



Sino-Danish Scientific Collaborations in Recent Decades

A report based on scientific publications indexed in Scopus

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\ ABBREVIATIONS

EU	European Union
US	United States of America
CN	People's Republic of China
UK	United Kingdom
DK	Denmark
FWCI	Field-Weighted Citation Impact
ASJC	All Science Journal Classification

1. Introduction

This report aims to provide an overview of the scientific collaboration between Denmark and China in the context of global scientific collaboration. The report is based on publications indexed in *Scopus* from 1990 to 2021 and mainly focus on the data from 2016 to 2021. In this report, 27 areas of study are covered and the classification method is Scopus' default scheme (ASJC – All Science Journal Classification). Based on the data of scientific publications, we analyzed the collaboration trends, quality and the mutual dependency of the collaboration between China and Denmark. Through this report, we hope to provide some useful information for future Sino-Danish scientific collaboration development.

2. Data and Methods

2.1 Scopus & Scival

There are two main indicators in this report, one is the number of scientific publications, the other is the citation data of the scientific publications. The data comes from the Scopus and Scival databases.

Scopus is the world biggest abstract and citation database. The journals indexed in Scopus are all professional journals reviewed by authoritative experts in the industry. So far there is more than 40,000 journals indexed in Scopus. Scival is a scientific research data management and analysis platform in which the data source is aligned with Scopus. In this report, we base our analysis on all the 538,622 publications, which has at least one author from Denmark (1990 – 2021) and similarly the 8,365,524 publications with at least one author from China (1990-2021). The types of publications include articles, reviews and conference paper.

2.2 Classification of publications in 27 areas of research in Scopus

In this report, we used the default classification scheme of publications in Scopus and Scival. The major 27 areas are as below:

- Engineering
- Physics and Astronomy
- Medicine
- Biochemistry, Genetics and Molecular Biology
- Physics and Astronomy
- Medicine
- Environmental Science
- Agricultural and Biological Science
- Materials Science
- Energy
- Neuroscience
- Decision Sciences
- Economics, Econometrics and Finance
- Health Professions
- Dentistry
- Chemistry
- Computer Science
- Earth and Planetary Sciences
- Chemical Engineering
- Mathematics
- Immunology and Microbiology
- Multidisciplinary
- Social Sciences
- Business, Management and Accounting
- Pharmacology, Toxicology and Pharmaceutics
- Psychology
- Arts and Humanities
- Nursing
- Veterinary

2.3 Methods

All publications with at least one author from Denmark and one author from another country will be treated as international publications of Denmark. All publications with at least one author from China (Mainland China) and one author from Denmark will be treated as Sino-Danish publications. Publications with authors only from one country will be treated as domestic publications.

For all the publications, bilateral collaborations (publications only with authors from China and authors from Denmark) and multinational collaborations (publications with authors from China, Denmark and other countries) are separated in this report.

Field-Weighted Citation Impact (FWCI) is used as an important indicator in this report to compare the quality of publications. Under normal conditions, citation data of a publication is seen as the value of this publication. This data keeps growing along with the time and it is area-related. Different area has different citation habits. Therefore, we chose FWCI (Field-Weighted Citation Impact) as the indicator to normalize the variance between different areas. The FWCI data source is from Scival and its classification method of areas is aligned to Scopus (27 areas as above).

3. Results

3.1 Trend of Sino-Danish Scientific Collaboration

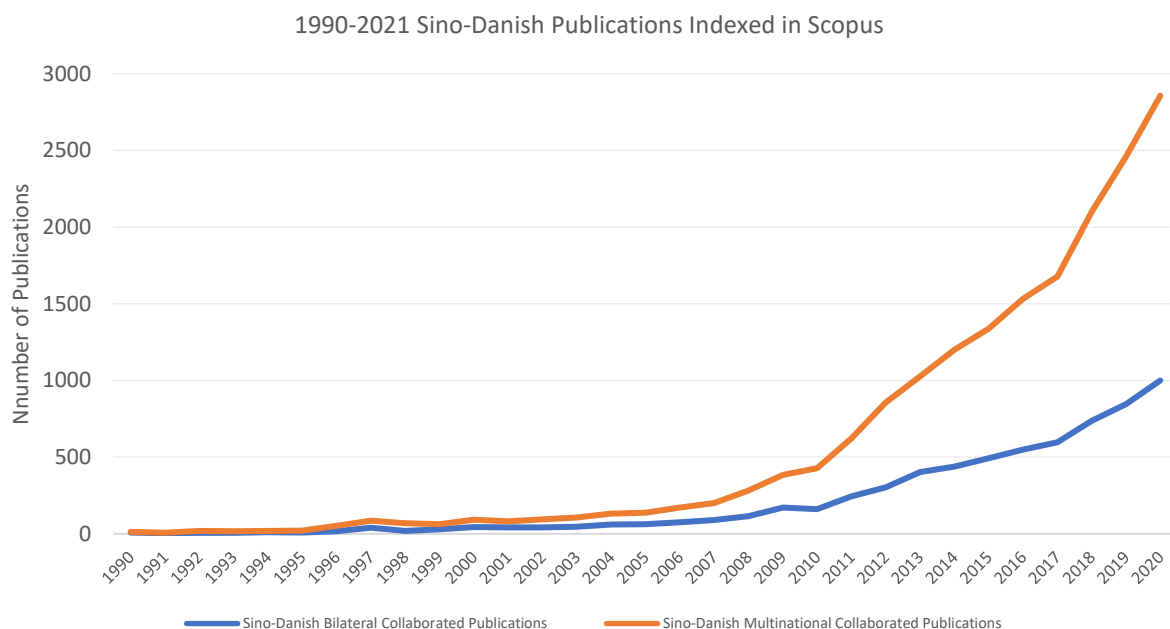


Figure 1. 1990-2021 Trend of Sino-Danish publications indexed in Scopus

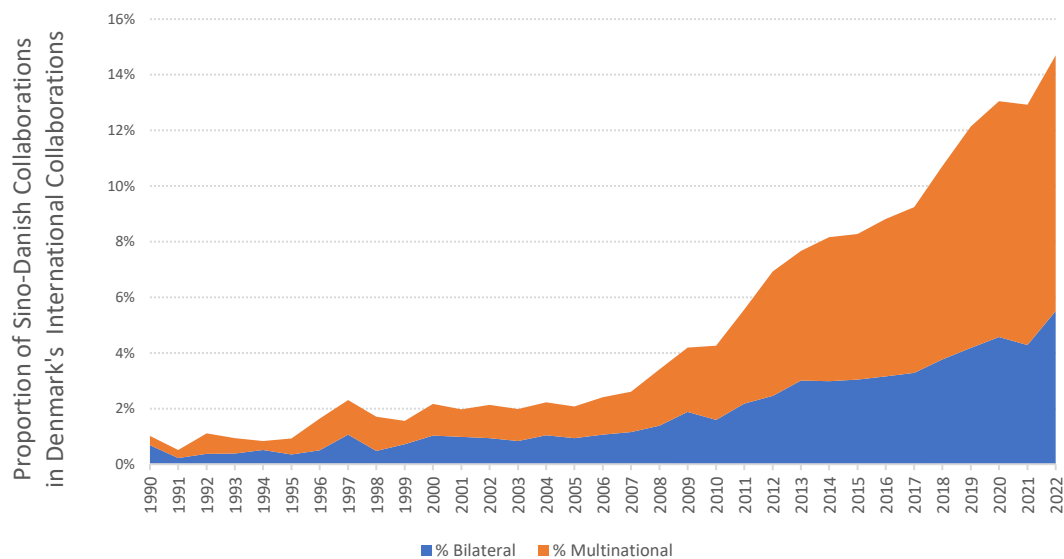


Figure 2. Proportions of Sino-Danish bilateral and multinational publications in Denmark's annual international collaborated publications

Both bilateral and multinational Sino-Danish collaborations are following an exponential growing trend from 1990 to 2021. The growth of multinational collaborations is at a higher rate. In 2021, the proportion of total Sino-Danish collaborations has reached 14% of Denmark 2021 total international collaborations. For Sino-Danish bilateral collaborations, it has reached 4.9% of Denmark's 2021 total international collaborations.

3.2 Domestic Publications in Denmark and China

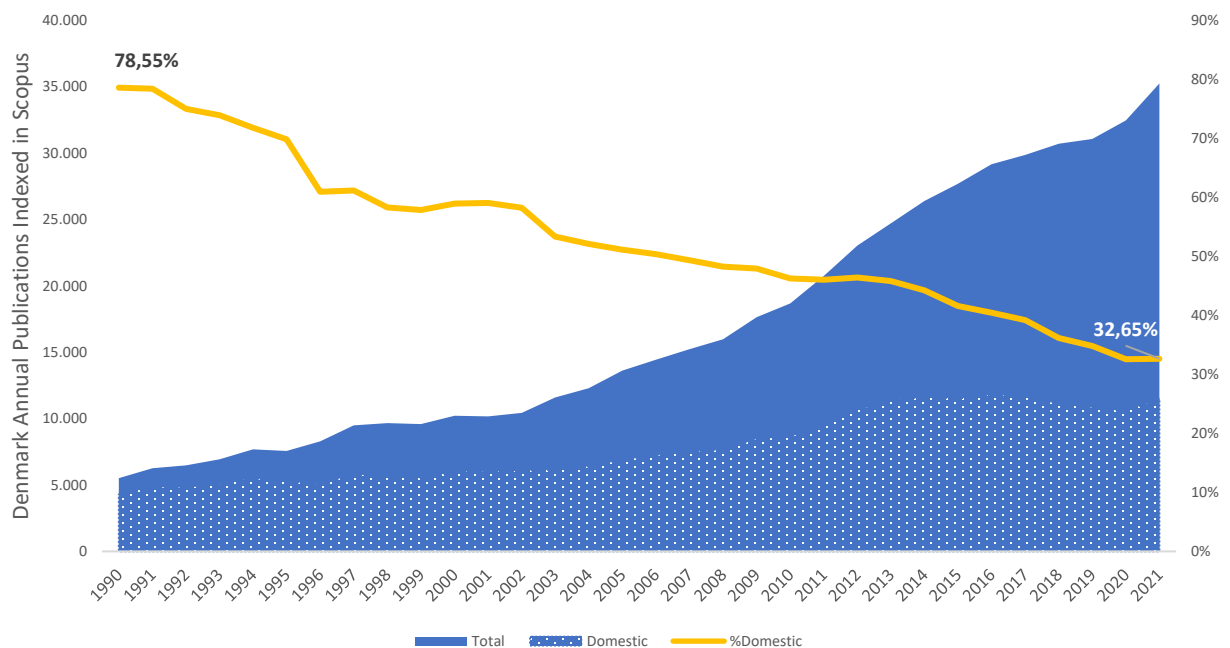


Figure 3. Annual count of Denmark total and domestic (no international co-author) research publications indexed in Scopus and the percentage of domestic publications.

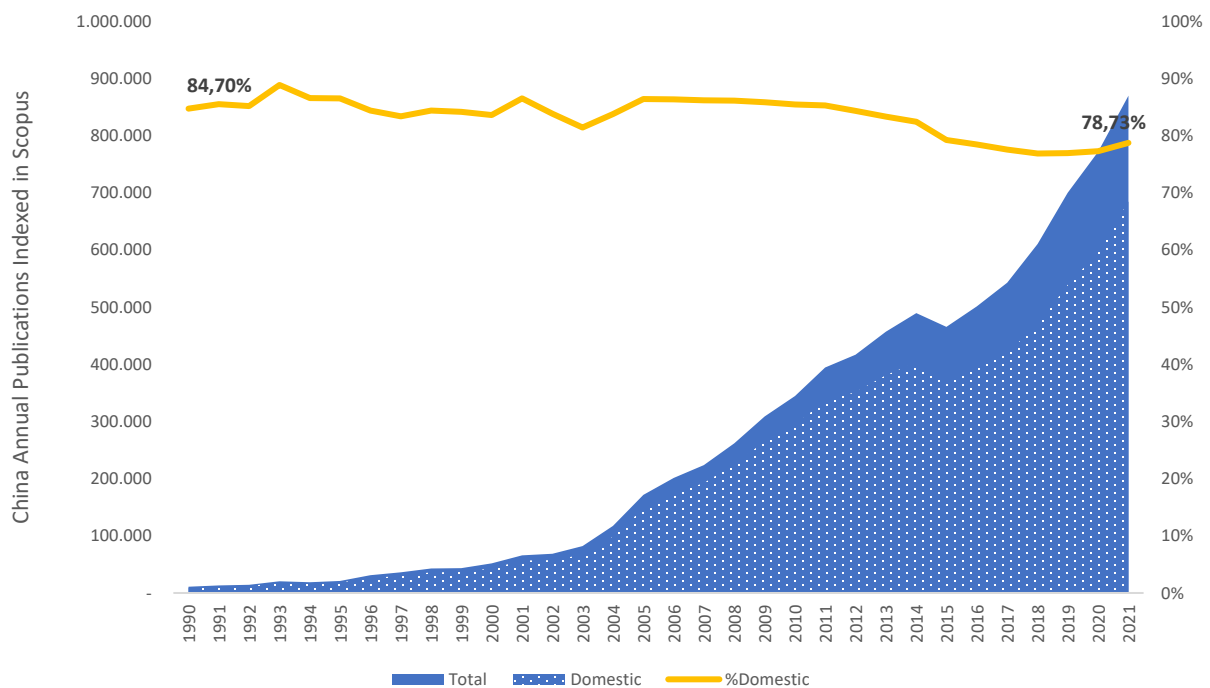
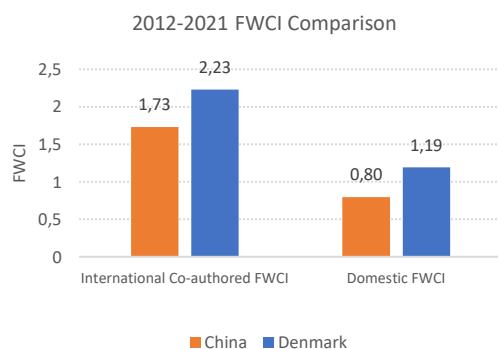


Figure 4. Annual count of China total and domestic (no international co-author) research publications indexed in Scopus and the percentage of domestic publications.

Both countries' gross publication outputs have increased annually during 1990 to 2021. The 2021 Denmark gross number of publications is 6.93 times of the number of 1990. After separated the domestic publications (publications with no international co-author) and internationally collaborated publications, it can be seen that Denmark's scientific publication is more and more driven by international collaboration. The proportion of international collaboration reached 67% in 2021 in Denmark country publications, while domestic publications dropped to 33%.

On the other side, China has a different pattern in the increase of total publications. Since 2002, China's total publications has an exponential rise from a very low volume and it is more driven by its domestic output. In 2021, China has reached a huge increase of 77 times growth compared to 1990's gross number which can hardly be completely absorbed by international collaborations. So far, China keeps a domestic rate of around 78% in the gross publications.



If we compare the Field-Weighted Citation Impact (FWCI) of China and Denmark's publications, we see that Denmark outweighs China in the quality of both international publications and domestic publications. For the period 2012-2021, China has reaches 0.8 FWCI in domestic publications, which is below the world average score, while Denmark keeps at around 1.2 FWCI in domestic publications.

Figure 5. Comparison of FWCI between Denmark and China in international publications and domestic publications

3.3 Ranking of International Scientific Research Partner of Denmark

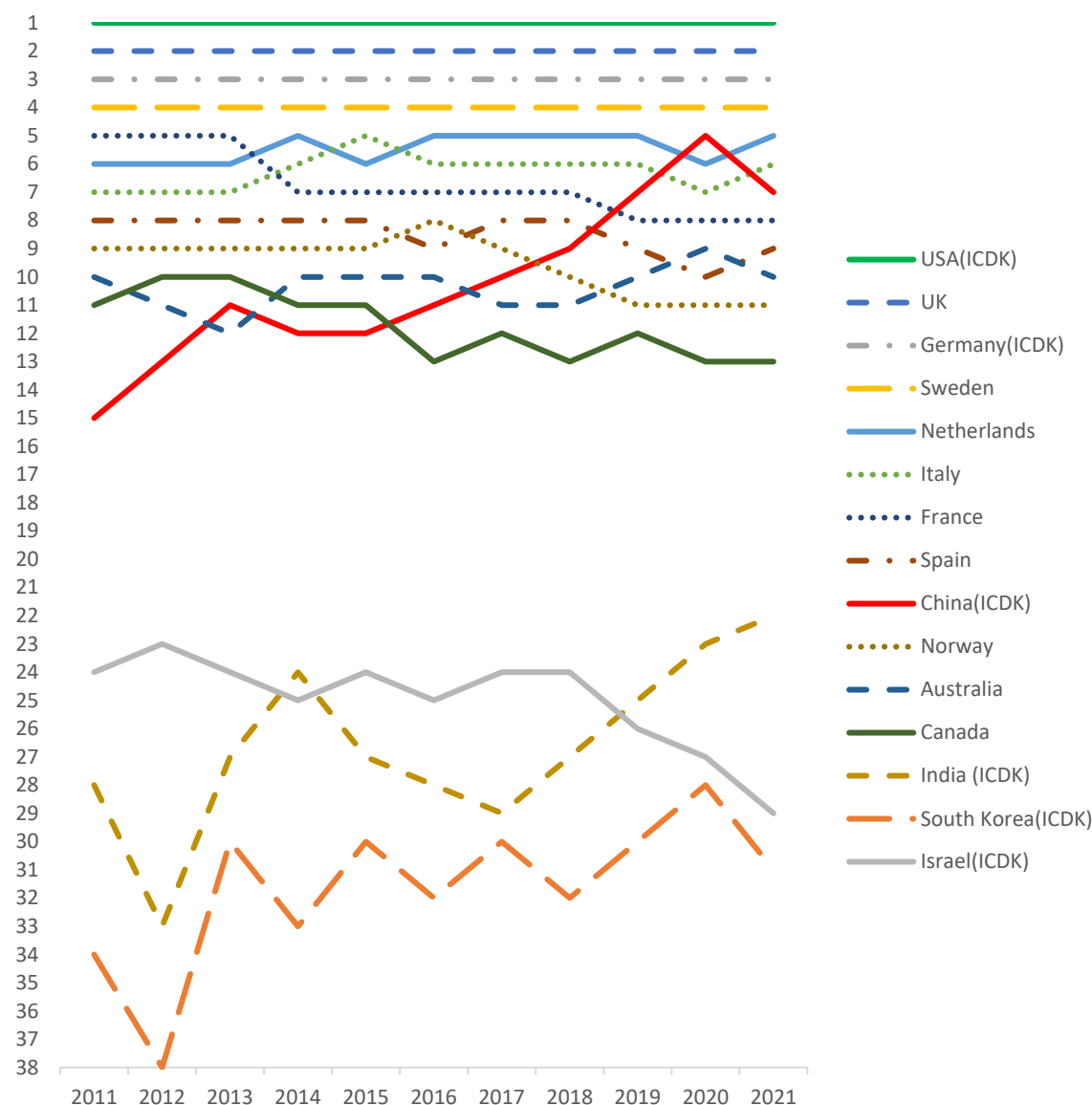


Figure 6. Ranking of Denmark's international partners from 2011 to 2021

Collaboration between China and Denmark increased from 7 co-authored publications in 1990 to more than 3000 publications in 2021, which is almost 8.5% of Denmark's total output and nearly 13% in Denmark's total international collaboration output.

Denmark has a rather firm structure of international scientific research partnership. USA, UK, Germany and Sweden have been the top 4 for several decades and have taken a huge proportion in Denmark's overall international collaboration. The number of US-Denmark co-authored publications is 2.2 times of the Sino-Danish co-authored publications in 2021, while number of UK-Denmark in 2021 is nearly 2 times of the Sino-Danish collaborations.

Other EU countries (Netherlands, France, Italy, Norway, Spain) all have a stable research collaboration with Denmark from 2011 to 2021. China, for the first time, became one of the Denmark's top 10 research partnership in 2017, and reached top 5 in 2020. The importance of China as a scientific research partnership is rising, but so far Denmark is more dependent on its own historical partnership structure of multinational scientific collaboration.

3.4 Sino-Danish Collaborations in 27 Areas

3.4.1 Number of Sino-Danish Collaborations in 27 Areas from 2016 to 2021

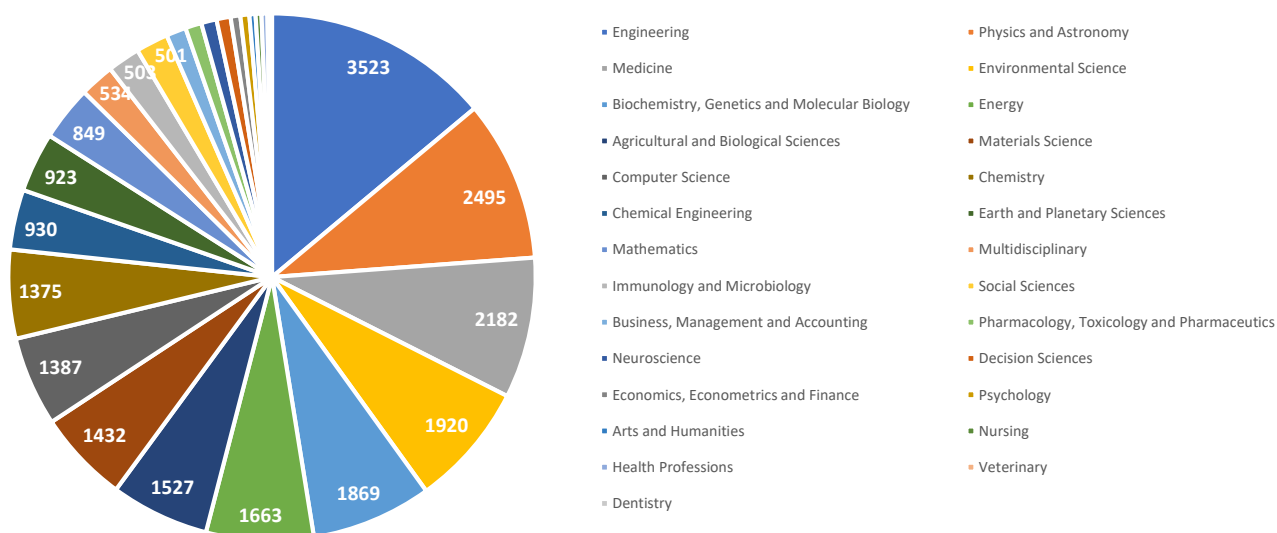


Figure 7. Sino-Danish collaborations in 27 areas from 2016 to 2021

From 2016 to 2021, Denmark has collaborated with China in all the 27 areas. Sino-Danish collaboration has the most output (3523) in Engineering area from 2016 to 2021. Ranked by number of co-authored publications, the top 5 areas are Engineering, Physics and Astronomy, Medicine, Environmental Science, Biochemistry, Genetics and Molecular Biology.

3.4.2 Denmark's Dependency on Chinese Partners in 27 Areas

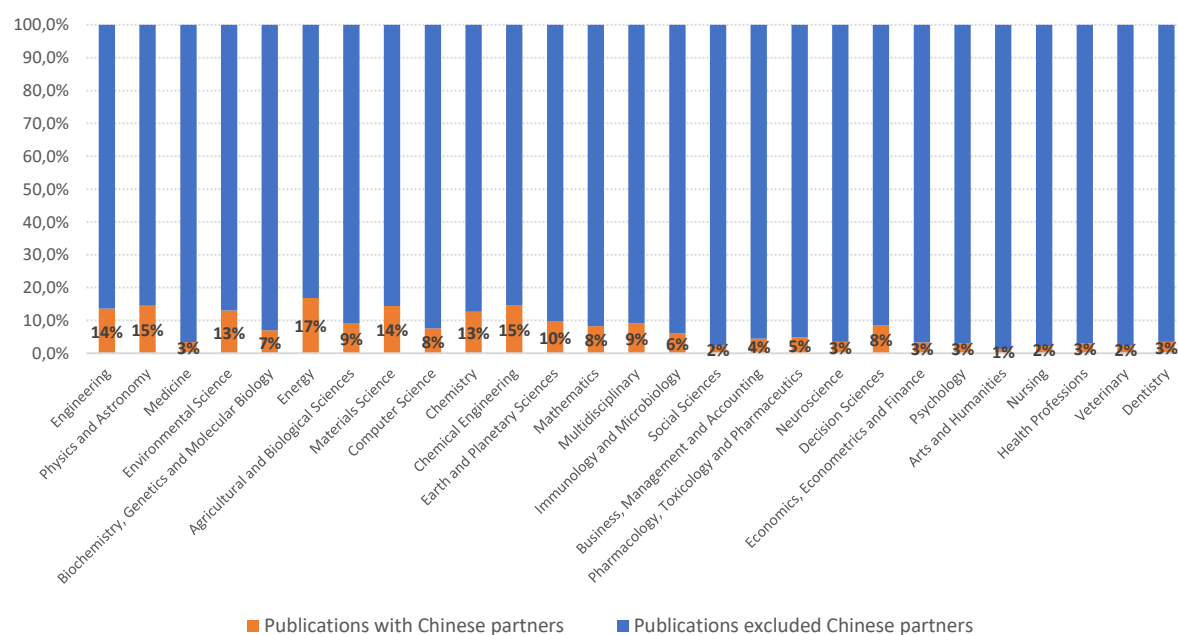


Figure 8. Percentage of publications with Chinese partners in 27 areas from 2016 to 2021

There are seven areas, where the Sino-Danish publications account for more than 10% of the total publications. These areas are Engineering (13.6%), Physics and Astronomy (14.5%), Environmental Science (12.7%), Material Sciences (14.4%), Energy (16.7%), Chemistry (12.4%) and Chemical Engineering (14.1%). For areas like Medicine and Biochemistry, Denmark is relatively less dependent on Chinese partners. The percentage of publications with Chinese partner in these two areas are only 3% and 7%.

3.4.3 Comparison between China and US as Denmark’s Scientific Research Partners

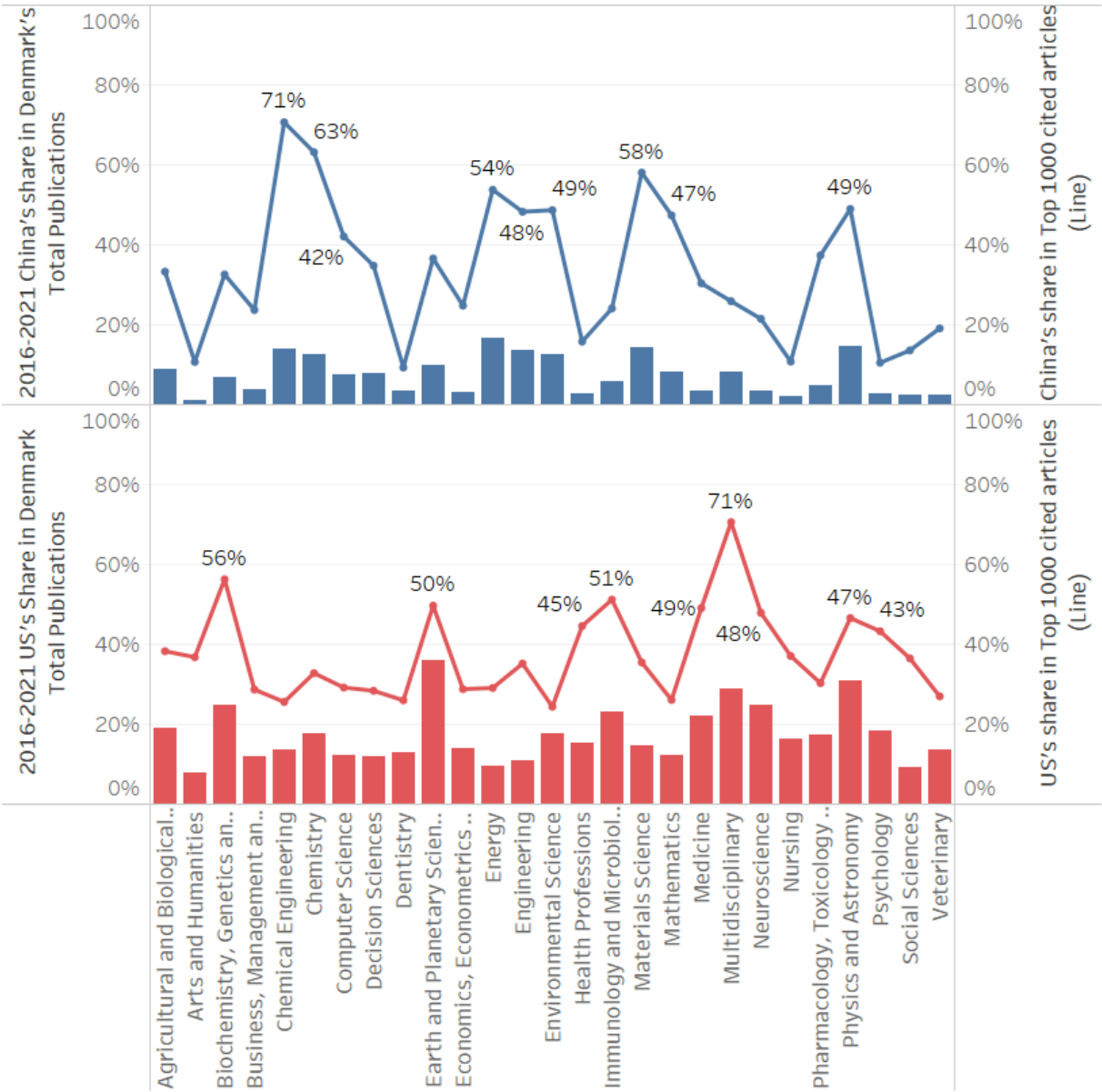


Figure 9. Comparison of China and US in share of Denmark’s collaborations and share of world top 1000 cited publications

To identify the strengths of China's research capacity in these 27 areas, we explore the share of China's publications in the top 1000 most-cited articles in the world from 2016 to 2021. Area in which China's share surpasses 40% indicates that China has a particular strong research capacity.

There are nine major areas, where China has a share of more than 40% in the top 1000 most-cited articles in the world. These are Engineering (48.3%), Physics and Astronomy (49.0%), Environmental Science (48.7%), Materials Science (58.1%), Energy (53.8%), Chemistry (63.2%), Chemical Engineering (70.7%), Computer Science (42.1%) and Mathematics (47.4%). These correlate with the most important areas of Sino-Danish collaboration except for computer science and mathematics.

To make a comparison with Sino-Danish scientific collaborations, the US-Denmark collaborations in 27 areas is also analyzed here. There are nine major areas, where the US has a share of more than 40% in the world top 1000 most-cited articles. These are Physics and Astronomy (46.6%), Medicine (49.1%), Biochemistry, Genetics and Molecular Biology (56.3%), Earth and Planetary Sciences (49.7%), Immunology and Microbiology (51.2%), Multidisciplinary (70.6%), Neuroscience (47.9%), Psychology (43.3%) and Health Professions (44.6%). US-Denmark scientific collaborations also concentrate in the areas where US has an outstanding share in the world top 1000 most-cited publications.

3.5 FWCI in Each Collaboration Area from 2016 to 2021

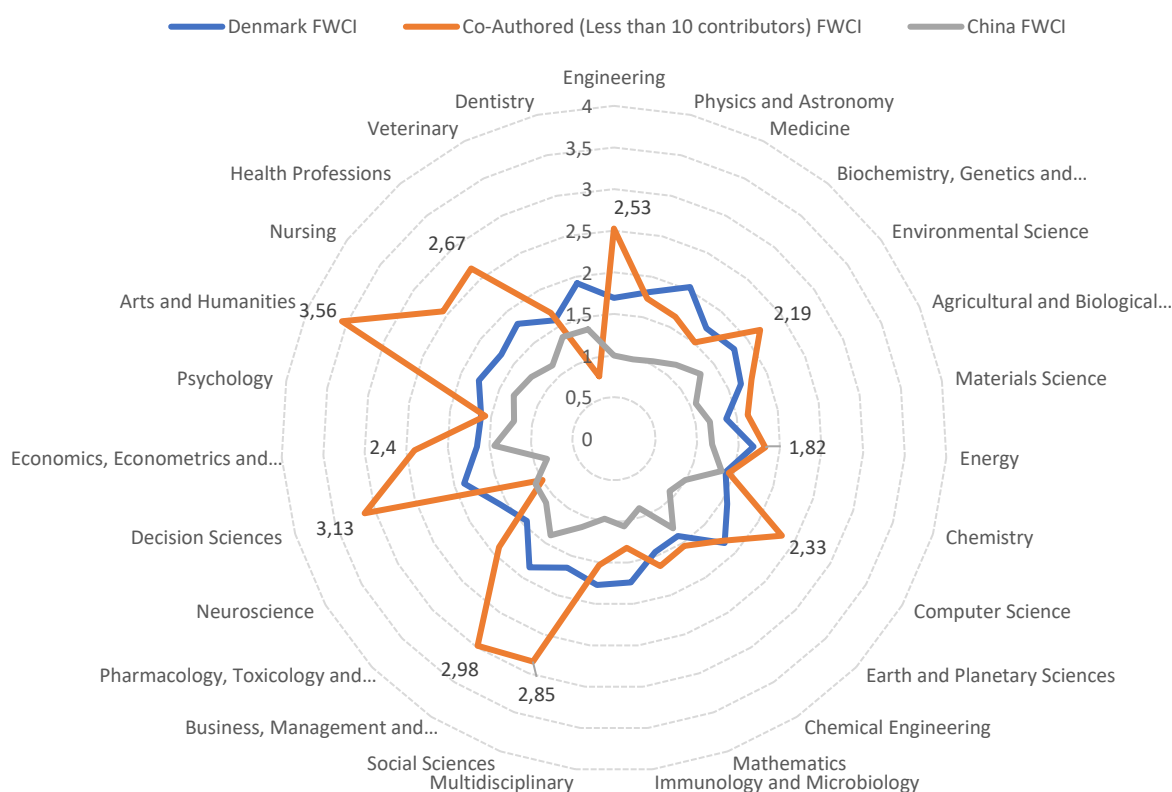


Figure 10. Field-Weighted Citation Impact (FWCI) of Denmark, China and Sino-Danish Co-Authoring Publications with less than 10 contributors in 27 Areas

The Field-Weighted Citation Impact (FWCI) of Denmark, China and collaborative publications in all the 27 areas are calculated and compared as Figure 10. To eliminate the influence of the collaborated publications with a long list of global contributors, we do the analysis based on publications with less than 10 contributors.

For the period 2016 to 2021, Denmark achieved a higher impact score in all areas than China. In areas like Engineering, Computer Science, Social Science, Business and Management, Decision Science, Economics, Arts and Humanities, Nursing, Health Professions, Sino-Danish Collaboration brings apparent improvements compared to the FWCI score of both countries. However, for some areas, the co-authored FWCI is lower than Denmark's average FWCI in the same area. This goes for Medicine, Biochemistry, Earth and Planetary Science, Immunology and Microbiology, Multidisciplinary, Neuroscience and Dentistry.

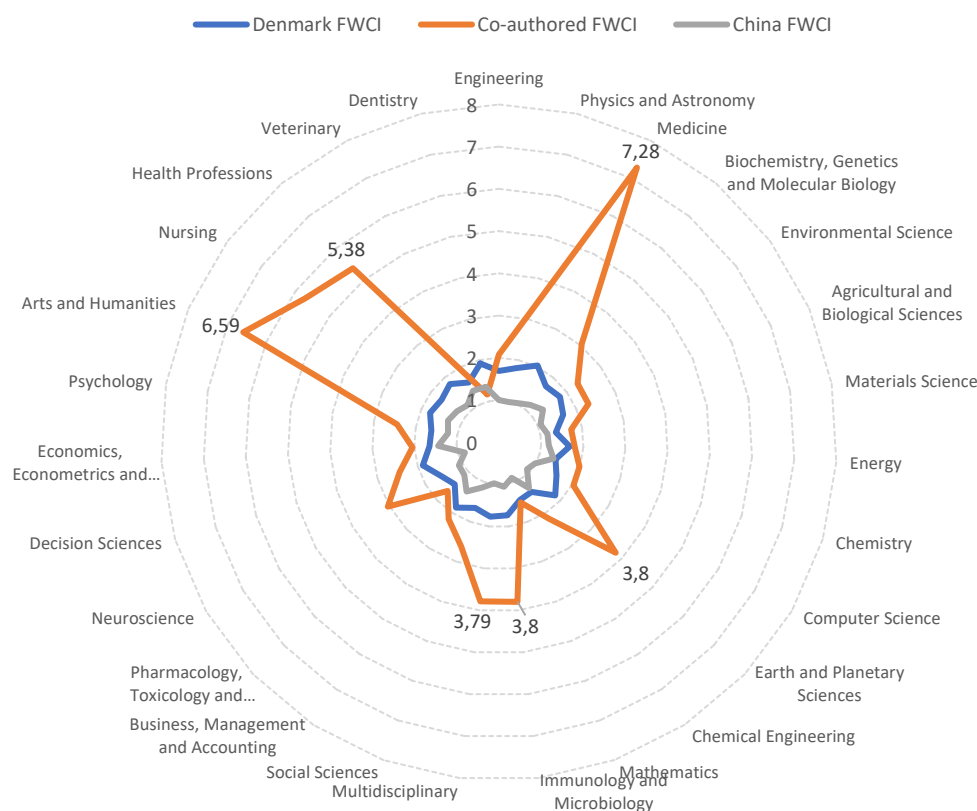


Figure 11. Field-Weighted Citation Impact (FWCI) of Denmark, China and Sino-Danish Co-Authoring Publications with any number of contributors in 27 Areas

Figure 11 shows another result of co-authored FWCI with no limits on the number of contributors. Therefore, some publications included in this analysis are emerged from a wide range of global cooperation and usually have extremely high academic value. Compared to Figure 10, the Figure 11 shows that being a part of a wider range of global scientific collaborations brings more significant increase in Denmark's research quality to nearly all the areas, except for Dentistry.

4. Summary

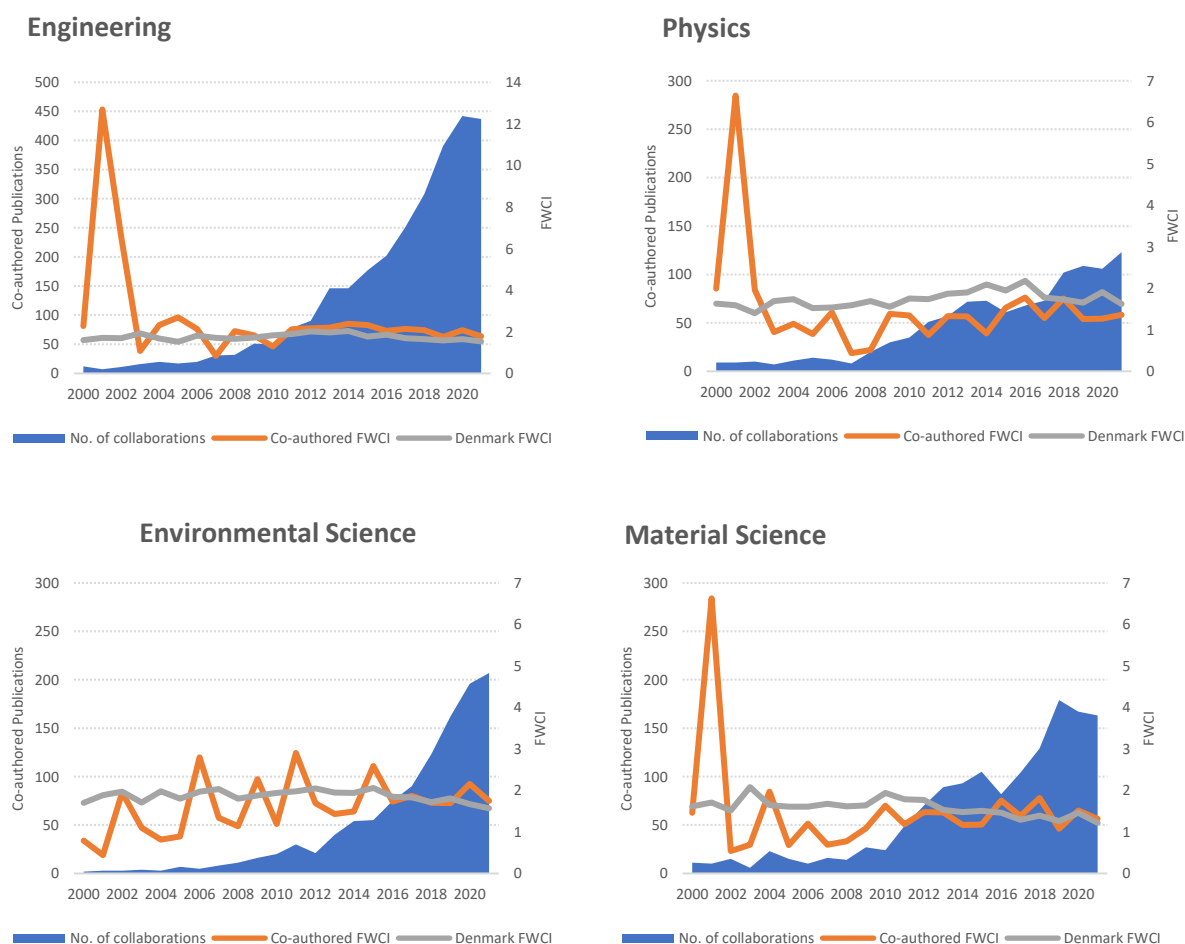
In the last 10 years, scientific collaboration between Denmark and China has been increasing. The quality of collaboration is of significant value and can create benefit to both countries' research development. Both countries have grown fast in the volume of total publications since 1990, while China's growth is much more driven by domestic research capacity.

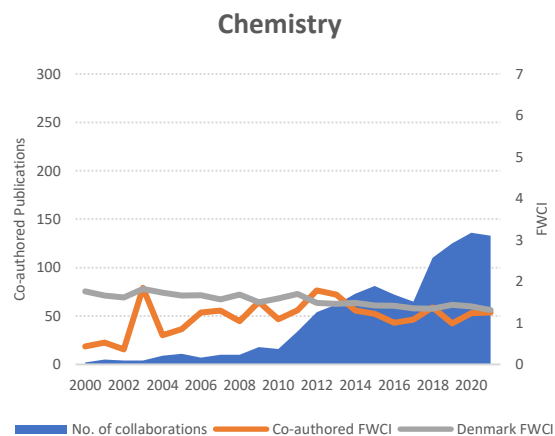
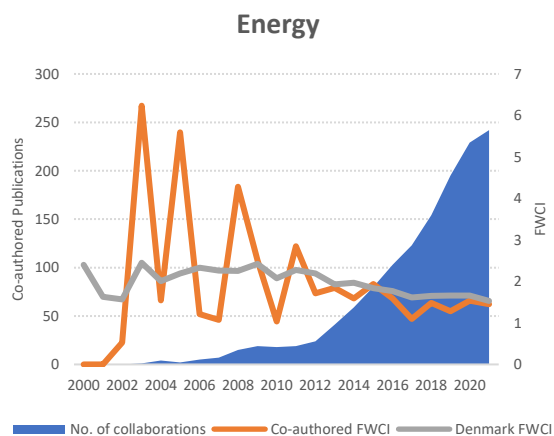
The citation impact of China's research publications is rising. In major areas, China's average FWCI has surpassed the world average since 2015, and the citation impact score would be even higher if we filter the first and second tier of universities/institutions, which indicates that the overall quality of China's research publications is rising. However, Denmark still outweighs China in all the 27 areas in citation impact.

So far, Denmark has been more dependent on its own historical scientific research partners like US, UK, Germany and Sweden in all areas. From 2016 to 2021, publications with Chinese partners didn't surpass 20% in any of the areas. The area with the highest proportion of Chinese partners is Energy (17%).

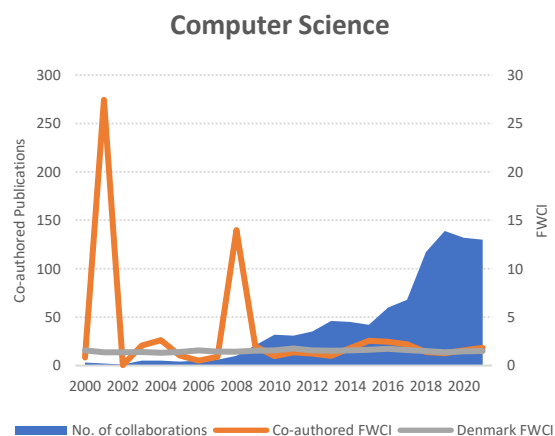
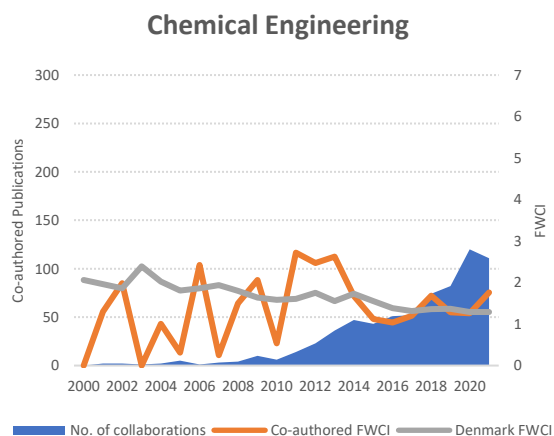
The analysis indicates that both Denmark and China benefits from the collaboration. The major areas of collaboration between Denmark and China correlate with the Chinese academic strongholds, such as Engineering, Chemistry, Chemical Engineering, Physics and Astronomy, Energy and Materials Science.

Appendix - Sino-Danish Bilateral Collaboration in Major Areas (Other Countries Excluded)





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ⁱ The 2001 FWCI outlier values in the areas of Engineering, Physics, Material Science and Computer Science are caused by one publication *Modal identification of output-only systems using frequency domain decomposition*, which has been cited for 1313 times. The authors are Brincker, Rune (Denmark); Zhang, Lingmi (China); Andersen, Palle (Denmark)