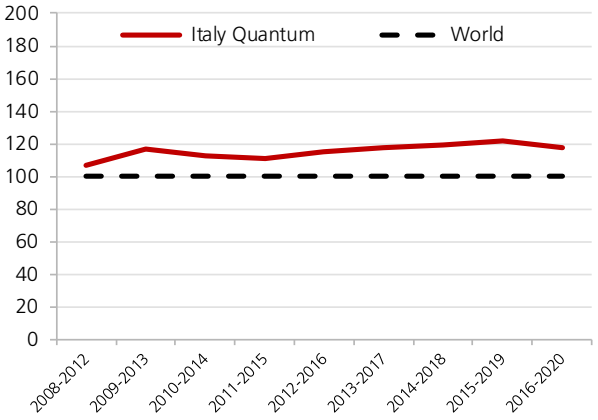
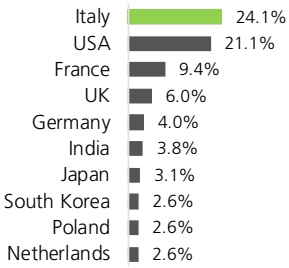


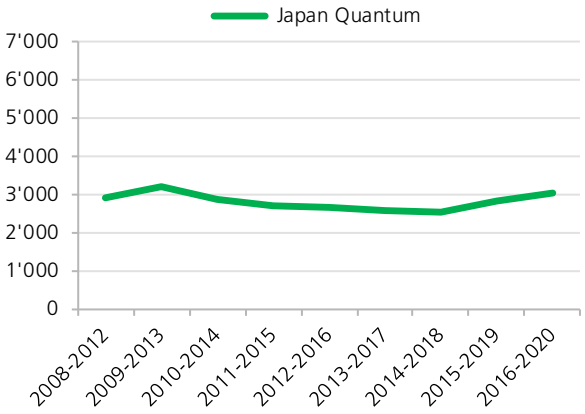
Partnerships, 2016–2020



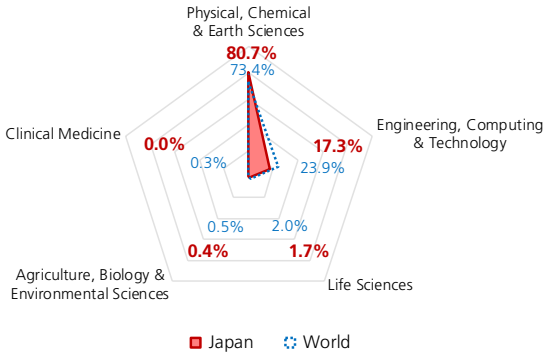
National collaboration comes in first, followed by collaborations with the United States, France and the UK. Its partnership rate with Switzerland is 0.9%, which places Switzerland 18th among Italy's partner countries.

Japan

Evolution of the number of quantum publications



Research profile, 2016–2020



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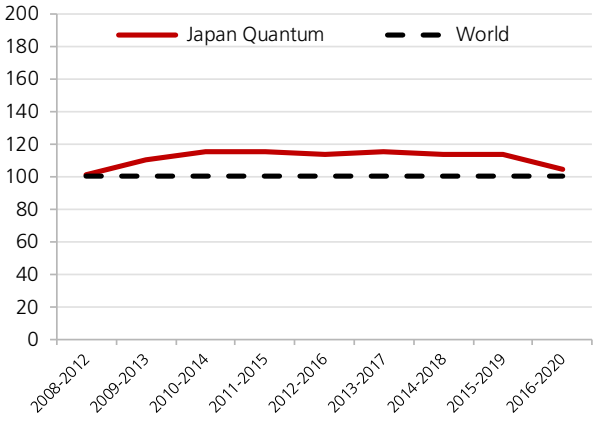
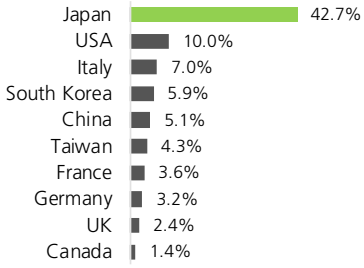


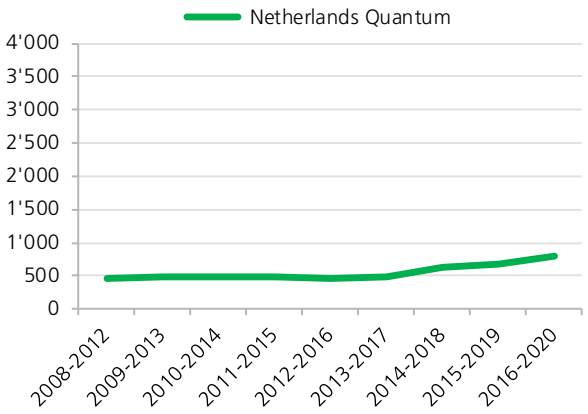
Partnerships, 2016–2020



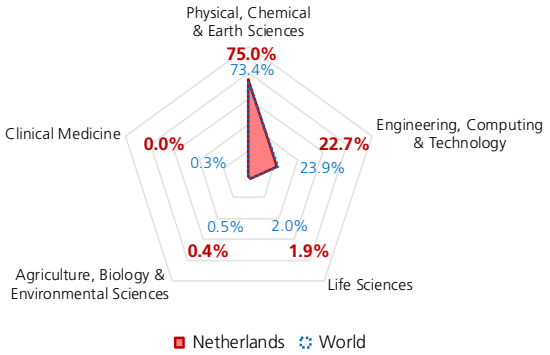
National collaboration comes in first, followed by collaborations with the United States, Italy and South Korea. Its partnership rate with Switzerland is 0.7%, which places Switzerland 17th among Japan's partner countries.

Netherlands

Evolution of the number of quantum publications



Research profile, 2016–2020



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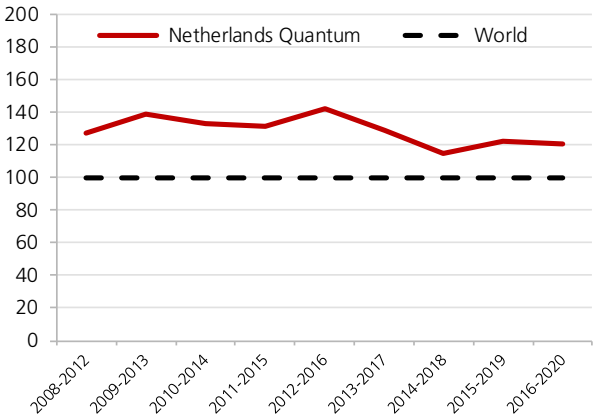
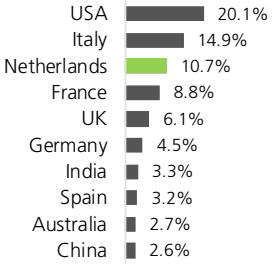


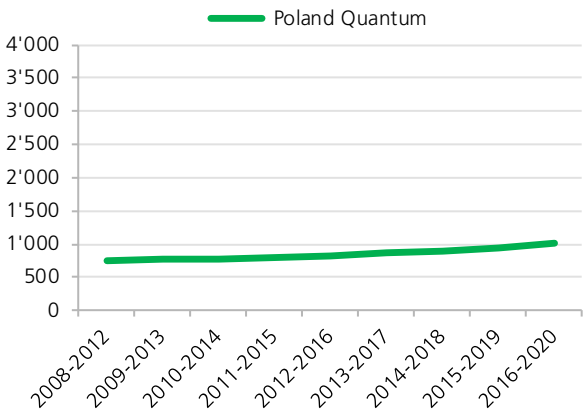
Partnerships, 2016–2020



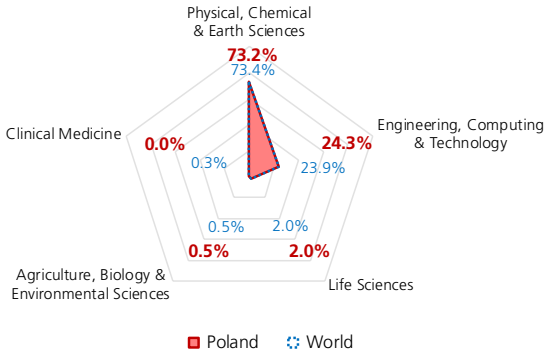
The Netherlands collaborates most with the United States, followed by Italy. National collaboration is only in third place. Its partnership rate with Switzerland is 1.5%, which places Switzerland 15th among the Netherlands' partner countries.

Poland

Evolution of the number of quantum publications



Research profile, 2016–2020



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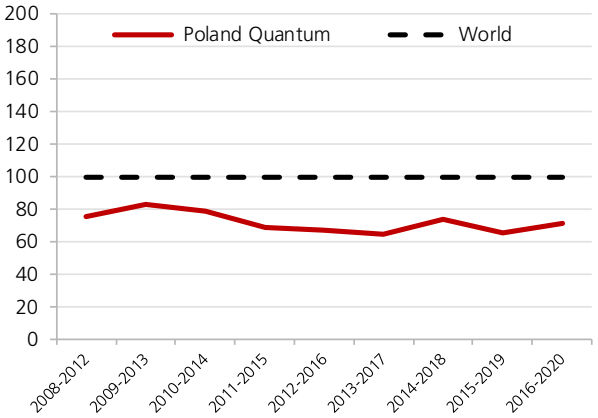
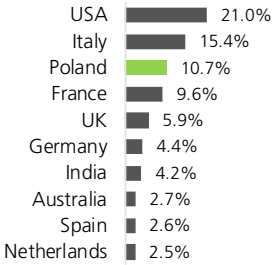


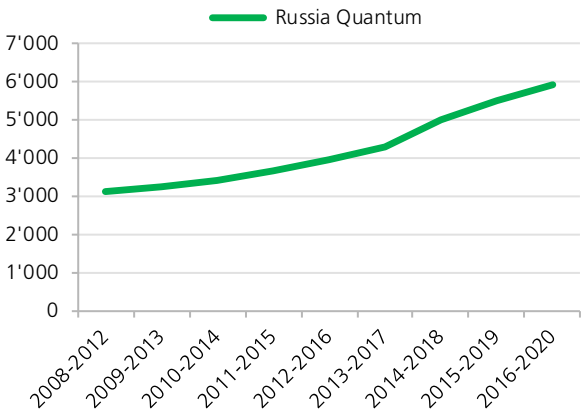
Partnerships, 2016–2020



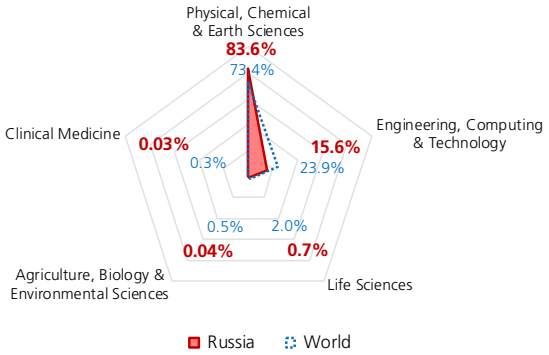
Poland collaborates most with the United States, followed by Italy. National collaboration is only in third place. Its partnership rate with Switzerland is 0.6%, which places Switzerland 19th among Poland's partner countries.

Russia

Evolution of the number of quantum publications



Research profile, 2016–2020



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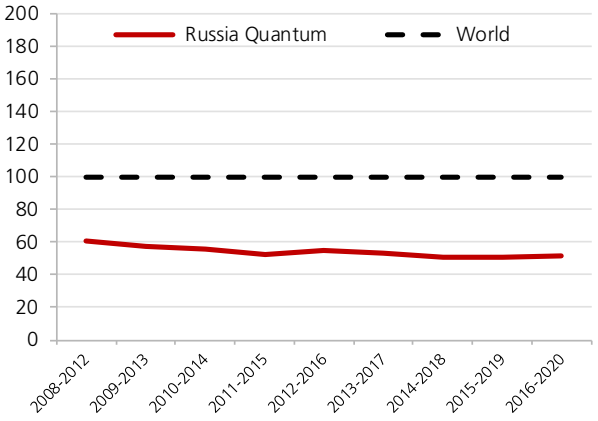
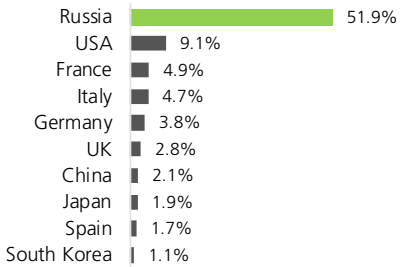


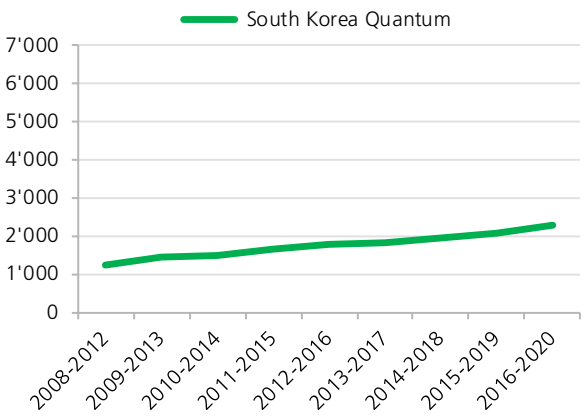
Partnerships, 2016–2020



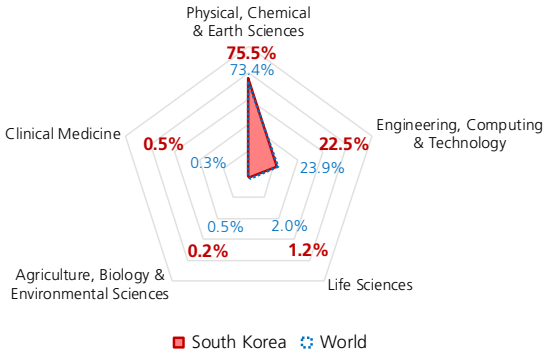
Russia has a strong network of national collaboration, followed by collaborations with the United States, France and Italy. Its partnership rate with Switzerland is 0.5%, which places Switzerland 22nd among Russia's partner countries.

South Korea

Evolution of the number of quantum publications



Research profile, 2016–2020



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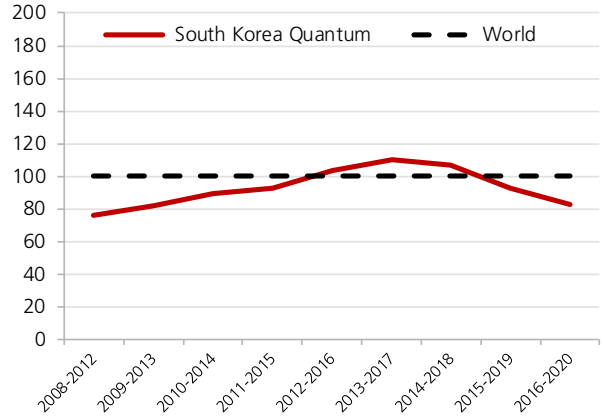
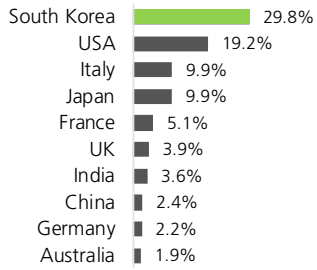


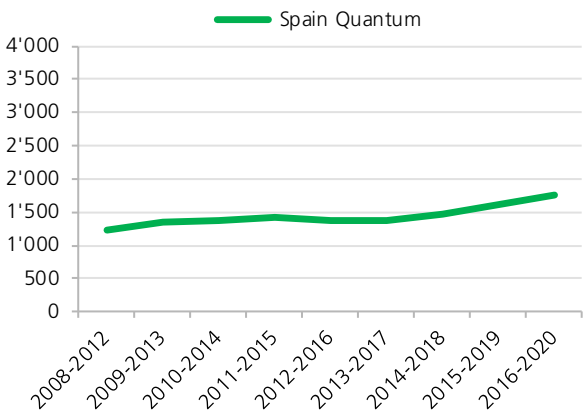
Partnerships, 2016–2020



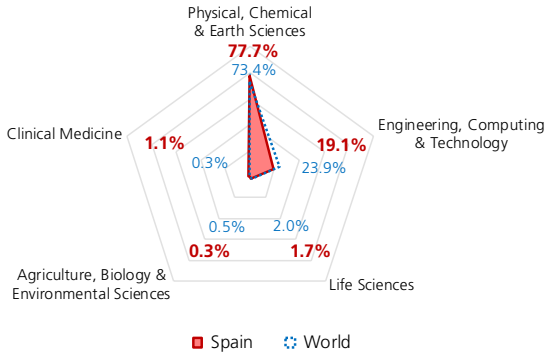
National collaboration comes in first, followed by collaborations with the United States, Italy and Japan. Its partnership rate with Switzerland is 0.2%, which places Switzerland 23rd among South Korea's partner countries.

Spain

Evolution of the number of quantum publications



Research profile, 2016–2020



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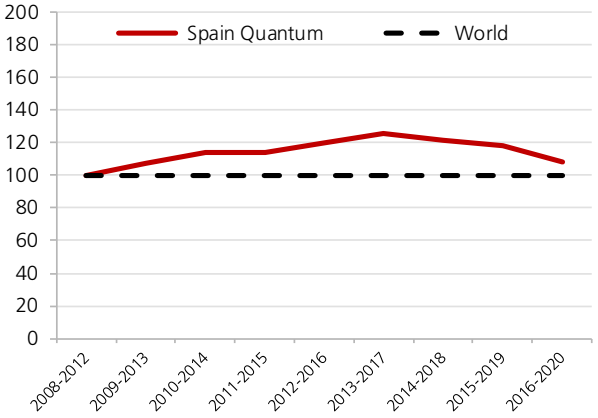
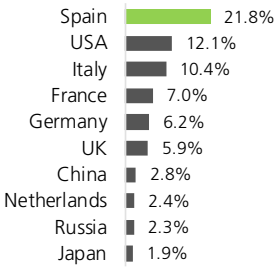


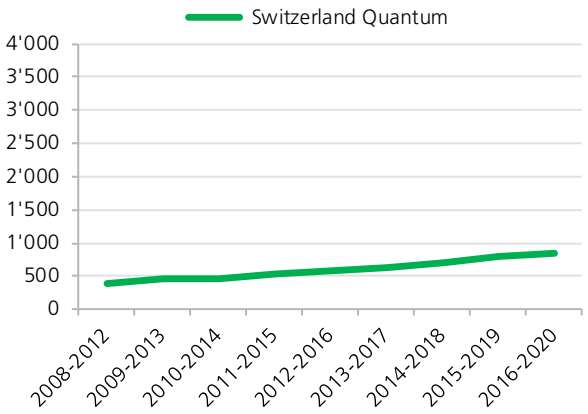
Partnerships, 2016–2020



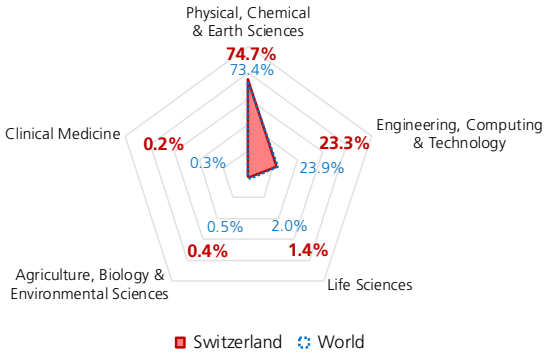
National collaboration comes in first, followed by collaborations with the United States, Italy and France. Its partnership rate with Switzerland is 1.5%, which places Switzerland 14th among Spain's partner countries.

Switzerland

Evolution of the number of quantum publications



Research profile, 2016–2020



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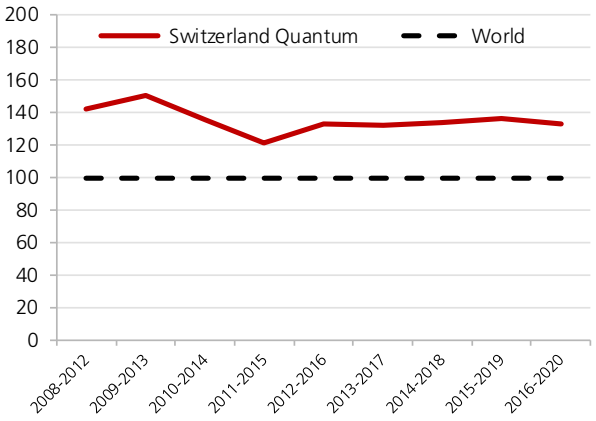
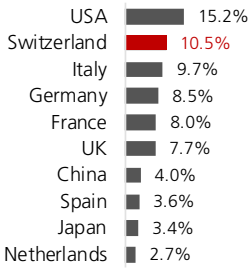


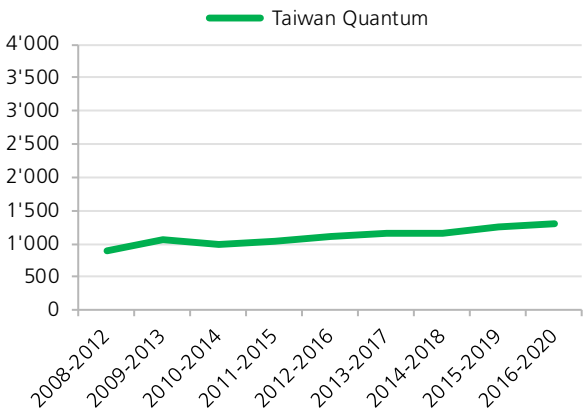
Partnerships, 2016–2020



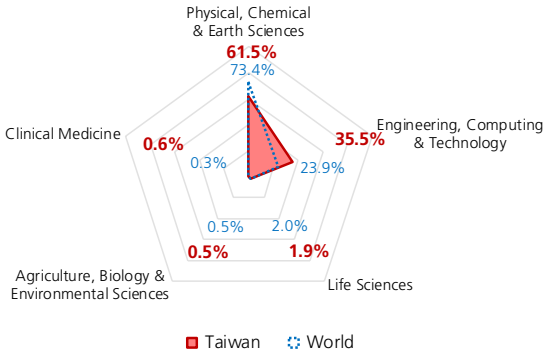
Switzerland collaborates the most with the United States, followed by national collaboration (10.5%) and collaborations with Italy, Germany and France.

Taiwan

Evolution of the number of quantum publications



Research profile, 2016–2020



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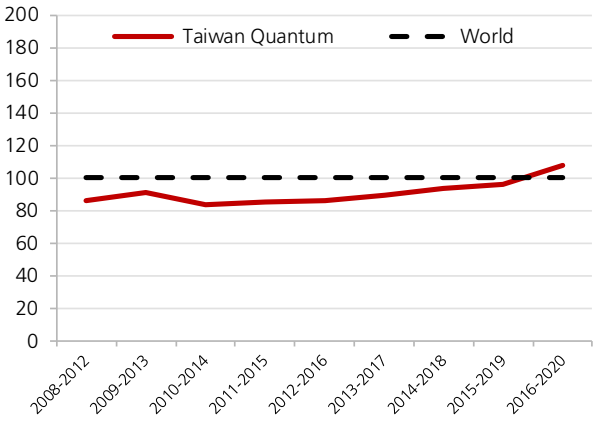
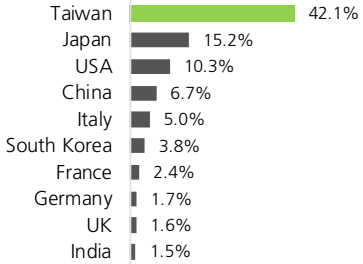


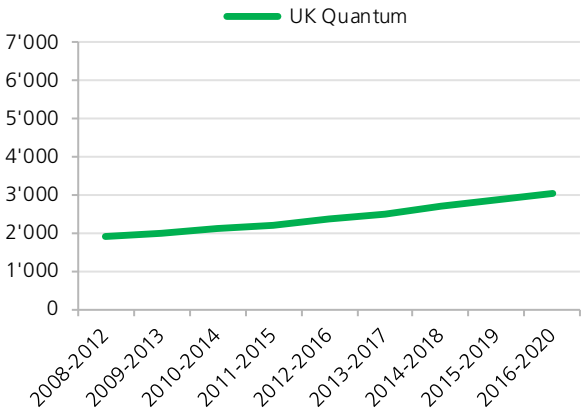
Partnerships, 2016–2020



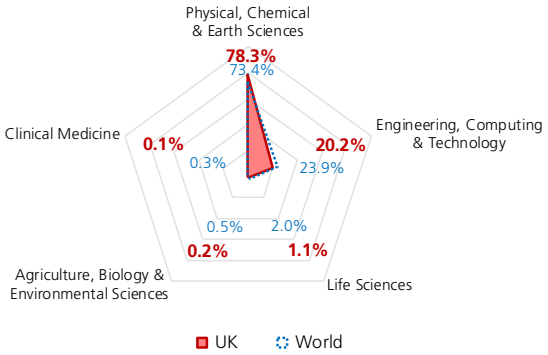
National collaboration comes in first, followed by collaborations with Japan, the United States and China. Its partnership rate with Switzerland is 0.4%, which places Switzerland 18th among Taiwan's partner countries.

UK

Evolution of the number of quantum publications



Research profile, 2016–2020



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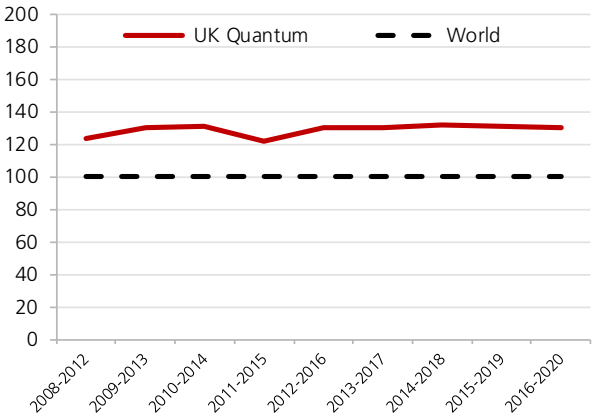
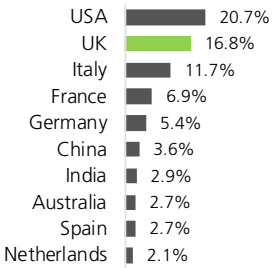


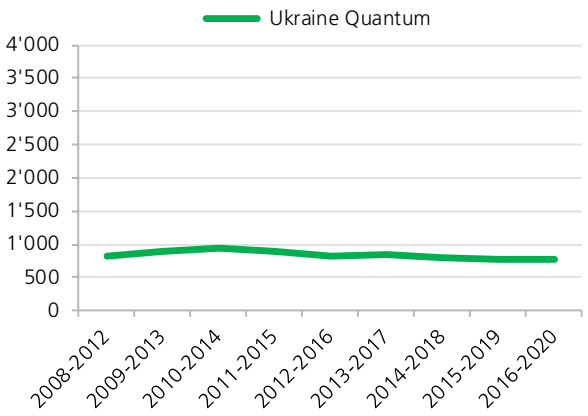
Partnerships, 2016–2020



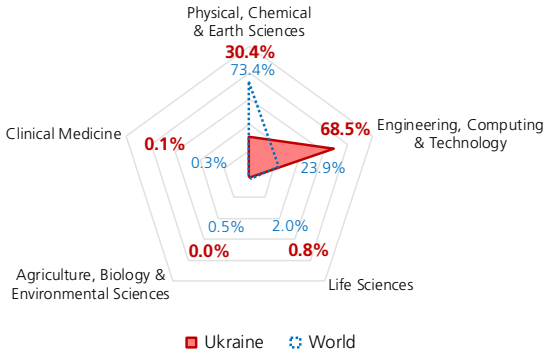
The UK collaborates the most with the United States, followed by national collaboration and collaborations with Italy and France. Its partnership rate with Switzerland is 1.5%, which places Switzerland 16th among the UK's partner countries.

Ukraine

Evolution of the number of quantum publications



Research profile, 2016–2020



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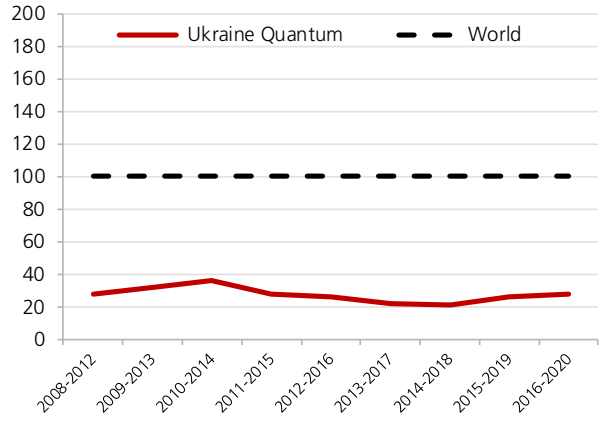
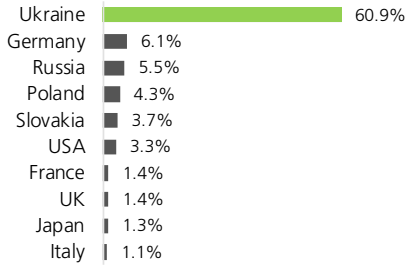


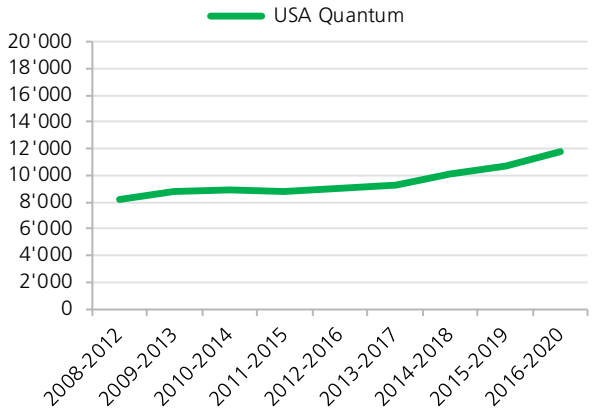
Partnerships, 2016–2020



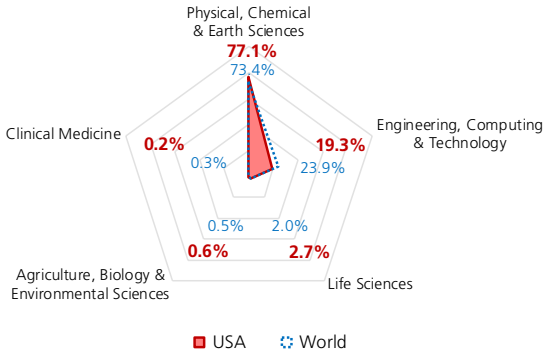
National collaboration comprises a large share, followed by collaborations with Germany, Russia and Poland. Its partnership rate with Switzerland is 0.1%, which places Switzerland 31st among Ukraine's partner countries.

United States

Evolution of the number of quantum publications



Research profile, 2016–2020



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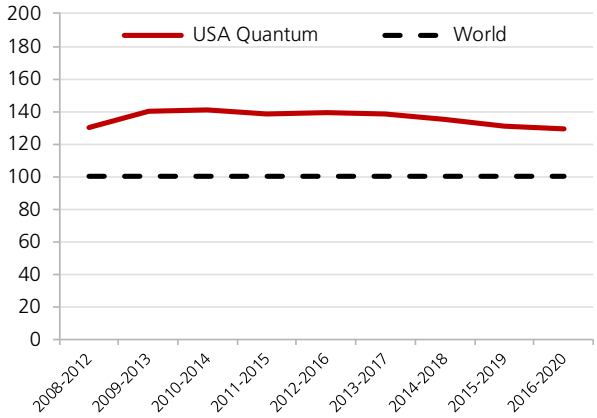
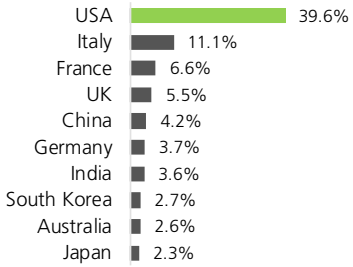


Partnerships, 2016–2020



The United States has a large network of national collaboration (almost 40% of partnerships), followed by Italy, France and the UK. Its partnership rate with Switzerland is 0.8%, which places Switzerland 18th among the United States' partner countries.

B Methods

B.1 Databases

The following databases were used in this report: the *Science Citation Index Expanded (SCIE)*, the *Social Science Citation Index Expanded (SSCIE),* the *Arts & Humanities Citation Index (A&HCI)* and the *Emerging Sources Citation Index (ESCI)* produced by Clarivate Analytics (formerly Thomson Reuters) for the years 2008 to 2020. These databases contain the bibliographical references of articles published in almost 24,000 peer-reviewed scientific journals, most of which have an international readership. Journals are selected by Clarivate Analytics according to an evaluation process.[2] Consequently, this bibliometric analysis does not take account of articles which are not recorded in this database, or articles printed in general-interest journals, books or at conferences.

B.2 Volume of publications

One of the key methodological issues is the method used to count publications. A scientific article usually has multiple authors, can contain one or more institutional addresses (institutional affiliation of the researchers), and authors can come from one or more countries. Attributing this article to a single author, institution or country would be unfair to the other authors, countries or institutions.

Bibliometric experts generally use one of two methods for counting scientific publications:

- **Full address counting** in which each address referred to in the article is counted as one unit. If an article has only one author who is affiliated to one institution in one country, it will be counted only once. If multiple institutions were involved (even with the same authors), the number of times that an article is counted will match the number of institutional addresses appearing on it.
- **Fractional address counting** divides each article by the number of institutional addresses indicated by its authors, so that the sum of the fractions relating to each publication is 1. In the case of multiple institutions or countries, an article will be counted once, but a share of this article (the relevant percentage) will be assigned to each institution and country.

In order to obtain comparable data, it is vital that scientific production is classified in the same way for all institutions and all countries. One way of doing this is to classify research activities by fields and sub-fields of research, so they can then be compared on the basis of their contribution to each of these fields of research. This report uses the Current Contents (CC) classification system. This divides research activities into seven research fields (Engineering, Computing & Technology; Physical, Chemical & Earth Sciences; Agriculture, Biology & Environmental Sciences; Life Sciences; Clinical Medicine; Social & Behavioural Sciences; and Arts & Humanities), which are in turn subdivided into 109 sub-fields (see list below).

[2] See journal selection process: https://clarivate.com/essays/journal-selection-process/

List of the seven research fields and 109 research sub-fields

Engineering, Computing & Technology

AI, Robotics & Automatic Control
Aerospace Engineering
Chemical Engineering
Civil Engineering
Computer Science & Engineering
Electrical & Electronics Engineering
Engineering Management / General
Engineering Mathematics
Environmental Engineering & Energy
Geological, Petroleum & Mining Engineering
Information Technology & Communications Systems
Instrumentation & Measurement
Materials Science & Engineering
Mechanical Engineering
Metallurgy
Nuclear Engineering
Optics & Acoustics

Physical, Chemical & Earth Sciences

Applied Physics / Condensed Matter / Materials Science
Chemistry
Earth Sciences
Inorganic & Nuclear Chemistry
Mathematics
Multidisciplinary in Physical, Chemical & Earth Sciences
Organic Chemistry / Polymer Science
Physical Chemistry / Chemical Physics
Physics
Space Science
Spectroscopy / Instrumentation / Analytical Sciences

Agriculture, Biology & Environmental Sciences

Agricultural Chemistry
Agriculture / Agronomy
Animal Sciences
Aquatic Sciences
Biology
Biotechnology & Applied Microbiology
Entomology / Pest Control
Environment / Ecology
Food Science / Nutrition
Multidisciplinary in Agriculture, Biology & Environmental Sciences
Plant Sciences
Veterinary Medicine / Animal Health

Life Sciences

Animal & Plant Science
Biochemistry & Biophysics
Cardiovascular & Hematology Research
Cell & Developmental Biology
Chemistry & Analysis
Endocrinology, Nutrition & Metabolism
Experimental Biology
Immunology
Medical Research, Diagnosis & Treatment
Medical Research, General Topics
Medical Research, Organs & Systems
Microbiology
Molecular Biology & Genetics
Multidisciplinary in Life Sciences
Neurosciences & Behavior
Oncogenesis & Cancer Research
Pharmacology & Toxicology
Physiology

Clinical Medicine

Anesthesia & Intensive Care
Cardiovascular & Respiratory Systems
Clinical Immunology & Infectious Disease
Clinical Psychology & Psychiatry
Dentistry / Oral Surgery & Medicine
Dermatology
Clin. Endocrinology, Metabolism & Nutrition
Environmental Medicine & Public Health
Gastroenterology & Hepatology
General & Internal Medicine
Health Care Sciences & Services
Hematology
Neurology
Nursing
Oncology
Ophthalmology
Orthopedics, Rehabilitation & Sports Medicine
Otolaryngology
Pediatrics
Clin. Pharmacology / Toxicology
Radiology, Nuclear Medicine & Imaging
Reproductive Medicine
Research / Laboratory Medicine & Medical Technology
Rheumatology
Surgery
Urology & Nephrology

Social & Behavioral Sciences

Anthropology
Communication
Economics
Education
Environmental Studies, Geography & Development
Law
Library & Information Sciences
Management
Political Science & Public Administration
Psychiatry
Psychology
Public Health & Health Care Science
Rehabilitation
Social Work & Social Policy
Sociology & Social Sciences

Arts & Humanities

Archaeology
Art & Architecture
Classical Studies
General
History
Language & Linguistics
Literature
Performing Arts
Philosophy
Religion & Theology

B.3 Impact (relative citation indicator)

A scientific publication usually cites other publications on which it draws. Impact is calculated by the number of citations received per publication. In principle, the more a publication is cited, the greater the impact it is considered to have. It can be concluded that the absolute number of citations is an adequate measurement of impact. This is true within a field of research, but not between different fields. As the number of citations depends on publication and citation practices, which can vary considerably according to the field of research, a more sophisticated and standardised indicator is needed to allow individual fields to be compared fairly with one another. The absolute number of citations received by publications is set against the world average of citations per publication for each research field, and then this relative indicator is standardised on a scale of 0 to 200, where 100 represents the world average.

A minimum of 50 publications per year are required in order to calculate this indicator.

B.4 Partnerships

Only articles written collaboratively are taken into account for this indicator. Partnerships are determined by the number of partnership pairs between the institutional addresses of authors featured on a single publication. For this indicator, publications are counted using the *full counting* method, which means that an article written collaboratively is attributed to each institutional address and to each contributing country. The number of partnerships does not therefore designate a number of articles, but the frequency with which a country is involved in collaboration. The counting of addresses allows us to calculate both national collaborations and those with other countries. The results (national or international partnerships) are expressed as a percentage of a country's total partnerships.

C References

SERI 2022 'Scientific publications in Switzerland, 2008–2020: A bibliometric analysis of scientific research in Switzerland'. This study is available on the SERI website under Publications & Services/ Publications, or at https://www.sbfi.admin.ch/dam/sbfi/en/dokumente/webshop/2022/pub-08-20.pdf.download.pdf/analyse-bibliometrique_2022_d.pdf