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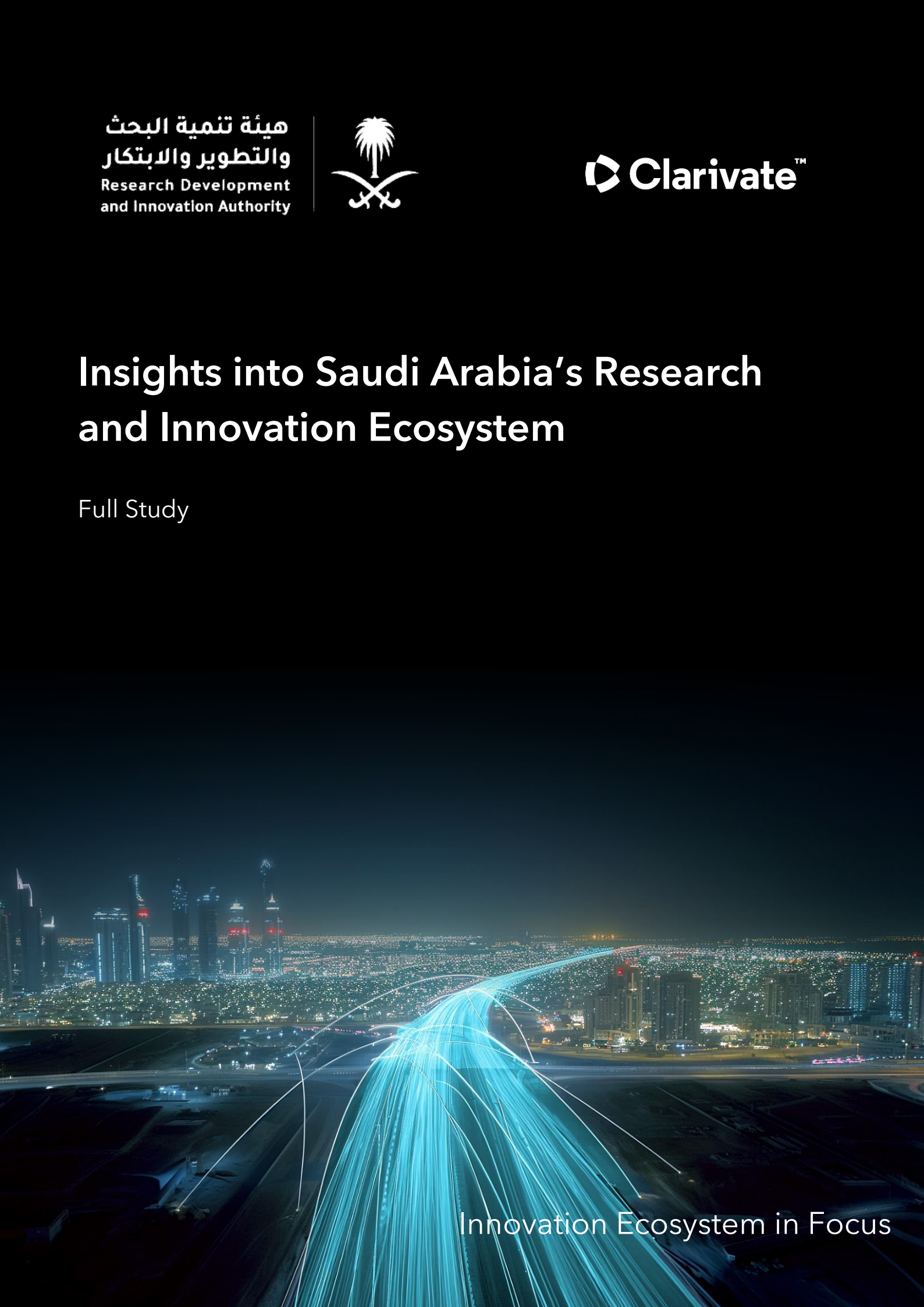
Research Development
and Innovation Authority

Clarivate™

Insights into Saudi Arabia's Research and Innovation Ecosystem

Full Study



Innovation Ecosystem in Focus

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1 Introduction and goals of this study

1.1 Introduction

The Kingdom of Saudi Arabia is undergoing a transformative journey emphasizing the importance of a knowledge-based economy as a driving force behind Saudi Vision 2030. This essential transformation is set to elevate the research, development, and innovation (RDI) landscape, positioning Saudi Arabia as a global leader within its national priorities:

- Health and Wellness
- Sustainability and Essential Needs
- Energy and Industrials
- Economies of the Future

His Royal Highness Prince Mohammed bin Salman bin Abdulaziz Al Saud has declared Saudi Arabia's goal of becoming a global frontrunner in science, technology, and innovation. The Kingdom targets investing 2.5% of its GDP in RDI by 2040. Establishing the Research, Development, and Innovation Authority (RDIA) in 2021 marked a pivotal step in steering RDI initiatives.

RDIA has engaged Clarivate, a global leader in research and intellectual property data analysis, to collect, collate, and analyse research relationships, outcomes, and documents in Saudi Arabia and worldwide. Examining this data has highlighted areas of strength in research and areas for improvement. This study aims to inform the reader about how these historical trends can guide the future allocation of resources dedicated to the RDI strategy.

This study is the second part of a comprehensive program focused on global and local research and innovation. The program aims to comprehensively understand the research ecosystem and its capabilities when viewed within the context of national priorities and specific technologies that align with these priorities. It seeks to examine the Saudi research ecosystem from the perspective of the robust academic research base established over the last 20-30 years. Additionally, it aims to explore how this research foundation interacts with industry to advance the development of that research into commercial technologies base. The role of academia in the research and development lifecycle is critical and is a foundation for a knowledge-based economy.

This part focuses on Research Ecosystems which cover the interrelated elements of a system and how they individually function as well as supporting the success of research in adjacent area. The elements of a research ecosystem are diverse but each element is critical to successfully achieving research excellence. This program presumes a natural progression pattern within research and innovation to assess the state of such collaborations. This progression of research from a concept to a product is necessary to evaluate historical performance and model future research priorities across national priorities. The model utilized by Clarivate to generate its modelling presumes the following sequence regardless of the specific research area:

Fundamental research - Research that seeks to enhance our understanding of nature and provides a foundation for future research through publication.

Early shift to applied research - As potential uses arise, further study to validate them. Patents may be filed.

General shift to applied research and development - Validates the commercial potential, reducing the associated risks, enabling focused development and investment towards commercialization.

Strong commercialization signals of developed technologies - Patented products are commercialized, competition arises as value becomes clear and litigation may occur.

The interaction between academia and industry has evolved from parallel relationships to closer, more productive partnerships. This evolution reflects the contemporary innovation landscape's increasing complexity and interdisciplinary

nature[1]. Empirical research—including studies conducted in Saudi Arabia—has underscored the strategic importance of such partnerships in fostering regional economic growth, nurturing research talent, and addressing complex societal challenges[2]. Successful collaborations are characterized by continuous feedback loops, enabling ongoing adaptation and enhancement of knowledge.

This study is part of a broader program to analyse global and local research and innovation. The program aims to understand the research ecosystem and its capabilities in detail, structured around Saudi Arabia's national priorities and individual technologies that align with them.

The more expansive program, of which this study is a part, therefore focuses on the nature and level of academic-corporate partnership evident within Saudi Arabian research and innovation as a feasible comparable proxy measure for the level of research dissemination, as compared to other countries and regions, and is further built on a structure that aligns with Saudi Arabia's national priorities. Universities and research institutions perform two essential functions:

- Education
- Research

Technology transfer involves translating research outcomes into products and services and facilitating the deployment of research outcomes into the broader economy through commercial agreements.

In this program, Clarivate used a standard approach for analyzing data and techniques, relying on proven methods that were developed in advance, including:

- Connecting the technical framework within the National Priorities to specific areas of research and technology using an international collection of scientific studies.
- Reviewing the levels of historical commercialization and applied research activities in Saudi Arabia compared to select comparable countries while profiling the capabilities, strengths, and resources available in Saudi Arabia today.
- Modelling the technical readiness level of global R&D for each research topic aligned with national priorities to evaluate the potential commercialization of future research in Saudi Arabia.
- Highlighting gaps in maturity areas to benchmark the current patent activity in Saudi Arabia as a proxy for the commercialization levels of applied research across each research topic in the national framework priorities.
- Review the study metrics for each national priority to identify research topics with the highest potential for significant impact.
- The production of scorecards for each national priority by leveraging:
    - RDIA expert view
    - Global technical maturity
    - Academic research base and Academic-Corporate Partnership activity level.
- Modelling an innovation ecosystem as it would compare globally in technology commercialization to inform future investments in research topics to achieve maximum impact.

This process captured multiple views and activity patterns into a holistic overview of the research opportunities and funding policy choices that can be pursued.

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[1] 'A New Model for University-Industry Partnerships', Havard Business Review (2024)
[2] Oxford Business Group, 'Global Collaboration Efforts Are Under Way to Diversify International Partnerships and Fuel Research, Development and Innovation' (2023)

The program aimed to understand the Saudi research ecosystem from an academic perspective, which has been impressively developed in Saudi Arabia over the past 20 to 30 years. It also seeks to explore further how this research foundation interacts with industry players to develop that research into a commercial technology base.

1.2 Goals

This program serves as the empirical foundation for subsequent analyses and evaluations of national RDI priorities. Its goal is to objectively assess the effectiveness of outcomes from academic-corporate partnerships in Saudi Arabia, focusing on research and innovation. This comprehensive analysis is essential for identifying existing areas of expertise and capability within Saudi Arabia. Additionally, the program aims to develop metrics for evaluating the throughput and impact of these partnerships.

The findings and identified opportunities will shape policy and inform decision-making. Related activities already enabled by RDIA include RDI Grants, Innovation Districts, National Alliances, and Industry Consortia. Subsequent studies will focus on prospective analyses and forecasting, examining technologies' global maturity and readiness for market deployment.

The Research, Development, and Innovation Authority (RDIA) drives Saudi Arabia's shift towards a diversified, knowledge-based economy. By providing strategic funding and fostering academic-industry collaboration, RDIA accelerates the commercialization of high-impact research, bridging the gap between theory and application. Investments in advanced research infrastructure and robust intellectual property frameworks ensure that innovations are protected, market-ready, and attract foreign investment. Through partnerships with government and industry, RDIA reduces barriers to innovation by shaping a supportive regulatory environment and offering incentives that de-risk R&D initiatives. Its efforts to build local talent and promote knowledge transfer strengthen the nation’s innovation ecosystem. Moreover, RDIA’s initiatives align with Vision 2030 goals, supported by rigorous evaluation and global benchmarking to enhance local capabilities. Key outcomes, such as increased R&D investment, patents filed, and revenue from new products, demonstrate RDIA’s role in fostering economic growth and solidifying Saudi Arabia's position as a global innovation leader. These efforts reflect international best practices in advanced economies, where academic-industry partnerships significantly contribute to GDP growth and job creation.

This study, the second part of a comprehensive program, aims to analyse the research output of Saudi Arabia in the period 2014-2023 and highlight key opportunities that will further enhance the productivity and quality of Saudi research performance (as indicated by its research publications). It considers both overall research performance and performance in specific national priority areas.

This comprehensive analysis is presented as a strategic assessment and roadmap for the Kingdom’s research and innovation community. The analysis focuses on Saudi Arabia’s research output over the past decade (2014–2023), with a particular emphasis on national priority areas. Key metrics such as research volume and impact, funding trends, and collaboration dynamics are examined to provide a holistic understanding of performance. This evaluation is further benchmarked against comparator countries to contextualize progress and identify areas for improvement.

A detailed SWOT analysis has been conducted to highlight critical areas where research capabilities can be enhanced. Combining this analysis with international benchmarking reveals targeted development opportunities to strengthen Saudi Arabia’s position in the global research landscape. As part of this assessment, the estimated number of active researchers in the national priority areas has been

analyzed to understand the current research base. This also identifies strategic areas where increasing the number of researchers could accelerate growth and impact. To further bolster research performance, this study analyses the participation of women in research. International best practices, policies, and initiatives aimed at enhancing the participation of women in research are also presented.

Finally, global success stories and proven strategies from leading research nations have been studied and mapped onto the Kingdom's identified development areas. From this exercise, specific initiatives, policies, and frameworks have been proposed to serve as a roadmap for enhancing research performance in Saudi Arabia. Through this assessment, the Kingdom's research and innovation community is provided with a clear, evidence-based guidance to drive sustainable growth and position Saudi Arabia as a global leader in research excellence.

2 Executive summary

In this study we have investigated the overall research performance of Saudi Arabia as well as the performance in the national priority areas Health and Wellness, Sustainability and Essential Needs, Energy and Industrials as well as Economies of the Future. From this analysis, we have identified performance strengths as well as areas with potential improvement.

Among the main strengths identified:

- A dramatic increase in the overall research output and research output in the national priority areas.
- High citation impact footprint of the overall research as well as in all the national priority areas.
- High research excellence performance when considering the Top 1% and Top 10% documents in the overall research as well as in the national priority areas.
- High percentage of open access documents in comparison to considered countries and regions.
- Most of the research topics constituting the national priority areas can be classified as strength or opportunity areas. Thus, the SWOT analysis indicates that Saudi Arabia has a solid research performance in the national priority areas that could support enhancing innovations in them.
- When considering the top 20 funding organizations of Saudi Arabia overall research and in the national priority areas we observe several international ones. This reflects the ability of Saudi affiliated researchers to attract international funding.
- Increase in the number and percentage of documents related the United Nations Sustainable Development Goals
- The percentage of women identified by active researchers in Saudi Arabia increased continuously from 19.3% in 2014 to 30.3% in 2023. This reflects the efforts performed in Saudi Arabia to increase the participation of women in research. The percentage of patent applications with the Patent Cooperation Treaty (PCT) and the share of women inventors among listed PCT inventors in Saudi Arabia also increased in the period 2014-2023.

On the other hand, we have identified areas for potential improvement, among which:

- Saudi Arabia has a high percentage of international collaboration in research. While valuable, by enhancing domestic research capacity alongside global partnerships, there is an opportunity to further strengthen contributions to scientific advancements, achieving a balance between international cooperation and locally driven research output.
- In the past and as indicated by the analyzed data, Saudi Arabia historically lacked a centralized organization for research funding. This changed in 2021 with the creation of the Research, Development, and Innovation Authority (RDIA), which took on the responsibility of centralizing research funding. Since then, RDIA has introduced various funding initiatives and awarded numerous grants targeting national missions and priority areas. This is expected to significantly boost Saudi Arabia's research output in alignment with its strategic RDI priorities.
- In the area of Health and Wellness we observe an increase in the number of research publications but a relatively lower citation impact and a relatively

lower performance in research excellence indicators. This signals a need to enhance the global relevance of the research in this area.

- The percentage of women identified from active researchers in Saudi Arabia although it increased in last 10 years, it is still lower than that of other G20 countries but higher than that of Japan and close to other GCC countries. Similar observations are made with metrics related to women participation in inventions. With the focus within Saudi Arabia's Vision 2030 on increasing women's participation in all sectors, including research and innovation, the growth observed in the last years is expected to continue which would support reaching levels within proportional representation zone.

We have also identified global policies, initiatives, and strategies for research development and for addressing gender equality and gender gap in research.

From the above-identified potential development areas and global practices in the context of research and development, this study highlights the following opportunities:

- The establishment of dedicated national research institutes targeting priority areas is essential. These institutes can be equipped with advanced research infrastructure, including state-of-the-art laboratories and innovation hubs, to provide researchers with the resources needed for conducting groundbreaking studies locally. RDIA supports such efforts through initiatives like the National Semiconductor Hub and the Innovation Districts Alliance, fostering local collaboration, building expertise, and aligning with national priorities.
- The establishment of RDIA as a centralized funding body, distributing resources based on national focus areas, will ensure alignment between research activities and the strategic goals of the nation. By setting specific funding criteria that prioritize national goals, including the development of key sectors and skills, Saudi Arabia can ensure that research output directly contributes to the growth of local talent and expertise that aligns with its strategic direction. RDIA has already launched research grants that are designed and prioritized to foster a thriving innovative ecosystem, developing highly skilled innovators and support cutting-edge research such as the Saudi Basic Science Initiative, Saudi Applied Research and Technology Initiative, and the Reactivating and Rebuilding of Existing Labs initiative.
- Creating national research awards or recognition programs for outstanding contributions in national priority areas can incentivize researchers to focus on topics of national importance and raise awareness in the research community about the importance of those topics.
- To enhance women's participation in research and innovation, both short-term and long-term strategies can be implemented. In the short term, incorporating gender considerations into funding allocation processes and mechanisms can serve as an effective driver of change. Over the long term, mandating Gender Equality Plans (GEPs) would take this effort further by requiring institutions to evaluate their internal gender equality status and implement necessary actions to address disparities.

Overall, the above findings indicate that Saudi Arabia has a strong basis to achieve its research development and innovation aspirations by 2040. First, Saudi Arabia has already demonstrated strong research performance in its national priority areas, reflecting that there is a strong foundation to further enhance research and innovation in those areas.

Second, Saudi Arabia’s already relatively high overall research performance and further enhancing and preserving this performance should reflect positively in

several GII metrics such as scientific articles and citation index. This will support Saudi Arabia's aspiration of achieving a position among the top 26 globally in this index.

Third, the dramatic increase in research output and accordingly in active Saudi affiliated researchers form a strong basis for reaching higher levels in the number of researchers employed in Saudi Arabia. Additionally, the focus on the national priority areas and underlying research topics will eventually lead to topics in which Saudi Arabia demonstrates global excellence. For instance, RDIA has introduced the Reactivation and Rebuilding of Existing Labs Initiative, which focuses on enhancing existing research infrastructure. These efforts, coupled with a goal to increase R&D expenditure, will attract researchers from around the world to conduct research in Saudi Arabia, particularly in areas of excellence.

Last, but not least, leveraging the overall good research performance while focusing on innovation and commercialization should form a strong basis to enhance innovation and ultimately increase the contributions to the GDP and create more job opportunities.

3 Research evaluation along the national priority areas

3.1 Overview and Main Findings

In this section, we analyze the research output and performance of Saudi Arabia over the last 10 years (2014-2023). To perform this analysis, we will use a comprehensive set of metrics to identify strength areas and areas for further development. Accordingly, this section of the study assesses the research output in terms of volume, growth, citation impact, open access documents and also analyzes funding and collaboration dynamics. The metrics used are described in the section Metrics. This assessment further benchmarks the research performance of Saudi Arabia against selected countries and regions. This benchmarking enables us to identify strength and performance gap areas, as well as quantify the gaps. The analysis is performed on the overall Saudi Arabia's research output level and national priorities level. The derived dataset per priority area is described in the section Dataset Description.

First, the evolution of the number of papers in each priority area and the overall research output in the period 2014-2023 is examined and benchmarked with the global baseline and other countries/regions. Afterwards, we have examined the citation impact. For this have used the Category Normalized Citation Impact (CNCI). CNCI is a valuable and unbiased indicator of impact irrespective of age, subject focus, or document type. Therefore, it allows comparisons between entities of different sizes and different subject mixes. A CNCI value of 1 represents performance at par with global average when considering the same document type, year and subject. A value above 1 reflects a performance higher than the global average while a value below 1 reflects a performance below the global average (for more information see Metrics). To further investigate the citation impact in the national priority areas, we look at excellence indicators. Specifically, the number and percentage of documents in Top 1% and documents in Top 10%. Documents in Top 1%/10% indicator is the top one/ten percent most cited documents in a given subject category, year and publication type. Accordingly, all these indicators are a measure of research excellence. To further understand the research dynamics in each of the national priority areas as well as in the overall research output we also look at top 20 countries in terms of number of papers collaborating with Saudi Arabia and top 20 funding organizations in terms of number of papers in each of the priority areas. Looking at the top 20 funders will allow to identify key organizations funding Saudi Arabia's research in the national priority areas. We also analyse the number and percentage of open access documents. Open access has several benefits including increasing the visibility of research which can potentially lead to higher number of citations. Thus, we analyse how Saudi Arabia research dissemination in open access documents evolved in the period 2014-2023. Finally, we analyse the research output and impact for each of the priority areas on a more granular level by performing a SWOT analysis of the categories constituting the national priority area. This allows classifying the underlying categories into strength, weakness, opportunity and threat areas. Accordingly, all of the above analysis will create a relatively detailed overview of Saudi Arabia research performance in each of the priority areas as well as in the overall research output.

Main Findings

Research volume:

- Over the last 10 years, Saudi Arabia's research output increased very rapidly from around 15K to around 56k, that is an annual growth rate of around 16%. In parallel, the number of active Saudi researchers increased by 3.5x from ~18k in 2014 to ~ 66k in 2023. This is excellent progress towards the RDIA aspiration of 140K researchers by 2040.
- The increase is observed across all national priority areas, with average annual growth rates exceeding that of the overall research output. The highest average annual growth rate is observed in the area Economies of the

Future with 28% followed by Sustainability and Essential Needs with 25%, Energy and Industrials 23% and Health and Wellness 20%.

- In parallel in each of the areas the number of active Saudi Arabia affiliated researchers increased from 2014 to 2023 by 9.7x in Economies of the Future, 8.1x in Sustainability and Essential Needs, 7.2x in Energy and Industrials and 6.5x in Health and Wellness.
- All the above reflects not only a huge increase in Saudi Arabia's research output in general but also a specific focus on the national priority areas.

Citation impact:

- The citation impact footprint of Saudi Arabia's overall research output in the last 10 years, measured by the CNCI, was 31% higher than the global average, slightly lower but close to that of USA and GCC excluding Saudi Arabia and higher than all other considered countries/regions.
- In the area of Health and Wellness Saudi Arabia's citation impact was 19% higher than the global average, but lower than several of the comparator countries/regions. This indicates that although Saudi Arabia has a relatively good citation impact performance in this area, this could be further improved as this is a national priority area.
- In the area Sustainability and Essential Needs and Energy and Industrials Saudi Arabia has a citation impact 57% and 64% (respectively) higher than the global average and higher than all other considered countries/regions. This indicates high citation impact performance in these areas.
- In the area of Economies of the Future, Saudi Arabia has a citation impact 57% higher than the global average, lower than that USA and GCC excluding Saudi Arabia and higher than all other considered countries and regions. Nevertheless, this indicates that Saudi Arabia is strong in this area.

Research excellence:

- In the areas Sustainability and Essential Needs, Energy and Industrials and Economies of the Future Saudi Arabia's research output had a percentage of Top 1%, Top 10% and Highly Cited Papers, higher than the global average and all considered comparator countries/regions. Only in the area Energy and Industrials the percentage of Top 1% and Top 10% was slightly lower but very close to that of USA and GCC excluding Saudi Arabia.
- This demonstrates research excellence of Saudi Arabia in the areas Sustainability and Essential Needs and Energy and Industrials, when measured by the percentage of Top 1%, Top 10% documents and Highly Cited Papers.
- In Health and Wellness Saudi Arabia had a percentage of Top 1% and Top 10% documents higher than that of the global average but lower than several of the considered countries/regions. Accordingly, and in alignment with the citation impact analysis the research excellence performance in Health and Wellness is relatively good but could be further improved.

Research funding:

- Among the top 20 funding organizations contributing to Saudi Arabia's overall research and its national priority areas, several are international funding agencies. This highlights the capability of Saudi-affiliated researchers to successfully secure funding from international sources and/or collaborate with international researchers.

- Historically, no central Saudi funding entity has been acknowledged in research funding, with the primary Saudi funders being academic institutions. However, the establishment of RDIA in 2021 marked a significant shift, positioning it as a central funding body. RDIA is now responsible for distributing funds based on nationally aligned criteria, such as missions, performance, and national priority areas across research institutions. For instance, RDIA recently allocated 120 million SAR to support 100 research groups in Health and Wellness, 135 million SAR for 36 research lab infrastructure projects in the same field, and 120 million SAR for research grants in the Sustainability and Essential Needs priority area. This targeted funding approach is poised to enhance Saudi Arabia's research output in these critical domains.

Research collaboration:

- Saudi Arabia has exceedingly high levels of international collaborations when considering its overall research output and in all of the national priority areas, with percentages exceeding all of the other considered countries and regions. At the same time this means that Saudi Arabia has the lowest number of papers with only national affiliations.
- Having high percentages of international collaborations has several advantages. as it broadens research horizons, and resources, addresses global challenges through united efforts and builds international networks.
- On the other hand, having exceedingly high percentage of international collaboration reflects a reliance on international networks and resources. While valuable, by enhancing domestic research capacity alongside global partnerships, Saudi researchers can further strengthen their contributions to scientific advancements, achieving a balance between international cooperation and locally driven research output.
- The top three collaborating countries with Saudi Arabia in terms of the number of papers when considering the overall research output as well as the research output in Sustainability and Essential Needs and Economies of the Future are Egypt, India, and Pakistan. In the area Energy and Industrials Egypt, Mainland China, and India are the top three collaborating countries, whereas in Health and Wellness, Egypt, India, and USA are the top three collaborating countries.

Open access:

- The number of Saudi Arabian open access publications increased significantly from 5,212 publications in 2014 to 25,653 in 2023. This growth represents an evolution from 34.1% of the Saudi Arabian research output being published as open access in 2014 to 63.74% in 2023. When considering the overall research output in this period, Saudi Arabia had a higher percentage of open access documents (52.21%) than that of all considered countries/regions except for Germany (54.32%). The relatively high percentage of open access documents could lead to higher research output visibility, knowledge dissemination and possibly citations.
- Similarly, we notice an almost continuous increase in the number and percentage of open access documents across the priority areas. While we observe in the Health and Wellness and Economies of the Future areas a percentage of 73.8% and 63.7% in 2023 respectively, we observe lower percentages in the areas Sustainability and Essential Needs and Energy and Industrials of 57.8% and 48.7% respectively. In different disciplines, there could be different dynamics regarding open-access documents, and this

could be the reason behind the discrepancy that one observes across the national priority areas.

Research output in the UN Sustainable Development Goals:

- The number of Saudi Arabia's documents in the SDGs areas increased continuously in the period 2014-2023. As the percentage of documents from the overall research output along the SDGs increased as well, this shows growth rate of SDG documents was slightly higher than the overall growth rate.
- Among the Saudi documents in the SDGs areas, we found the highest number of the documents are in the SDG 03 (Good Health and Well-being), SDG 07 (Affordable and Clean Energy and SDG 13 (Climate Action).

SWOT analysis:

- When considering the national priority areas, all can be classified as strength areas. However, increasing the output of papers in Health and Wellness will be important to preserve the strength status.
- When investigating the research topics of the national priority areas, we observe that most research topics are either strengths or opportunities and very few are weaknesses or threats.
- Depending on the priority of a certain research topic, improving the research output and/or impact in research topics that are currently not classified as strength areas, would eventually lead to a classification among the strength areas

3.2 Saudi Arabia overall research output performance analysis

3.2.1 Research volume analysis

The number of Saudi Arabia papers grew continuously from 15,256 papers in 2014 to 55,832 papers in 2023 as shown in Figure 1. This reflects a double-digit growth for most of the considered years, for some years the growth rate was above 30%, and a much higher growth rate than the global rate. It is worth highlighting that although globally there was a negative growth rate between 2022 and 2023 (-7%), in Saudi Arabia we still observe a positive growth rate of 1.4%.

In the considered period, Saudi Arabia had a yearly average growth rate almost six times the average global rate and also higher than all the benchmark countries/regions (Figure 2). It is worth mentioning that this growth rate is not only higher than countries with almost saturated research output such as Japan, Germany and the USA but is also higher than that of countries/regions with growing research output such as Mainland China and the GCC excluding Saudi Arabia. All of the above indicates a transformation in Saudi Arabia's research output over the last 10 years.

In Figure 3, the number of active Saudi affiliated researchers per year is shown. The number of active researchers is calculated by considering the number of unique

researchers appearing on papers with an affiliation to an organization in Saudi Arabia in a certain period.

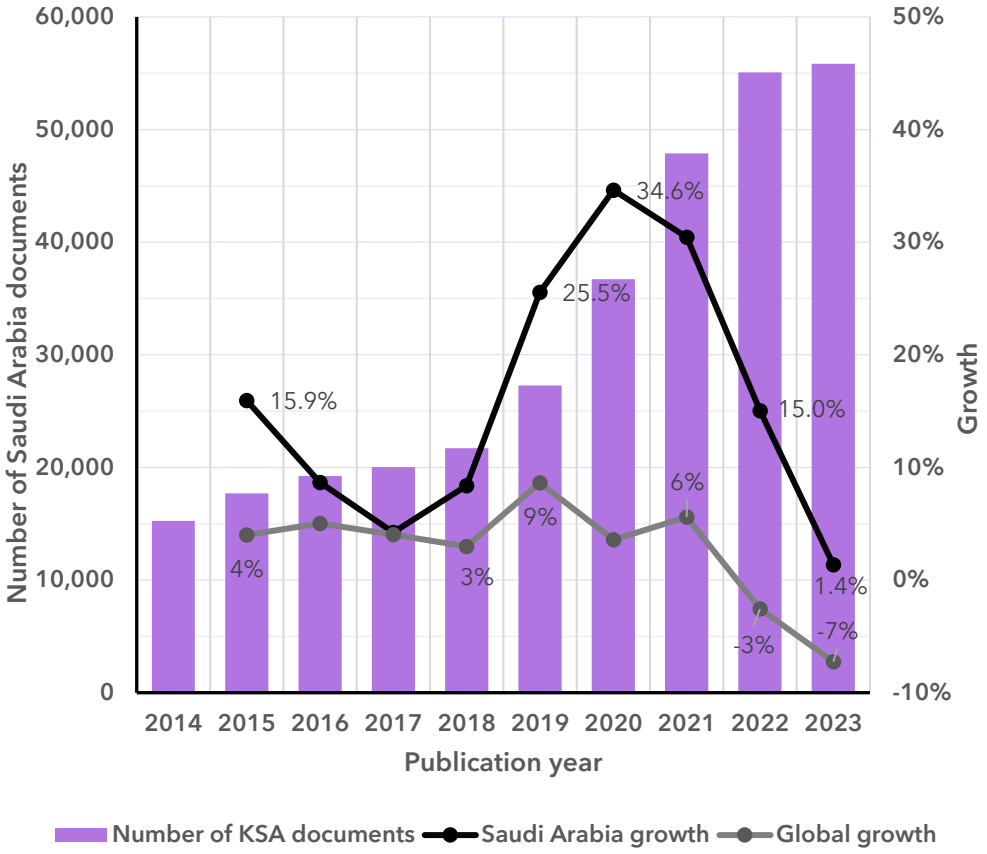

Figure 1: Saudi Arabia's number of papers and yearly growth rates in the period 2014-2023

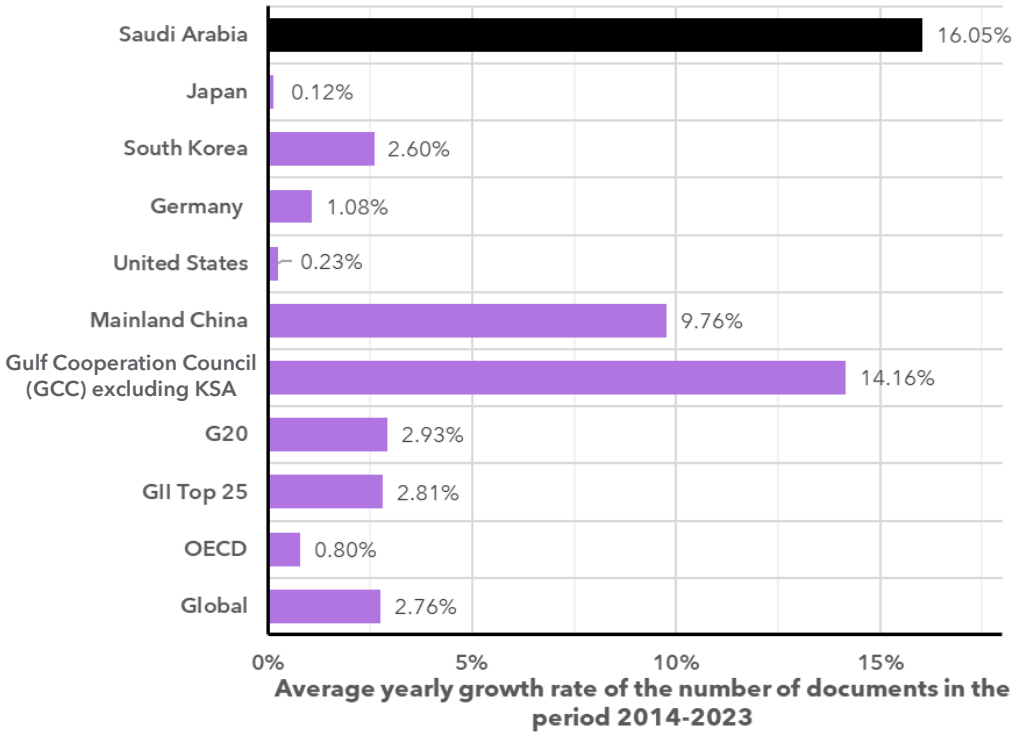

Figure 2: Average yearly growth rate of the number of documents in the period 2014-2023

For more information on the methodology used please see the section Number of active researchers. It is important to note that this does not reflect the number of Full Time Equivalent (FTE) researchers, but rather unique researchers appearing on papers with an affiliation to an organization in Saudi Arabia.

As observed earlier, the number of research papers from Saudi Arabia has steadily increased over the past decade (2014–2023). Similarly, the number of active researchers has grown consistently, reflecting a 3.5-fold increase during this period, which indicates a significant expansion of the research base in Saudi Arabia.

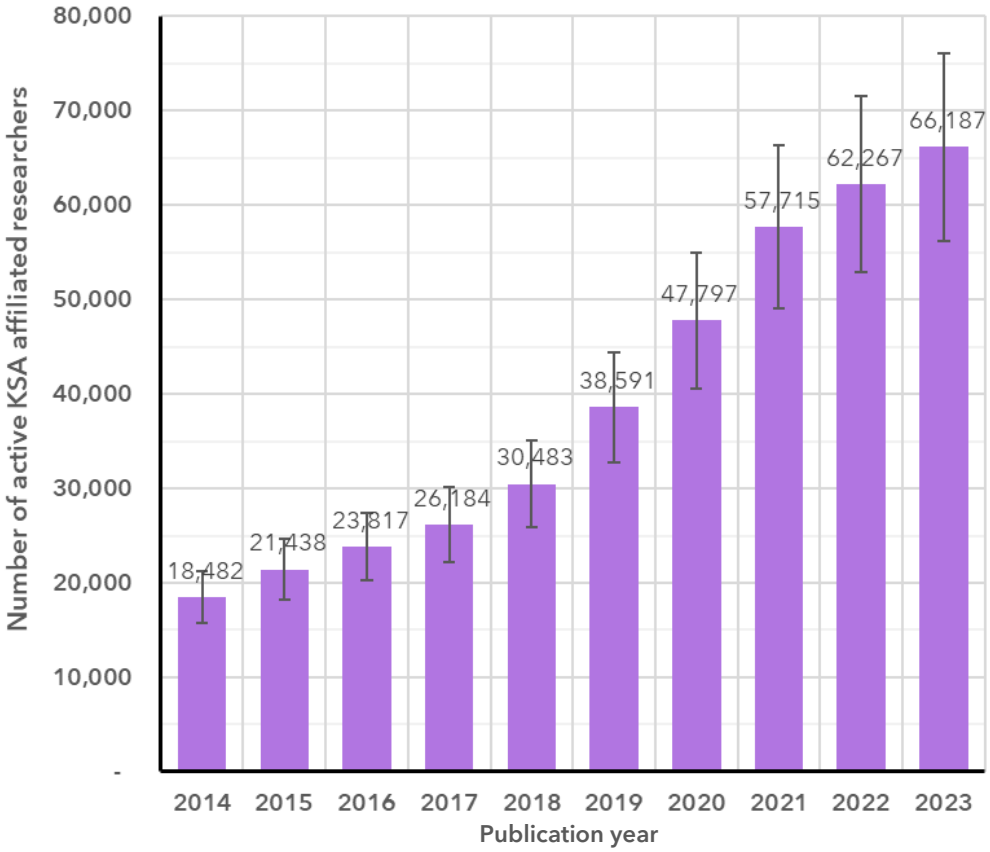

Figure 3: Number of active Saudi affiliated researchers during the period 2014-2023

3.2.2 Citation impact analysis

The category normalized citation impact (CNCI), an indicator measuring citation impact normalized over subject, year and document type (see Category Normalized Citation Impact), of Saudi Arabia in the period 2014-2023 was always above 1 indicating a citation impact performance above the global average as shown in Figure 4.

The CNCI fluctuated in this period between 1.18 and 1.46 and increased continuously from 1.2 in 2019 to 1.46 in 2023. Saudi Arabia also achieved a CNCI in this period higher than that of Japan, South Korea, Germany, Mainland China, GII Top 25, G20, OECD and a slightly lower CNCI than that of GCC excluding Saudi Arabia and USA as shown in Figure 5.

This is indicating a relatively high citation impact footprint. Usually, it is known that citation impact decreases in periods with high volume growth, because in such periods the knowledge and expertise are being accumulated by the expanded researcher's base. Thus, it is worth noting that in this case, the citation impact (CNCI) increased in a period of high research output growth.

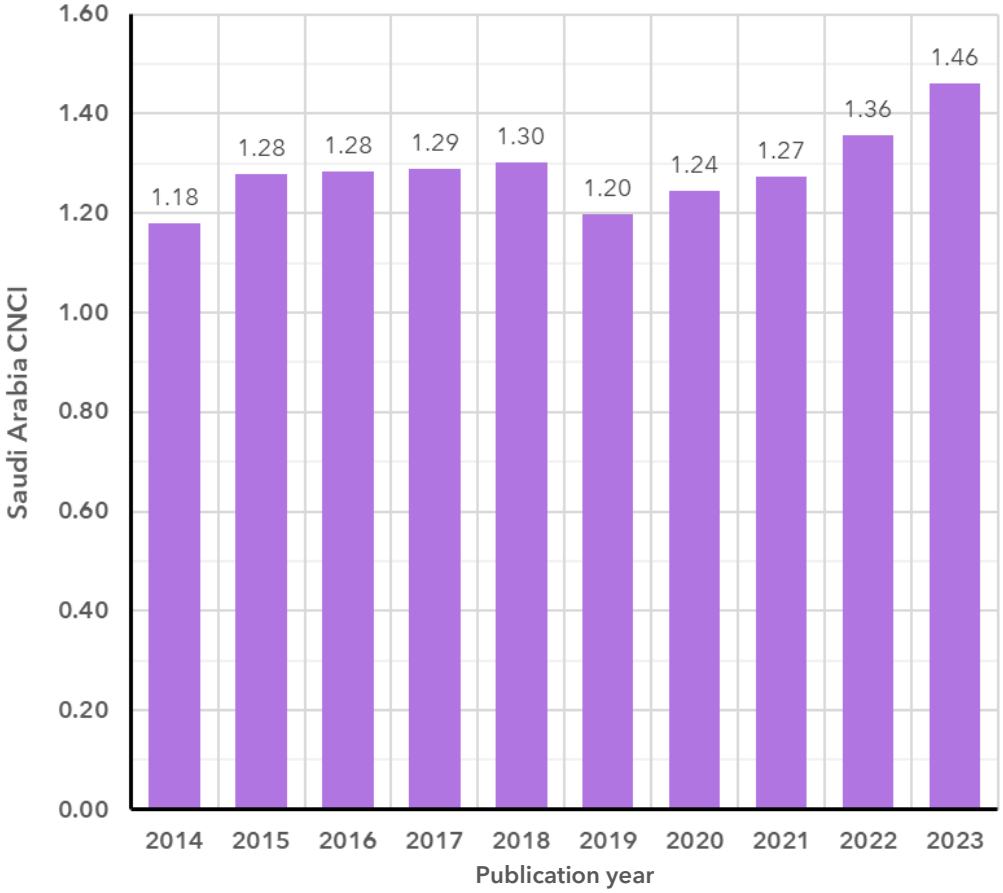

Figure 4: Saudi Arabia yearly category normalized citation impact (CNCI) of the overall research output in the period 2014-2023

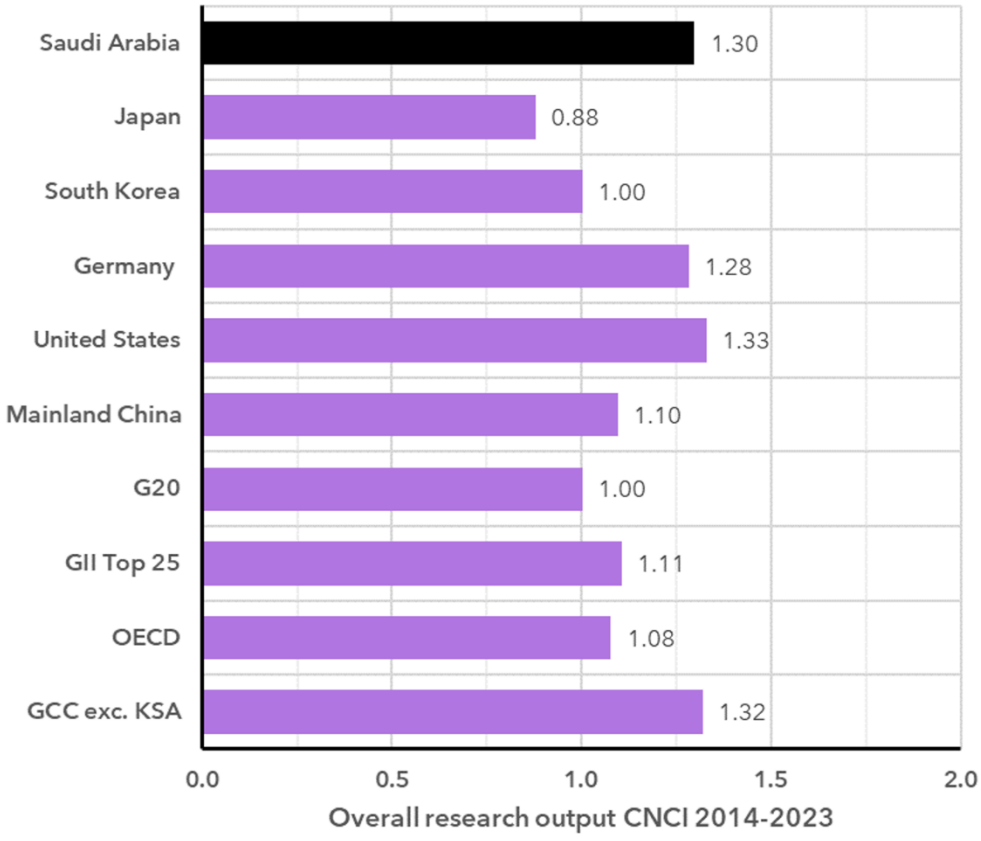

Figure 5: Research output CNCI of Saudi Arabia and groups of countries in the period 2014-2023

3.2.3 Research excellence analysis

To investigate research excellence performance, we analyse the number and percentage of Top 1% documents. Documents in Top 1% indicator is the top one percent most cited documents in a given subject category, year and publication type. The percentage of Saudi Arabia's Top 1% documents increased from 1.88% in 2014 to 2.25% in 2018 then and then decreased to 2.03% in 2020 and increased afterwards continuously to 2.41% in 2023 as shown in Figure 6.

On the other hand, the number of Top 1% documents increased almost continuously from 287 documents in 2014 to 1,350 documents in 2023. In general, the percentage as well as the number of Top 1% documents in Saudi Arabia increased in the considered period.

Considering that the global average performance is ~1.13% as shown in Figure 7, this shows that the performance of Saudi Arabia was higher than the global average during the period 2014-2023.

Additionally, when considering the research output over this period, Saudi Arabia had a higher percentage of Top 1% documents than all considered countries/regions. This shows a high research excellence performance of Saudi Arabia, when considering the metric percentage of Top 1% documents.

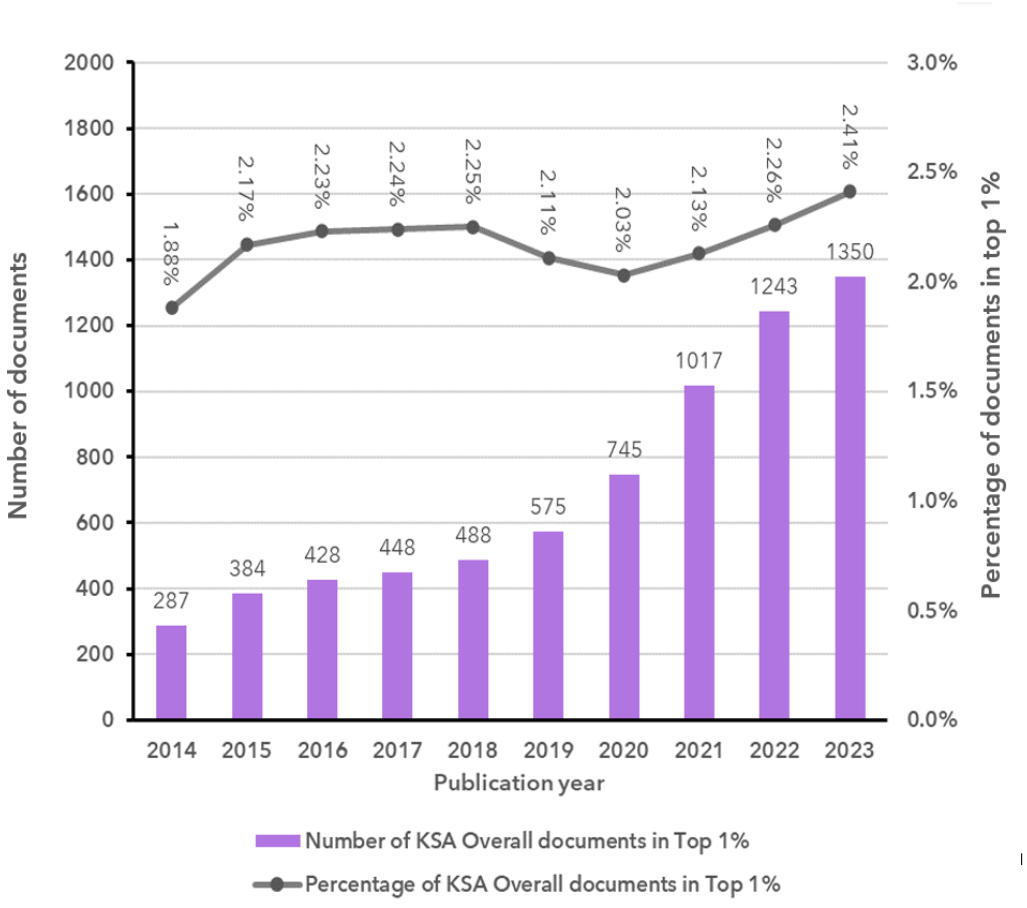

Figure 6: Number and percentage of Top 1% documents from overall research output

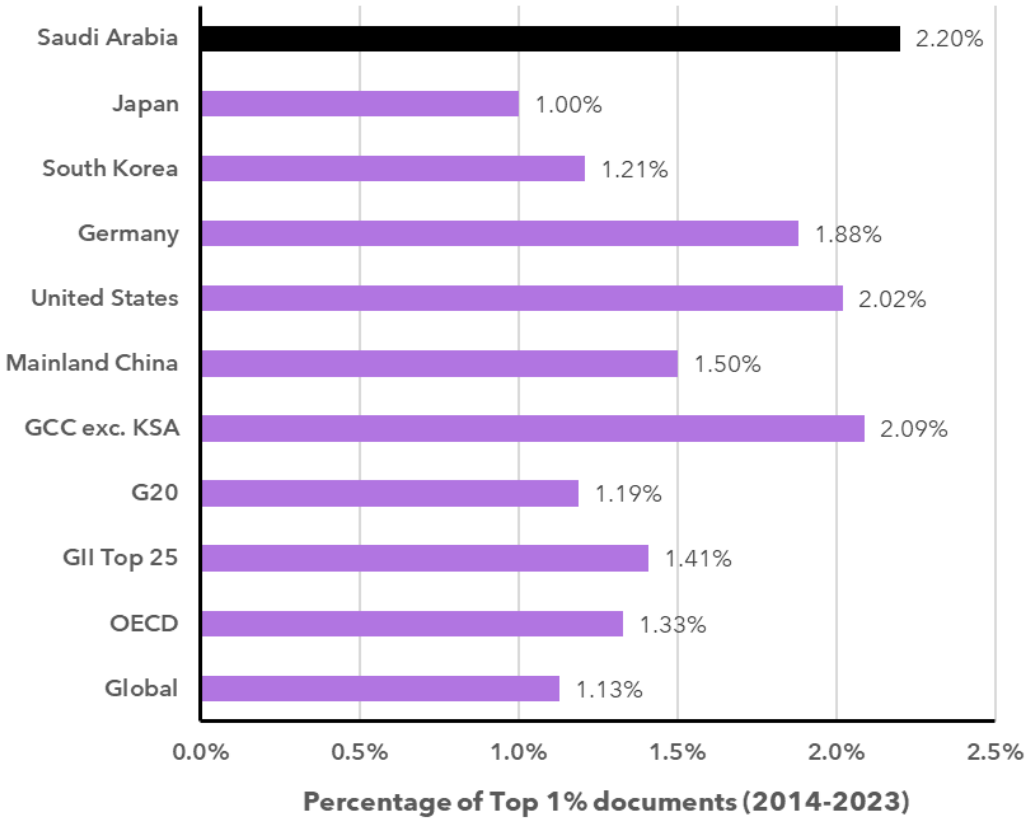

Figure 7: Percentage of Top 1% documents from overall research output in the period 2014-2023

The percentage of Saudi Arabia's Top 10% documents increased almost continuously in the period 2014-2023, from 13.43% in 2014 to 16.10% in 2023 as shown in Figure 8.

We observe only a slightly decrease in the percentage in 2019, with a continuous increase afterwards till 2022 and a slight decrease in 2023. The number of Saudi Arabia Top 10% documents increased continuously from 2014 till 2022 followed by a slight decrease in 2023. When considering the global average of the percentage of Top 10% documents in the period 2014-2023 (Figure 9), Saudi Arabia had a percentage of Top 10% higher than that of the global average in all considered years.

Additionally, in the considered period, Saudi Arabia had a percentage of Top 10% documents higher than that of all considered countries/regions. This reflects a very high performance of Saudi Arabia in terms of research excellence when measured by the percentage of Top 10% documents.

This aligns with the findings with the previously analyzed metric the number and percentage of Top 1% documents. Both findings indicate a high research excellence performance of Saudi Arabia.

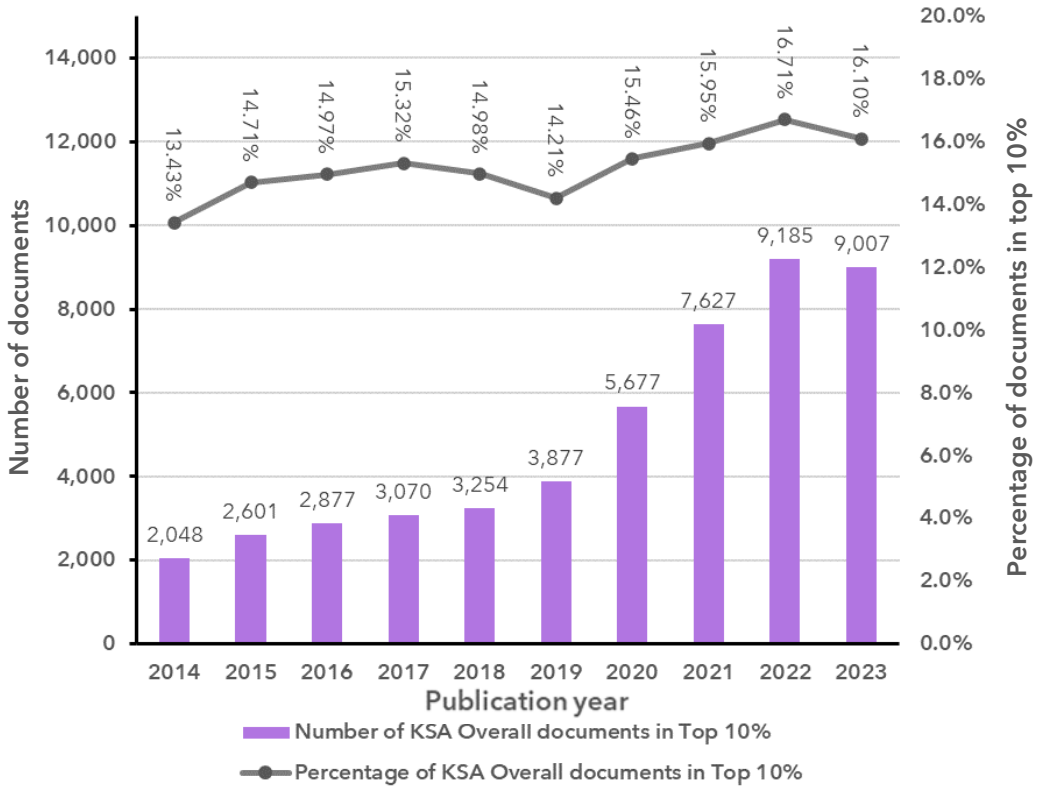

Figure 8: Number and percentage of Top 10% documents from overall research output

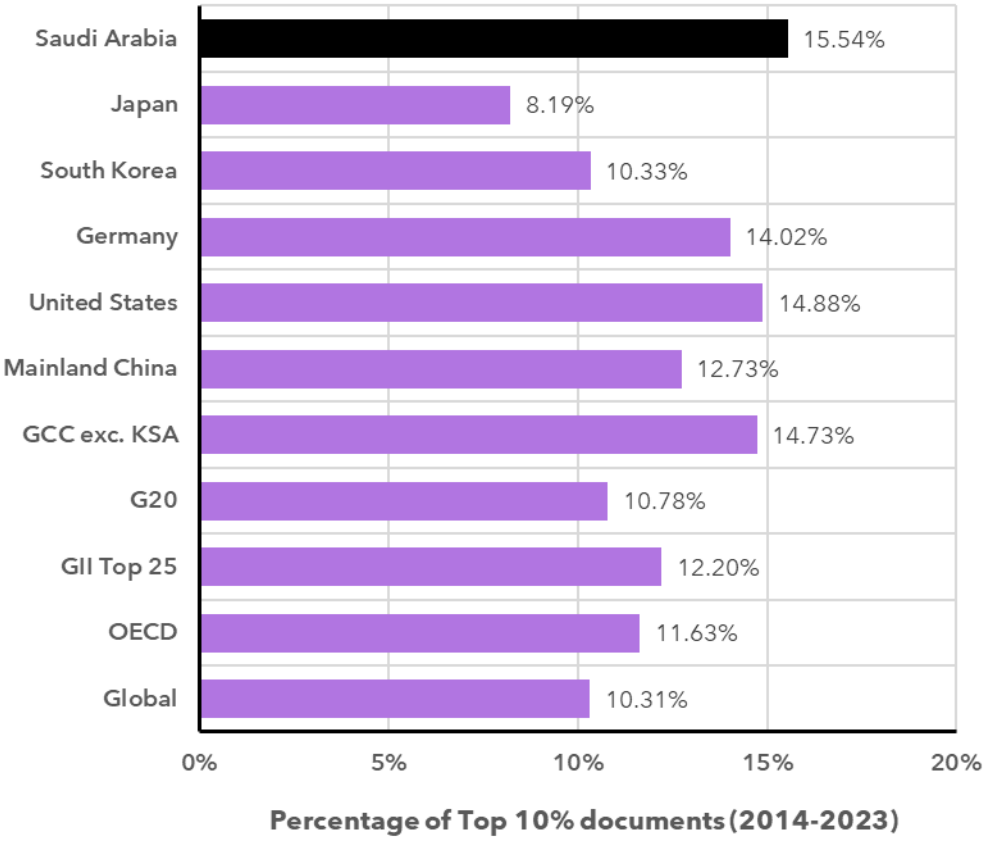

Figure 9: Percentage of Top 10% documents from overall research output in the period 2014-2023

3.2.4 Funding dynamics analysis

Funding is an important part of the research process and is essential to secure the required resources to perform the research. In Figure 10 we see the percentage of papers from overall research output that have a funding acknowledgment. It is important to note that analyzing funding acknowledgement does not indicate the type of funding received for a research project, nor the specific relationship between a particular author and the funding provided. In addition, authors of a publication may choose not to acknowledge funding received. Nevertheless, the analysis of funding acknowledgements can provide important information on the funding dynamics of a given entity or location.

When looking at the number of publications with funding acknowledgment from overall publications in Saudi Arabia we notice a percentage of ~60% higher than that of the global baseline, GCC excluding Saudi Arabia, United States, OECD and G20 and similar to that of Japan, GII top 25 and Germany but lower than that of Mainland China and South Korea.

The highest percentage of publications with funding acknowledgment is observed in Mainland China among the considered benchmark countries, with ~82%.

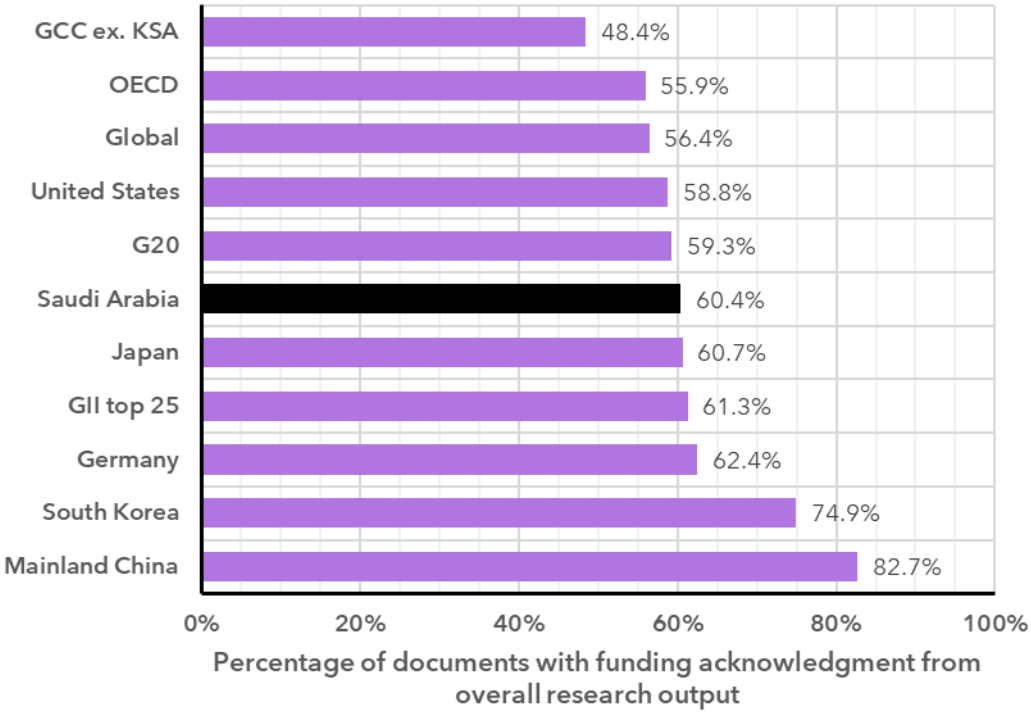

Figure 10: Percentage of documents with funding acknowledgment from overall research output in the period 2014-2023

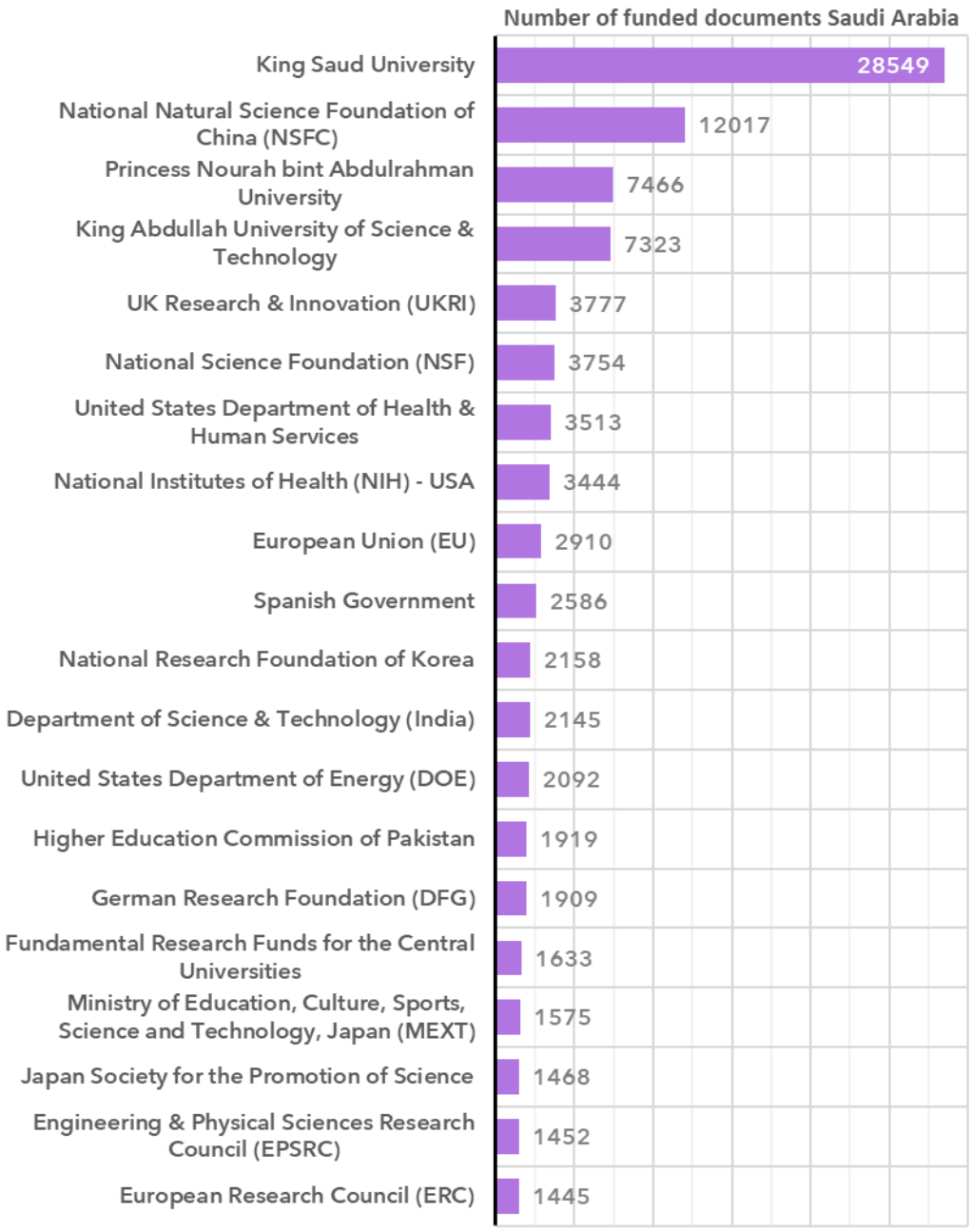

Figure 11: Saudi Arabia top 20 funding organizations of Saudi Arabia publications in terms of number of documents in the period 2014-2023

In Figure 11, the top 20 funding organizations of Saudi Arabia publications with industry collaborations are ranked by the number of documents that have been funded collaborations. The top three funding organizations are King Saud University followed by National Natural Science Foundation of China (NSFC) and Princess Nourah bint Abdulrahman University with 28549, 12017 and 7466 documents, respectively.

In general, we notice several international funding organizations among the top 20. This shows the ability of Saudi affiliated researchers to attract international funding and/or collaborate with international researchers. On the other hand, we do not historically observe a central Saudi funding acknowledgement organization, but rather the main Saudi funding organizations are academic institutions. The establishment of RDIA, including responsibilities as a central funding entity enables fund distribution according to nationally aligned criteria such as but not limited to

missions, performance and priorities areas rather than concentrating funds in a certain organization.

RDIA has introduced several funding initiatives centred on the national priority areas. For example, the Saudi Basic Science Initiative aims to strengthen basic and fundamental scientific research within the Kingdom. The Saudi Applied Research and Technology Initiative focuses on advancing technology development and commercializing research outputs.

Additionally, the Reactivation and Rebuilding of Existing Labs Initiative is designed to enhance the capabilities of existing research facilities, ultimately boosting both the volume and quality of research output in Saudi Arabia. Within these initiatives, RDIA has recently allocated 120 million SAR to support 100 research groups in the Health and Wellness sector, 135 million SAR for developing infrastructure in 36 research labs within the same field, and another 120 million SAR for research grants in the Sustainability and Essential Needs national priority area.

This targeted funding strategy is expected to significantly enhance Saudi Arabia's research output in these critical domains.

3.2.5 International collaboration dynamics analysis

The percentage of Saudi Arabia papers with an international collaboration of ~74% is higher than that of all considered benchmark countries/regions as shown in Figure 12. At the same time this means that Saudi Arabia has the lowest number of papers with only national affiliations.

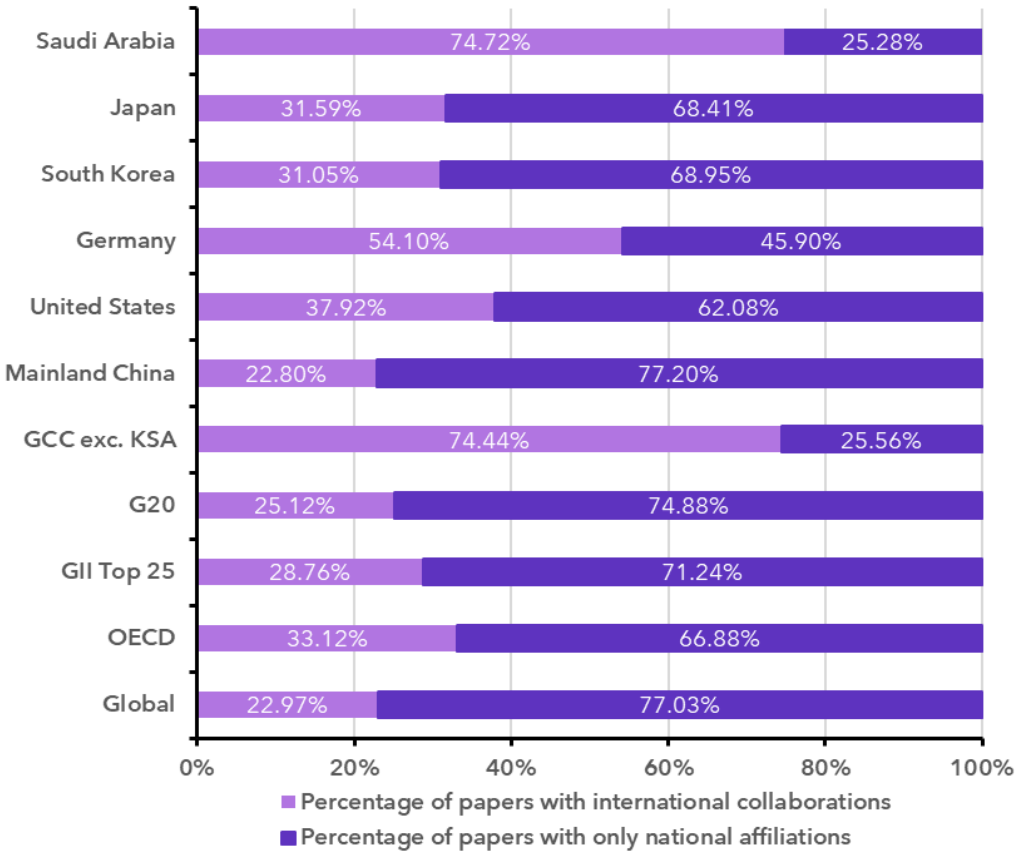

Figure 12: Percentage of papers with an international collaboration or only national affiliations in the period 2014-2023

Having high percentages of international collaborations have several advantages. For example, research with international collaborations enhances research quality and academic reputation, broadens research horizons and resources, addresses global challenges through united efforts and builds international networks. At the same time,

building local expertise and skills is essential for innovation and for enhancing and/or building a knowledge economy.

Therefore, there is an opportunity to balance and enhance the percentage of papers performed locally in comparison to ones performed through international collaboration. Expanding research grants specifically aimed at developing local expertise in national priority areas can significantly boost research capabilities. Initiatives like the Young Scholars Grant and the Research Consortium Grant, launched by RDIA under the Saudi Basic Science Initiative, exemplify such efforts.

Additionally, RDIA fosters local collaboration through initiatives like the National Semiconductor Hub and the Innovation Districts Alliance. These efforts are instrumental in further developing local expertise.

Egypt, followed by India and Pakistan had the highest number of documents in collaboration with Saudi Arabia affiliated researchers in the period 2014-2023, with 60,824, 38,974 and 37,794 documents respectively as shown in Figure 13 and Figure 14. In terms of citation impact measured by the CNCI, papers in collaboration with Japan followed by Spain and Taiwan had the highest citation impact with a CNCI of 4.19, 3.65, and 3.52, respectively.

Nevertheless, research with all the top 20 collaborating countries with Saudi Arabia resulted in a CNCI higher than 1, reflecting a performance higher than the global average.

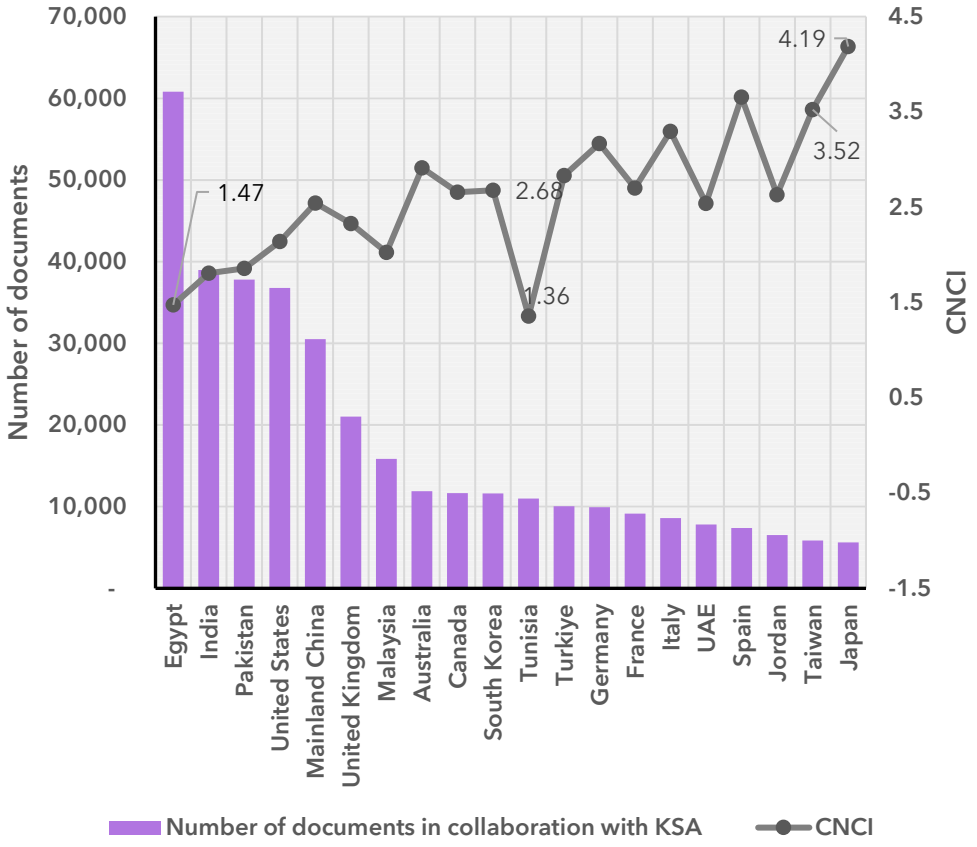

Figure 13: Top 20 collaborating countries with Saudi Arabia in the period 2014-2023

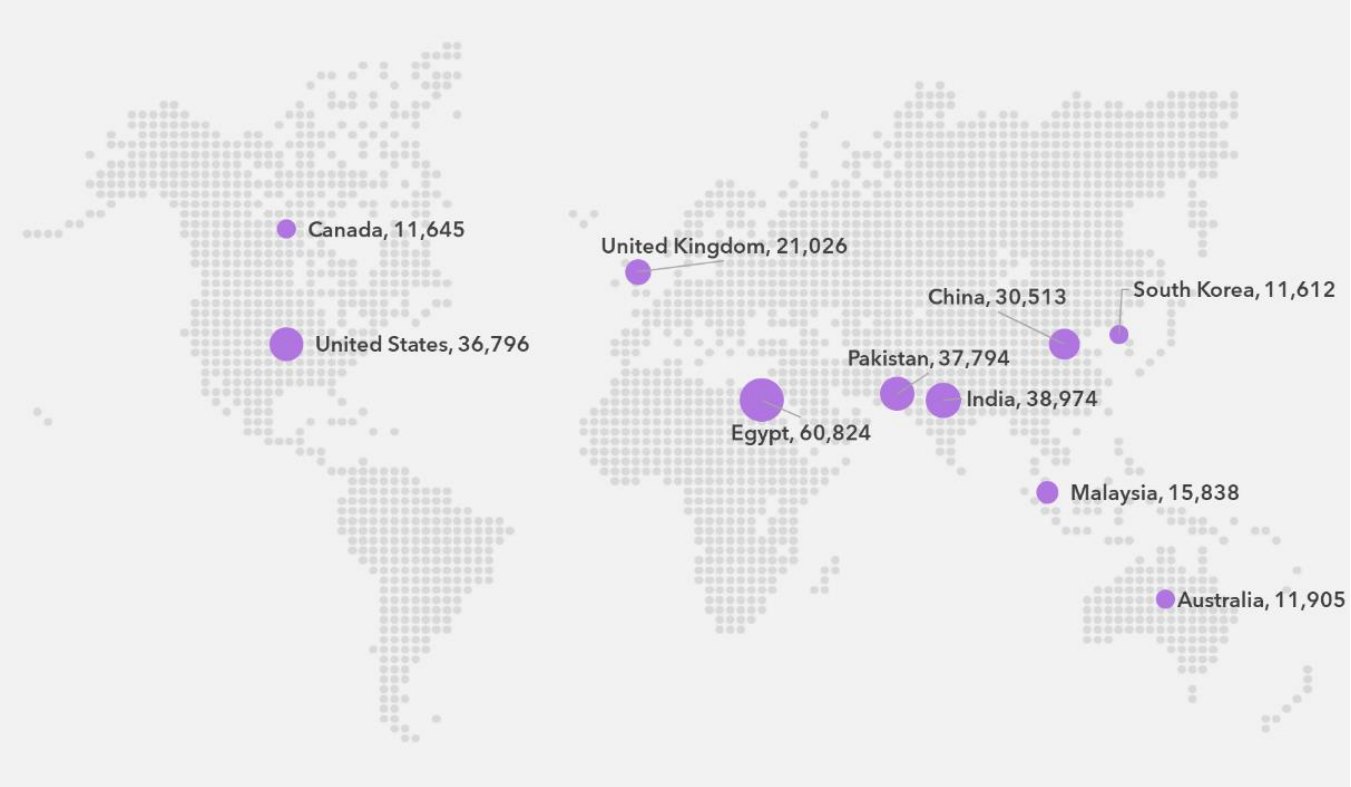

Figure 14: Top 10 collaborating countries with Saudi Arabia in the period 2014-2023

3.2.6 Open access publications analysis

The number and percentage of Saudi Arabia's open access documents increased continuously from 2014 till 2023 as shown in Figure 15. Moreover, the percentage of open access documents from overall research output of Saudi Arabia was higher than that of all considered countries/regions except for Germany (Figure 16).

This reflects a relatively high percentage of Saudi Arabia's open access documents. Open access has several benefits.

For example, it increases visibility of research as potentially more people are able to view research findings, it strengths research integrity as research outputs are freely available, enhances collaboration possibilities as more potential collaborators can view the research outputs and last but not least can potentially lead to higher number of citations.

Accordingly, the continuous increase in Saudi Arabia's number and percentage of open access documents as well as the relatively high percentage of open access documents in comparison to other considered countries/regions, shows the efforts of Saudi Arabia to enhance research visibility, accessibility and eventually research impact.

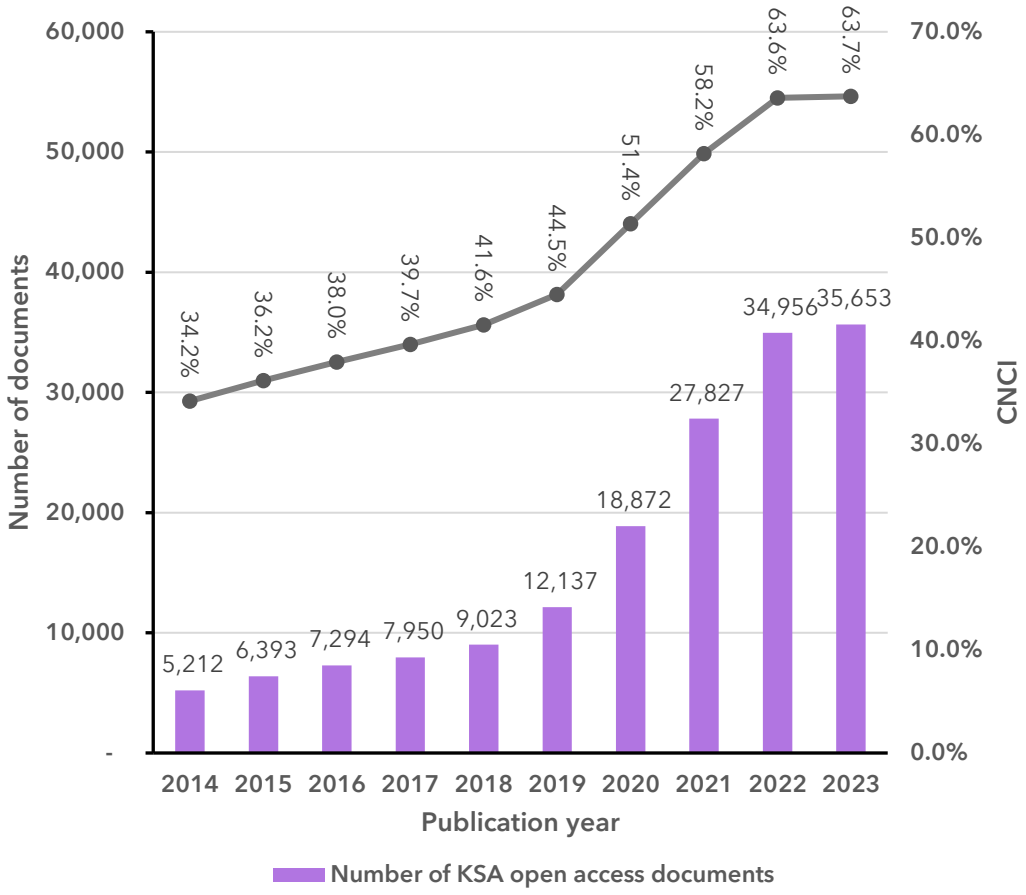

Figure 15: Number and percentage of Saudi Arabia open access documents in the period 2014-2023

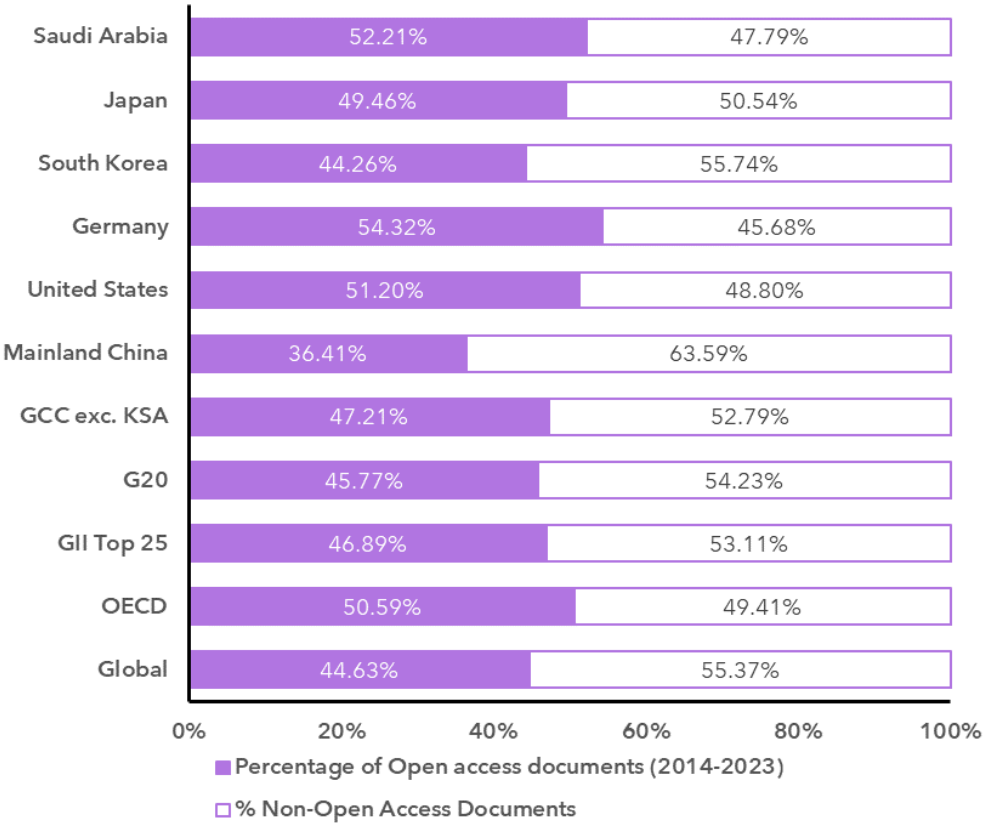

Figure 16: Percentage of open access documents from overall research output in the period 2014-2023

The top Saudi organizations in terms of number of open access documents in the period 2014-2023 are King Saud University with 34,112 followed by King Abdulaziz University with 26,313 and King Abdullah University of Science & Technology with 13,107 documents as shown in Figure 17.

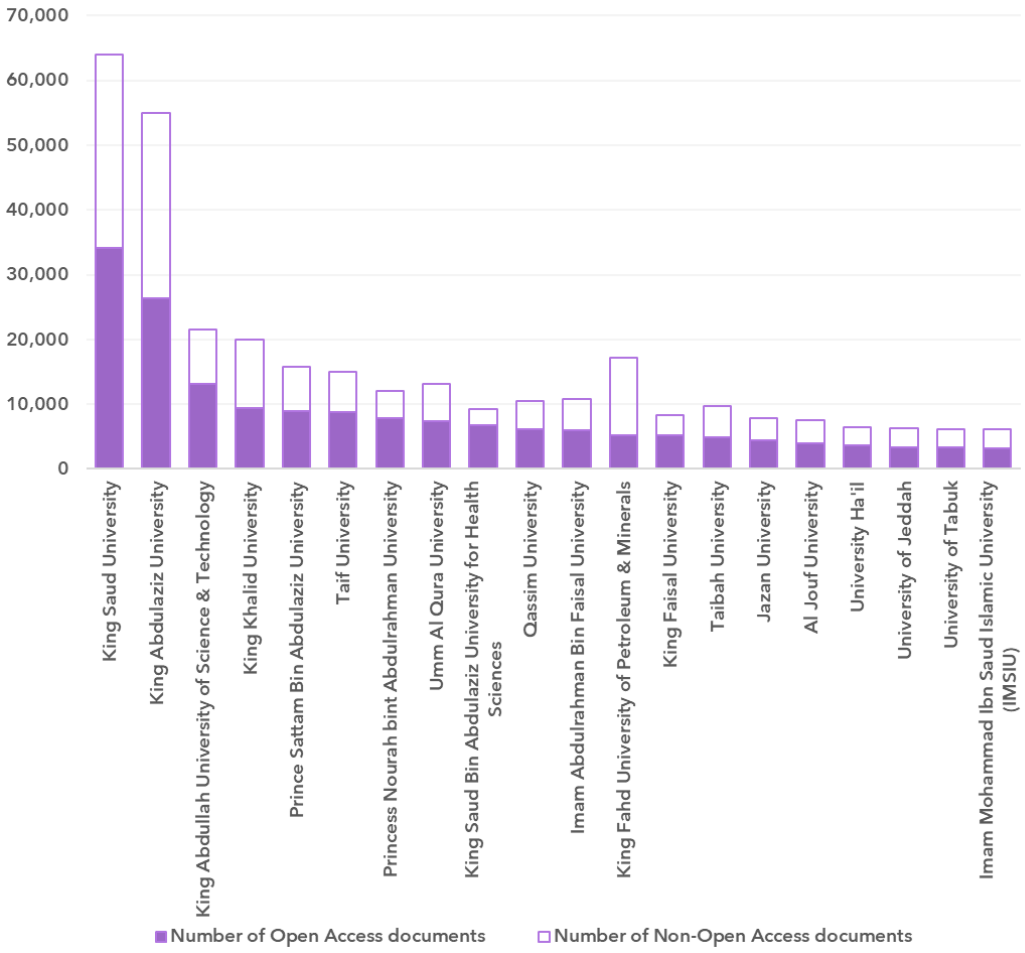

Figure 17: Top 20 Saudi organizations in terms of number of open access documents in the period 2014-2023

In terms of percentage of open access documents from overall research output in the same period, King Saud Bin Abdulaziz University for Health Sciences has the highest percentage with 73.72% followed by Princess Nourah bint Abdulrahman University with 64.53% and King Faisal University with 61.91% as shown in Figure 18.

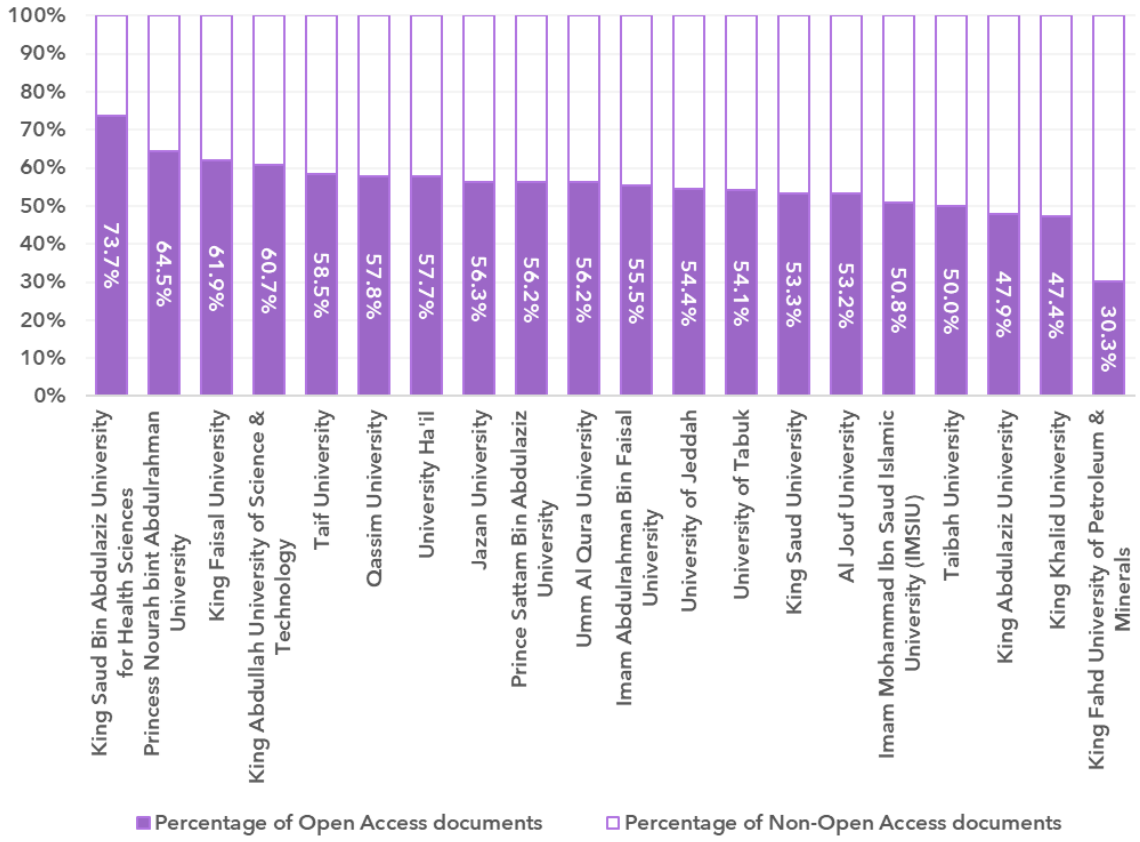

Figure 18: Top 20 Saudi organizations in terms of percentage of open access documents in the period 2014-2023

3.2.7 Saudi Arabia research output in United Nations Sustainability Development Goals research areas

The 2030 Agenda for Sustainable Development, adopted by all United Nations Member States in 2015, provides a shared blueprint for peace and prosperity for people and the planet, now and into the future. Key focus is the 17 Sustainable Development Goals (SDGs)[3]. In this context, Clarivate introduced the Sustainable Development Goals schema, which allows to explore and analyze the research output of an entity along the 17 SDGs. The schema is based on Category-to-category mapping where Sustainable Development Goals are mapped to sets of related Micro Citation Topics (for more information see Sustainable Development Goals Schema). Accordingly, to analyze Saudi Arabia research output along the 17 SDGs we use this Schema.

Saudi Arabia had put forward several efforts to achieve the SDGs. Among which, fiscal measures are being implemented to create fiscal space to finance the specific initiatives outlined in Vision 2030 and SDGs. Saudi Arabia has made remarkable progress in economic and social development. Since then, Saudi Arabia and UNDP have built a strategic partnership for development[4]. The implemented efforts and initiatives along the SGDs are outlined on Saudi Arabia national portal GOV.SA.

In Figure 19, we examine here the research output of Saudi Arabia along the SDGs in the period 2014-2023. In this period, the number of Saudi Arabia documents in the SDGs areas increased continuously from 9,719 documents in 2014 to 38,159

[3] https://sdgs.un.org/goals
[4] https://www.my.gov.sa/

documents in 2022 and then slightly decreased to 37,990 in 2023 as shown in Figure 19.

Considering that the percentage also increased from ~63% in 2014 to ~68% in 2023, this shows the number of Saudi Arabia documents in the SDGs grew at a rate slightly higher than the overall growth rate as it is showing in Figure 19.

This indicates a focus of Saudi Arabia affiliated researchers to publish in SDG related areas and the efforts performed to ensure research contribution to the SDGs.

Saudi Arabia had the highest number of documents published in the period 2014-2023 in relation to the SDG 3, Good Health and Well-being, followed by SDG 7, Affordable and Clean Energy and SDG 13, Climate Action as shown in Figure 20.

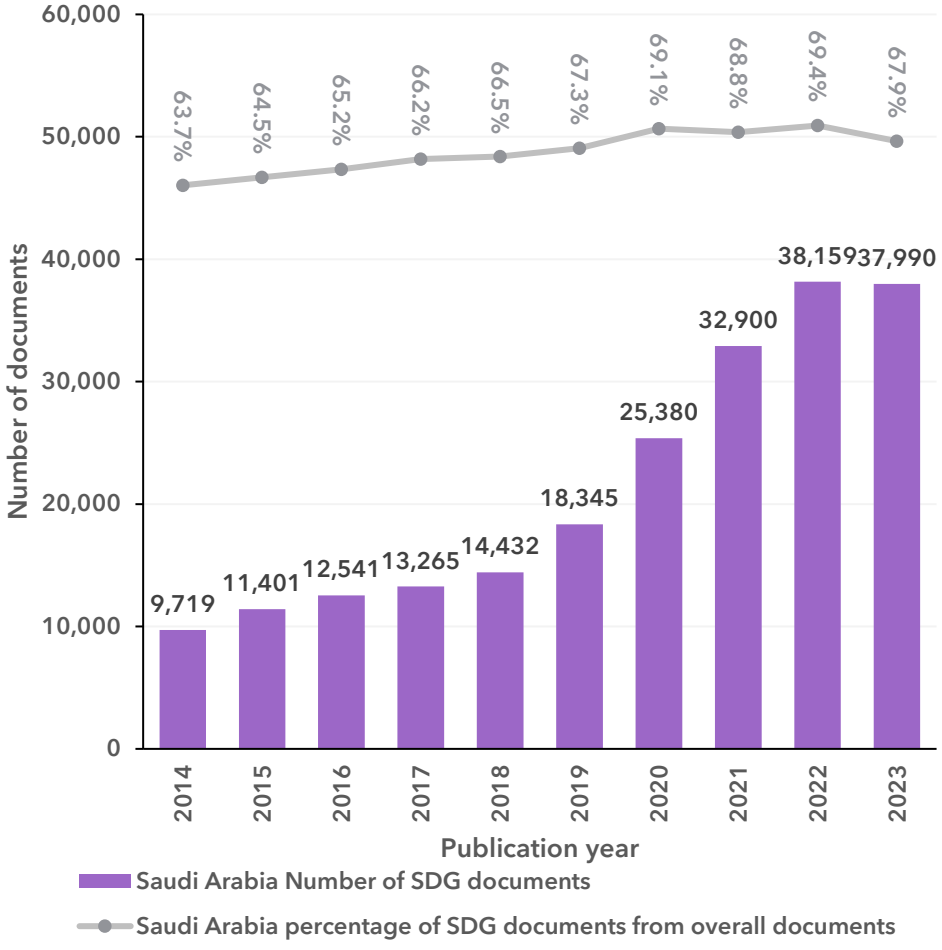

Figure 19: Saudi Arabia number and percentage of documents in the SDG research areas

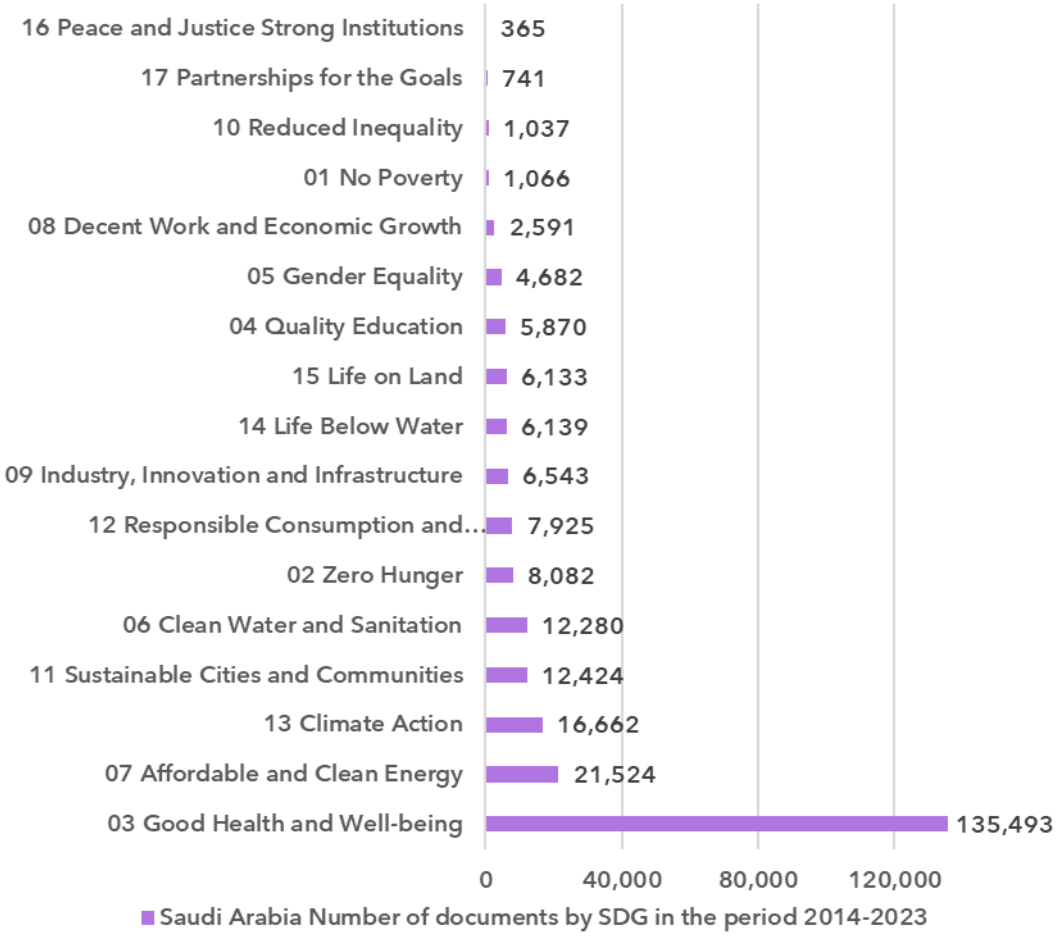

Figure 20: Saudi Arabia number of documents in the SDG research areas and in the period 2014-2023

3.2.8 Top 20 Saudi organizations in terms of number of publications

The top 20 organizations in Saudi Arabia in terms of number of documents published in the period 2014-2023 are King Saud University with 63,973 documents followed by King Abdulaziz University with 54,957 and King Abdullah University of Science & Technology with 21,608 documents as shown in Figure 21.

In terms of citation impact measured by the CNCI, the highest CNCI is achieved by King Abdullah University of Science & Technology followed by University Ha'il and King Abdulaziz University with a CNCI of 1.77, 1.66 and 1.62 respectively.

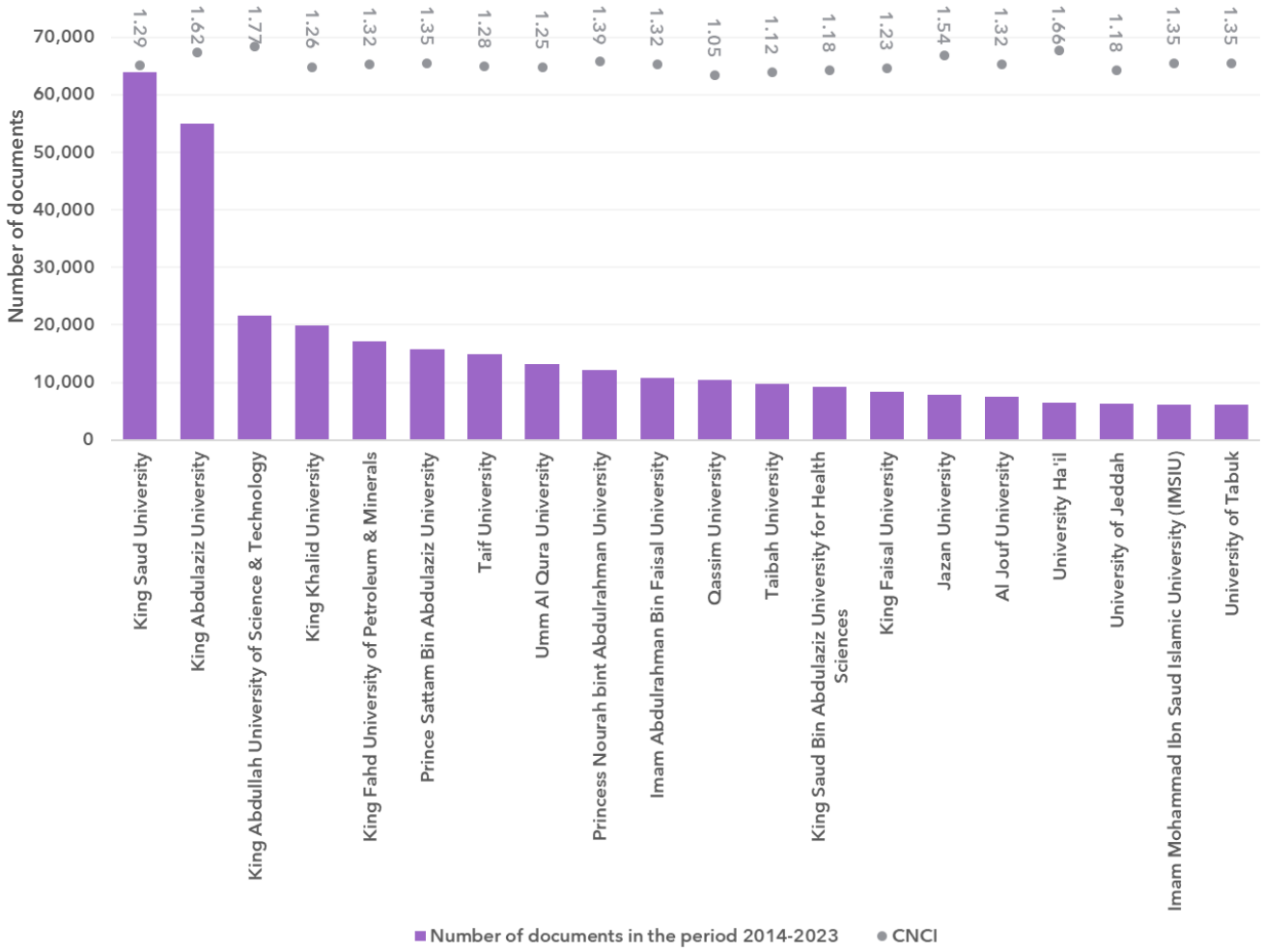

Figure 21: Top 20 Saudi organizations in terms of documents published in the period 2014-2023

3.2.9 Top 20 Saudi affiliated researchers in terms of number of publications

The top 3 Saudi affiliated researchers in terms of number of documents published in the period 2014-2023 are Ahmed Alsaedi affiliated to King Abdulaziz University with 1,836 documents followed by Abdullah M. Asiri also affiliated to King Abdulaziz University with 1,654 documents and Mohamed-Slim Alouini affiliated to King Abdullah University of Science & Technology with 1,152 documents as shown in Table 1.

Among the top 20, Thabet Abdeljawad affiliated to Prince Sultan University had the highest CNCI with 3.57, while Abdullah M. Asiri had the highest number of Top 1% documents with 82 documents and Ahmed Alsaedi had the highest number of Top 10% documents with 576 documents.

Table 1: Top 20 Saudi affiliated researchers in the period 2014-2023 in terms of number of published documents

Name	Affiliation	Web of Science Publications	CNCI	Documents in Top 1%	Documents in Top 10%
Alsaedi, Ahmed	King Abdulaziz University	1836	1.86	57	576
Asiri, Abdullah M.	King Abdulaziz University	1645	1.90	82	444
Alouini, Mohamed-Slim	King Abdullah University of Science & Technology	1152	1.78	39	256
Mahmoud, Mohammed Attia	Prince Sattam Bin Abdulaziz University	1126	2.16	67	346
Naglah, Ahmed Mohamed	King Saud University	920	1.83	42	242
Nisar, Kottakkaran Sooppy	Prince Sattam Bin Abdulaziz University	892	2.46	57	309
Abdulsalam, Abdulla	King Abdulaziz University	652	2.35	43	228
ALOthman, Zeid A.	King Saud University	616	1.81	52	154
Luque, Rafael	King Fahd University of Petroleum & Minerals	594	1.46	16	131
Ahmad, Bashir	King Abdulaziz University	564	1.83	18	163
Saad, Mekhilef	King Abdulaziz University	550	1.67	22	132
Yahia, Ibrahim Sayed	King Khalid University	543	1.16	4	76
Umar, Ahmad	Najran University	534	1.38	14	114
Seadawy, Aly R.	Taibah University	489	3.24	46	229
Abdeljawad, Thabet	Prince Sultan University	482	3.57	55	210
Hallit, Souheil	Holy Spirit Univ Kaslik	478	1.43	6	93
Ahmed, Ahmed	Alfaisal University	477	1.25	11	67
Aslam, Muhammad	King Abdulaziz University	449	0.82	0	37
NAUSHAD, M.	King Saud University	435	2.58	47	181
Abdel-Daim, Mohamed M.	Batterjee Medical College	421	1.72	11	107

3.2.10 SWOT analysis of the national priority areas

In this part we have a more granular look by analyzing the research performance of Saudi Arabia along the national priority areas. The aim is to have an overview of the performance of Saudi Arabia in the national priority areas in terms of research output and impact.

To achieve this we perform a Strength, Weakness, Opportunity and Threat (SWOT) analysis. The analysis is based on two main metrics: productivity relative to the global productivity and impact measured by the CNCI. For a more detailed description, please see the following Strengths, Weakness, Opportunities and Threats Analysis (SWOT).

As shown in Figure 22, all national priority areas can be classified as strength areas, as they all lie within the upper right quadrate. This means that Saudi Arabia has in all areas a CNCI above 1, i.e. a citation impact above the global average in the same area, as well as a productivity relative to the world above 1, i.e. a share from the world in the corresponding area higher than the share of Saudi Arabia research from the world research in the period 2014-2023. This suggests that Saudi Arabia has a good performance in the national priority areas when considering research output and impact. Only the area of Health and Wellness lies near the lower boundaries of the upper right quadrate. Thus, improving the research output in this area would be important to preserve the strength status of this national priority area, which is an essential basis to also enhance innovations within this area. Saudi Arabia has the highest impact and relative output in the area Energy and Industrials, followed by a very close performance in both Sustainability and Essential Needs as well as Economies of the Future. Thus, in all these three areas, Saudi Arabia has a solid research performance that could support enhancing innovations in them.

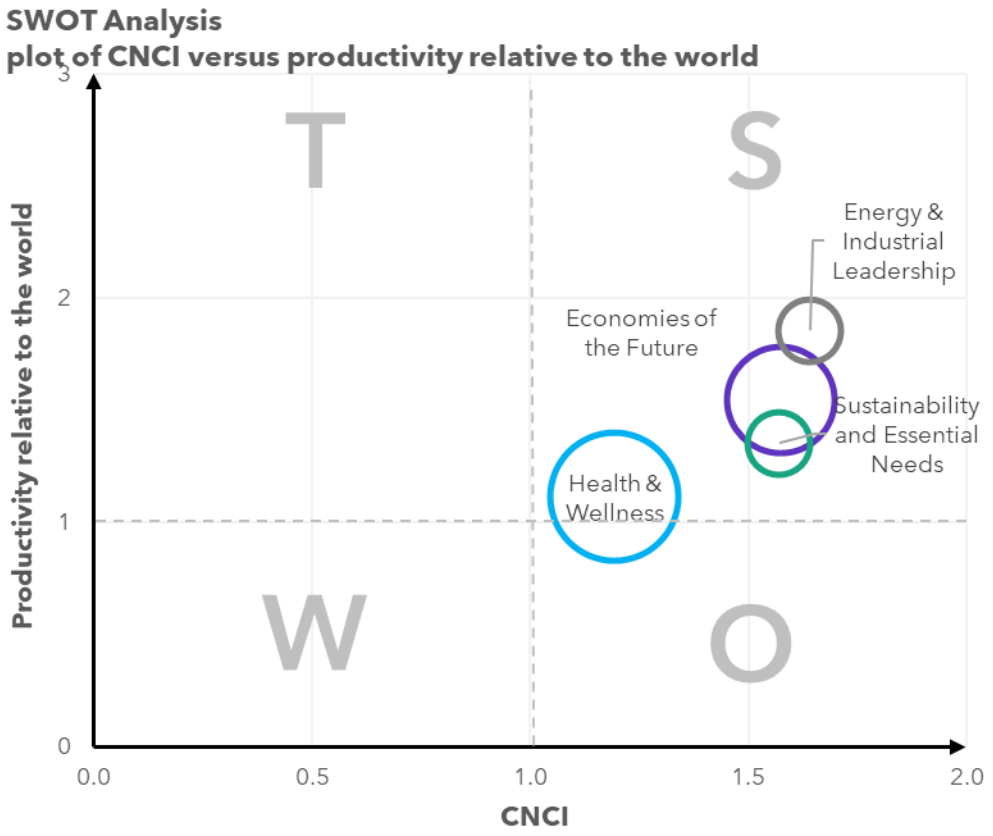

Figure 22: SWOT analysis of Saudi Arabia in the national priority areas. The y-axis shows the productivity relative to the global productivity (share of Saudi Arabia from the global productivity in the national priority area normalized by Saudi Arabia's share from global productivity when considering overall research). The x-axis shows the impact relative to the global average.

3.3 Saudi Arabia research output performance in Health and Wellness (HW)

3.3.1 Research volume analysis

The number of research papers published by Saudi Arabia in the national priority area of Health and Wellness has shown consistent growth, increasing from 2,697 papers in 2014 to 13,166 papers in 2023, as illustrated in Figure 23.

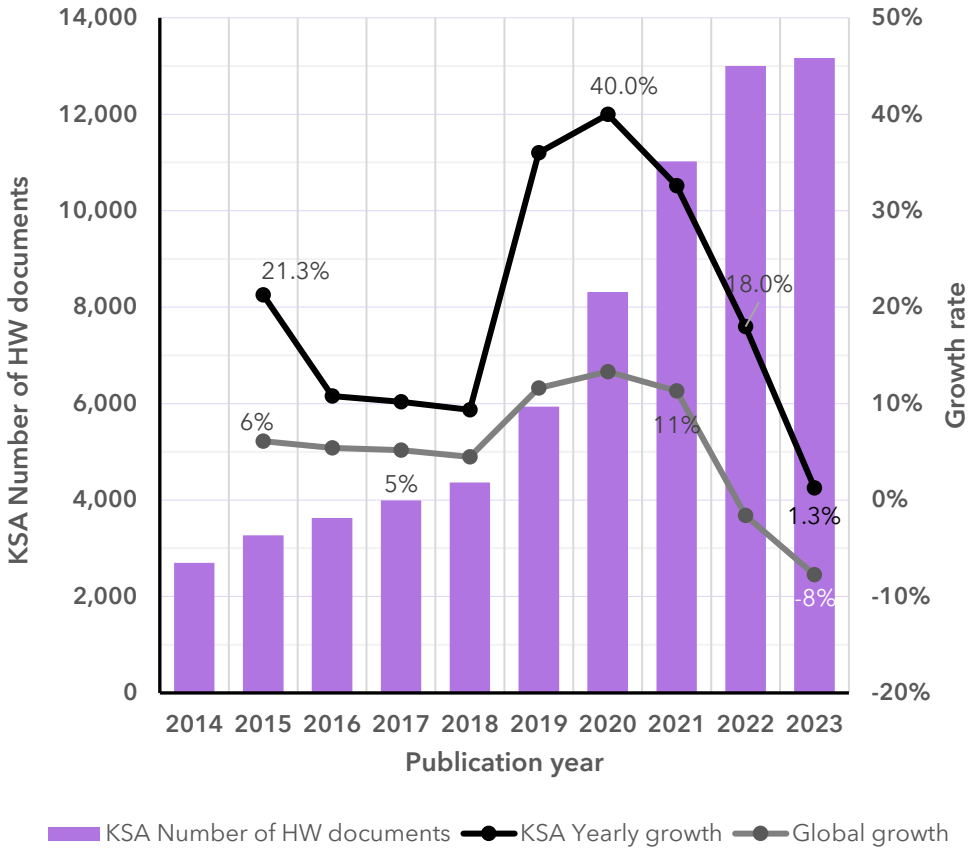

Figure 23: Saudi Arabia number of papers and growth in the national priority area Health and Wellness

This demonstrates double-digit growth in most of the years analyzed, with growth rates exceeding 30% in certain years, significantly outpacing the global growth rate in the same field. Notably, while the global growth rate declined by 8% between 2022 and 2023, Saudi Arabia maintained a positive growth rate of 1.3%. Over the period considered, Saudi Arabia achieved an annual average growth rate nearly four times higher than the global average and surpassed all other benchmark countries or regions, as shown in Figure 24. These trends underscore the strong national emphasis on enhancing research activity within this priority area.

Figure 25 shows the number of active Saudi affiliated researchers per year in the area of Health and Wellness. For more information on the methodology used to investigate the number of active researchers please see the section Number of active researchers.

As we have seen earlier the number of Saudi Arabia's papers in the area Health and Wellness increased continuously in the last 10 years 2014-2023. Similarly, the number of active researchers in this area also increased continuously in the same period. This reflects a x6.5 increase in this period indicating the growing research population in this national priority area.

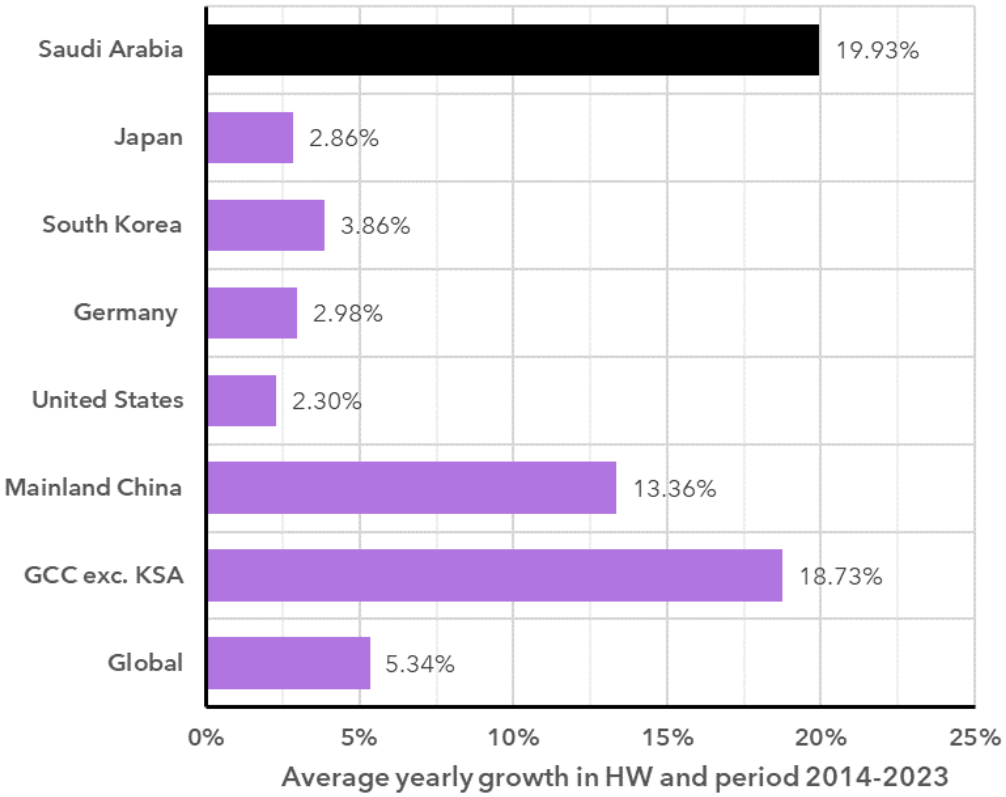

Figure 24: Average yearly growth of number of papers in the area Health and Wellness and in the period 2014-2023

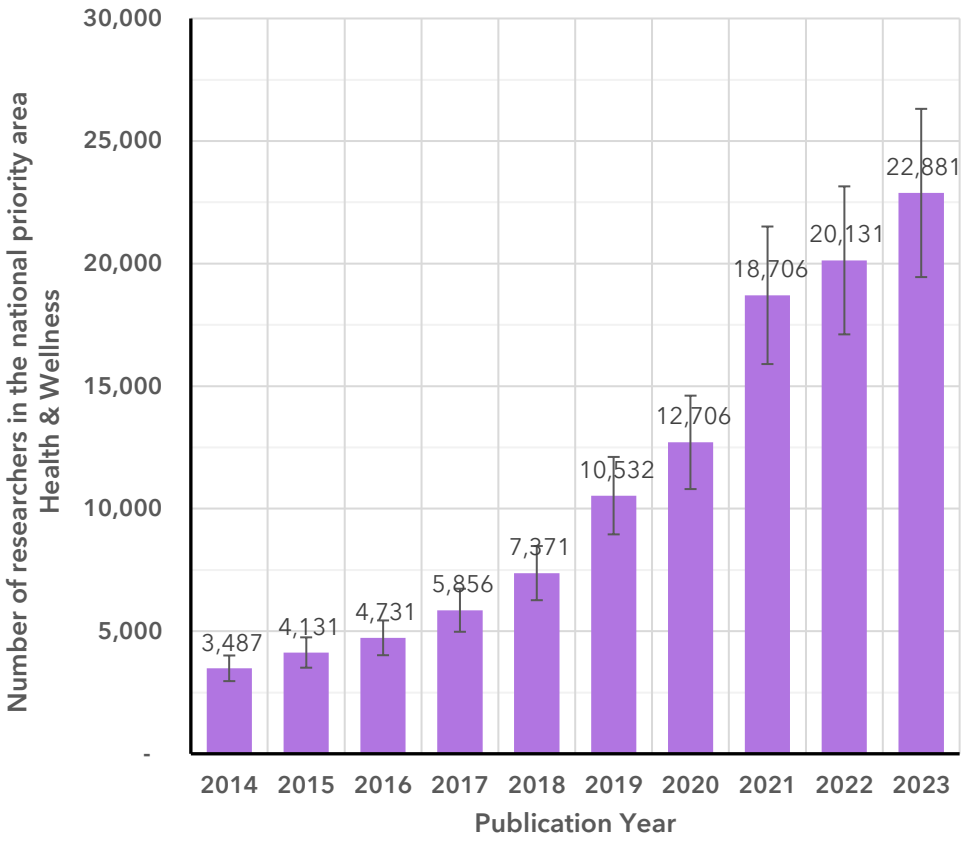

Figure 25: Number of active Saudi affiliated researchers in the area Health and Wellness

3.3.2 Citation impact analysis

The category normalized citation impact (CNCI) of Saudi Arabia during the period 2014–2023 consistently exceeded 1, signifying a citation impact at least equal to the global average, as illustrated in Figure 26. During this time, the CNCI varied between 1.02 and 1.40. Saudi Arabia's CNCI in this period and field surpassed those of Japan, South Korea, and Mainland China but fell below the levels observed in Germany, the USA, and the GCC (excluding Saudi Arabia), as depicted in Figure 27.

This reflects a solid citation impact performance, though there is potential for further enhancement. Typically, a decline in citation impact is observed during phases of substantial growth in research output, as the expanding researcher base accumulates knowledge and expertise. This trend was evident in 2018–2019 when research output increased by 36%, accompanied by a 20% reduction in CNCI. However, the CNCI subsequently recovered, reaching 1.23 and 1.19 in 2022 and 2023, respectively. Importantly, the high citation impact was maintained despite the significant expansion in research output during this period

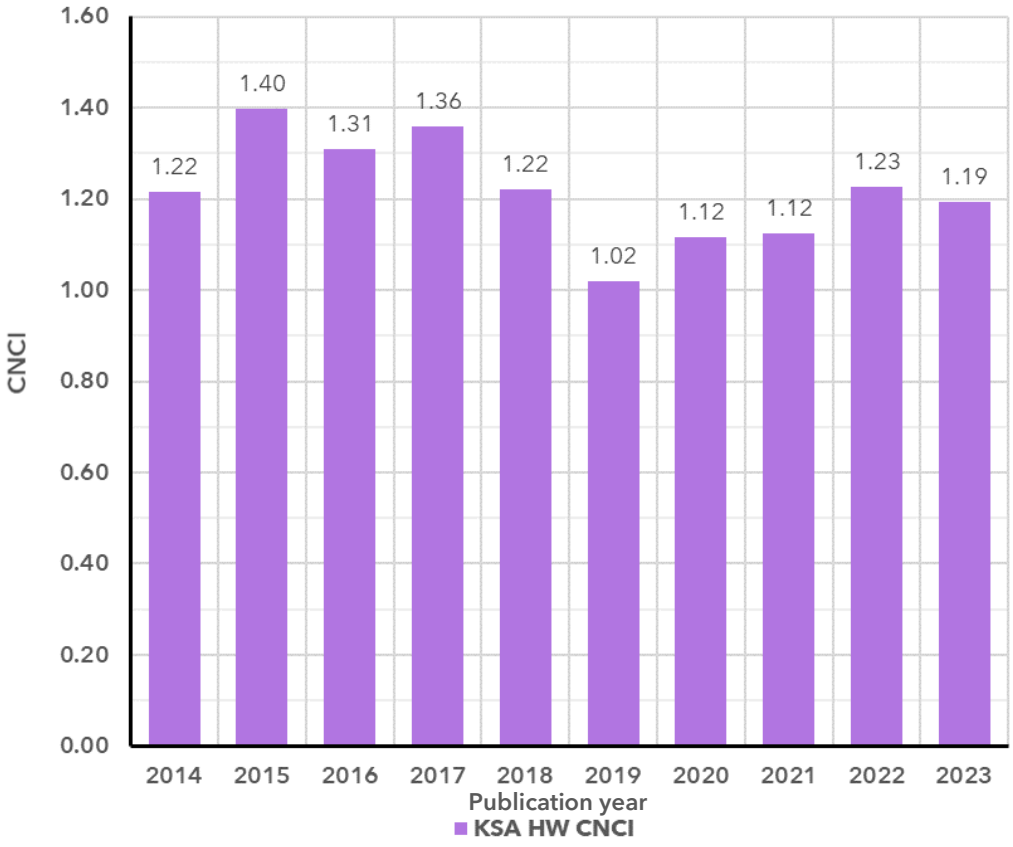

Figure 26: Saudi Arabia yearly category normalized citation impact in the area Health and Wellness

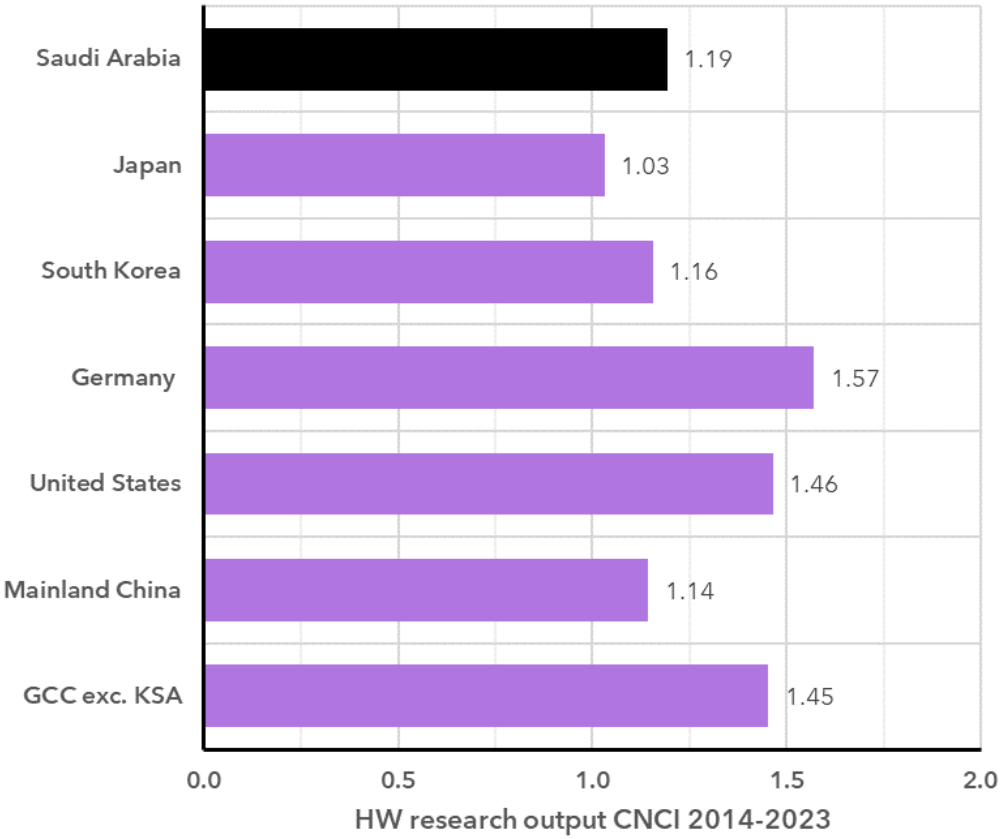

Figure 27: Health and Wellness research output CNCI in the period 2014-2023

3.3.3 Research excellence analysis

The percentage of Saudi Arabia's Top 1% documents in the area of Health and Wellness decreased from 2.23% in 2015 to 1.34% in 2020 and then increased continuously to 1.76% in 2022 as shown in Figure 28. Afterwards the percentage decreased to 1.6% in 2023.

On the other hand, the number of Top 1% documents increased almost continuously from 48 documents in 2014 to 229 documents in 2022 and then decreased to 210 documents in 2023. In general, the percentage of Saudi Arabia's documents in the area of Health and Wellness fluctuated between 1.34% and 2.23%. Considering that the global average performance is ~1.27% as shown in Figure 29, this shows that for all years the performance of Saudi Arabia in this area was at least 5% higher than the global average.

Additionally, when considering Health and Wellness research output over the whole period 2014-2023, Saudi Arabia had a higher percentage of Top 1% documents than Japan, South Korea, Mainland China but lower that of Germany, USA and GCC excluding Saudi Arabia. This shows a relatively good performance of Saudi Arabia in research excellence performance in this area, when considering the Top 1% documents but one that could be further improved.

Typically, we observe a decline in citation impact during periods of rapid growth in research volume, as these times often involve the accumulation of knowledge and expertise across a broader base of researchers. We notice for example that Saudi Arabia's percentage of Top 1% documents in Health and Wellness started to recover in 2021 after a double-digit growth period.

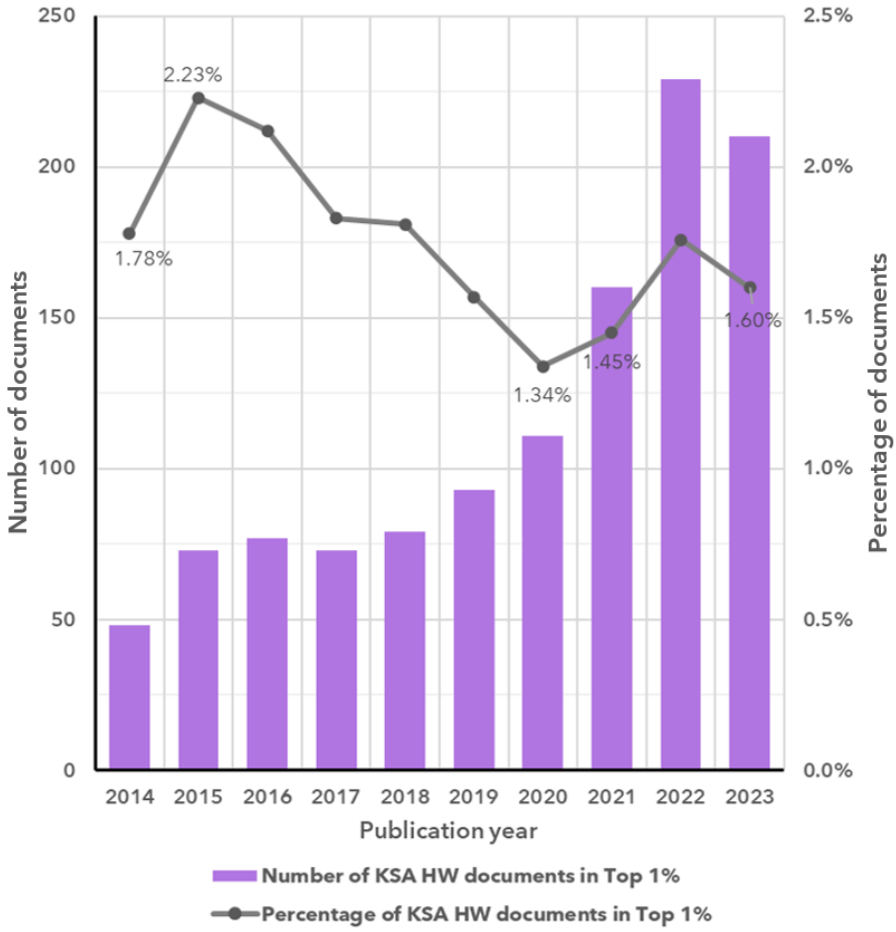

Figure 28: Number and percentage of Saudi Arabia's Top 1% documents in the area Health and Wellness

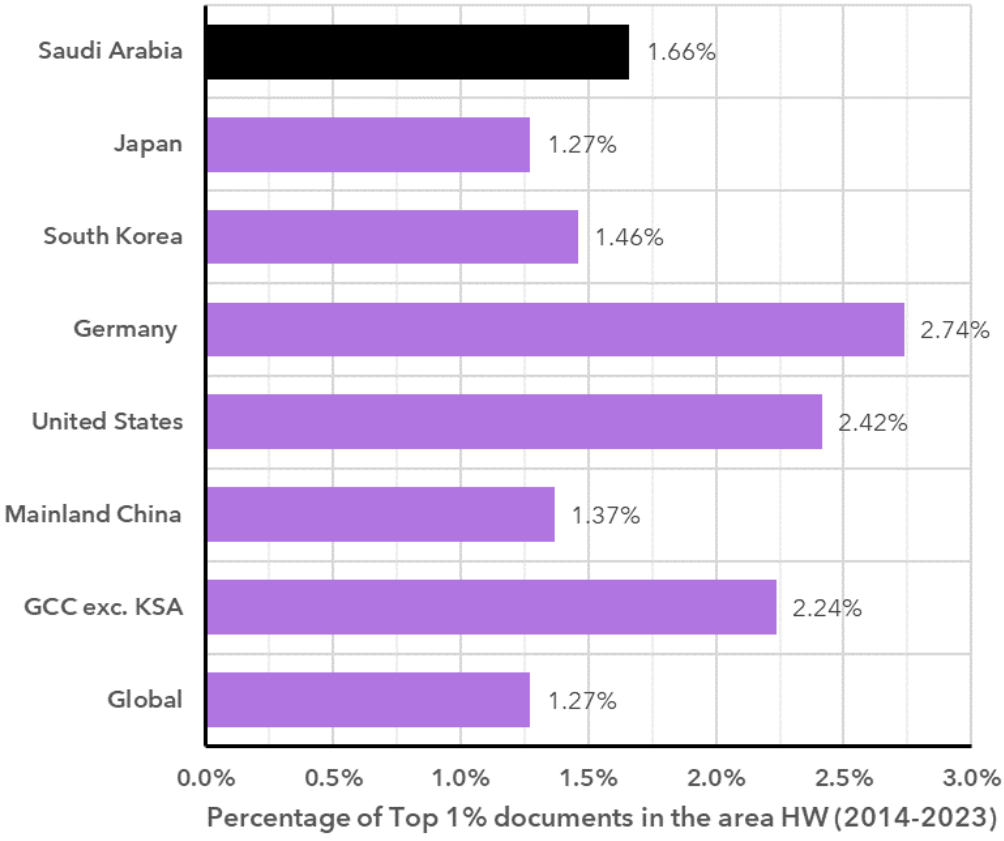

Figure 29: Percentage of Top 1% documents in the Health and Wellness area during the period 2014-2023

The number of Saudi Arabia's Top 10% documents increased continuously from 342 documents in 2014 to 1,863 documents in 2022 and then decreased slightly to 1,611 documents in 2023 as shown in Figure 30.

In the same period the percentage of Top 10% documents decreased from 14.12% in 2015 to 11.32% in 2019 then increased to 14.33% in 2022 and then decreased to 12.24% in 2023. When considering the overall research output in the area Health and Wellness in the period 2014-2023 Saudi Arabia's percentage of Top 10% documents was higher than that of Japan, South Korea and the global average but lower than that of Germany, USA, Mainland China and GCC excluding Saudi Arabia as shown in Figure 31.

Similar to the previous research excellence metrics that we analyzed in this area we notice a relatively good performance of Saudi Arabia that could be further improved. Also, we notice that percentage of Saudi Arabia's Top 10% documents in Health and Wellness started to recover in 2020.

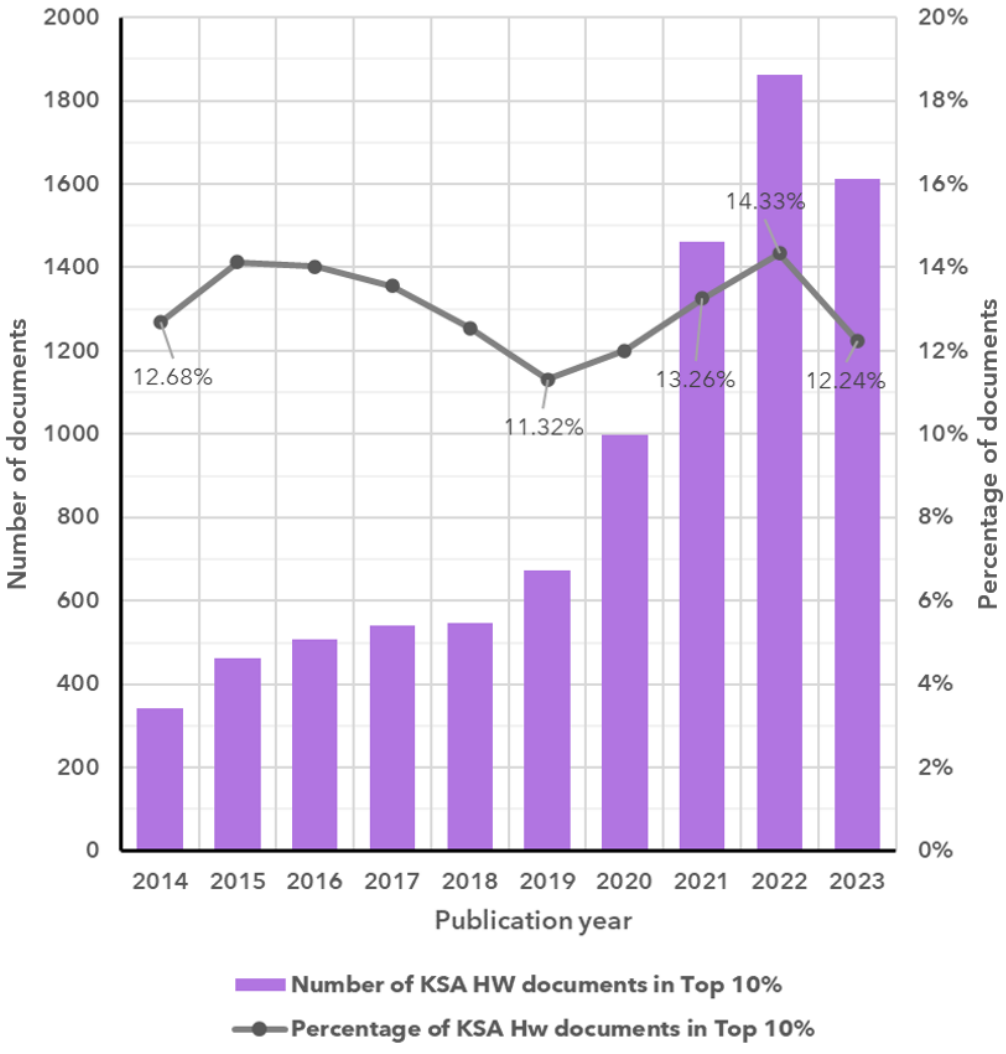

Figure 30: Number and percentage of Saudi Arabia's Top 10% documents in the area Health and Wellness

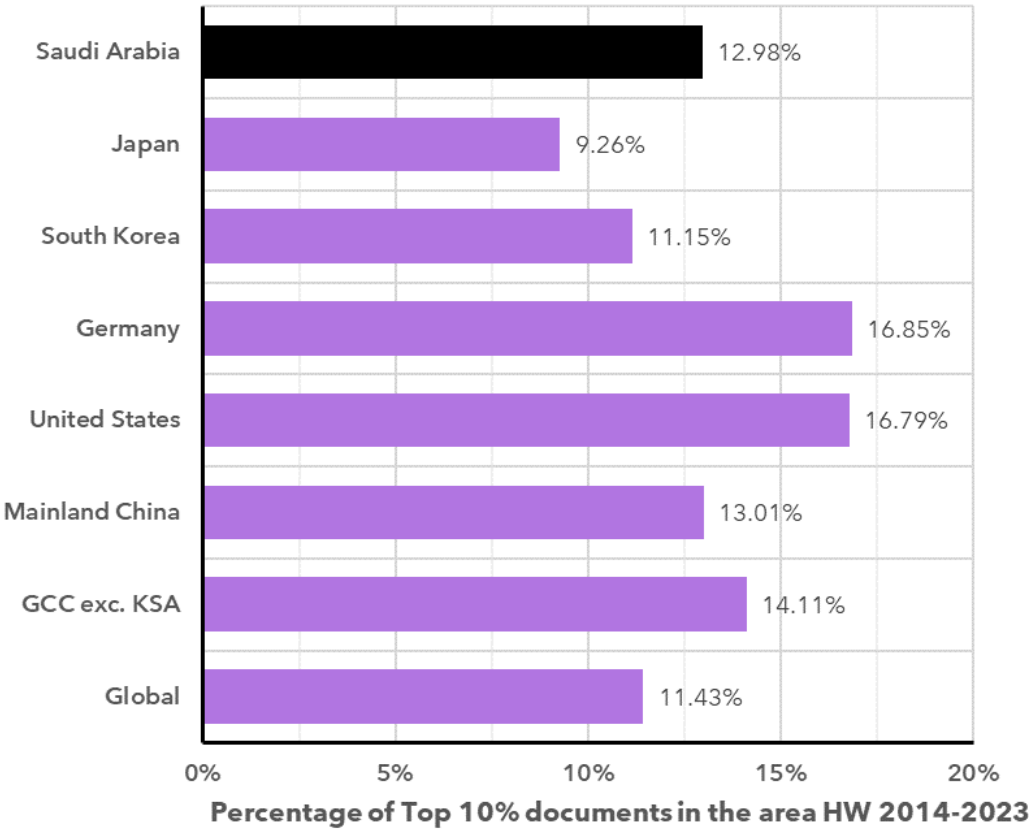

Figure 31: Percentage of Top 10% documents in 2014-2023 in the area Health and Wellness

3.3.4 Funding dynamics analysis

The percentage of Saudi Arabia's papers in the area of Health and Wellness with funding acknowledgement is lower than the global baseline as well as all considered countries/regions except for the GCC excluding Saudi Arabia as shown in Figure 32.

The top 3 funding organizations mentioned in the funding section of Saudi Arabia documents in the area of Health and Wellness during the period 2014-2023 are King Saud University, United States Department of Health & Human Services and the National Institutes of Health (NIH) – USA with 6,436, 1,853 and 1,823 documents respectively as shown in Figure 33.

Saudi Arabia research output in the area Health and Wellness that was funded by Medical Research Council UK (MRC) resulted in the highest citation impact measured by CNCI followed by Japan Society for the Promotion of Science and UK Research & Innovation (UKRI) with a CNCI of 9.84, 9.01, and 8.60, respectively.

The lowest CNCI was observed in papers funded by King Saud University, though the CNCI is still 18% higher than the global average and one should consider the high volume of funded papers relative to the other organizations. We observe here as well that there are three funding organizations based in Saudi Arabia among the top 20. RDIA has recently allocated 120M SAR for 100 research groups and 135M SAR for 36 research lab infrastructure in the area Health and Wellness.

As research publications result from these funded research projects and the respective authors mention RDIA in the funding acknowledgment, this will consequently be reflected in the analysis of the funding data.

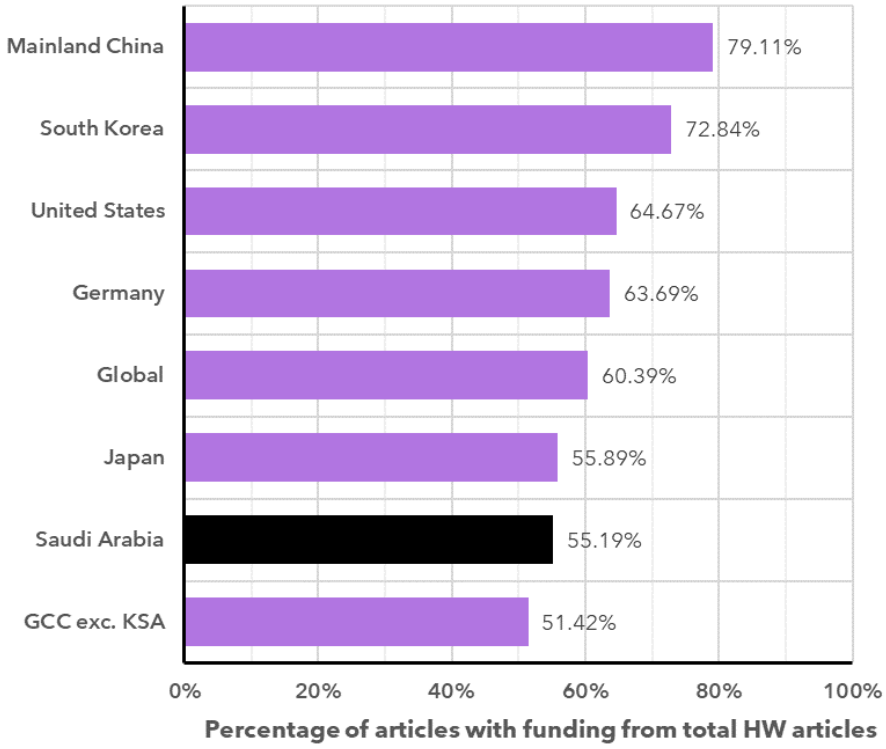

Figure 32: Percentage of publications with funding acknowledgement from overall Health and Wellness publications in the period 2014-2023

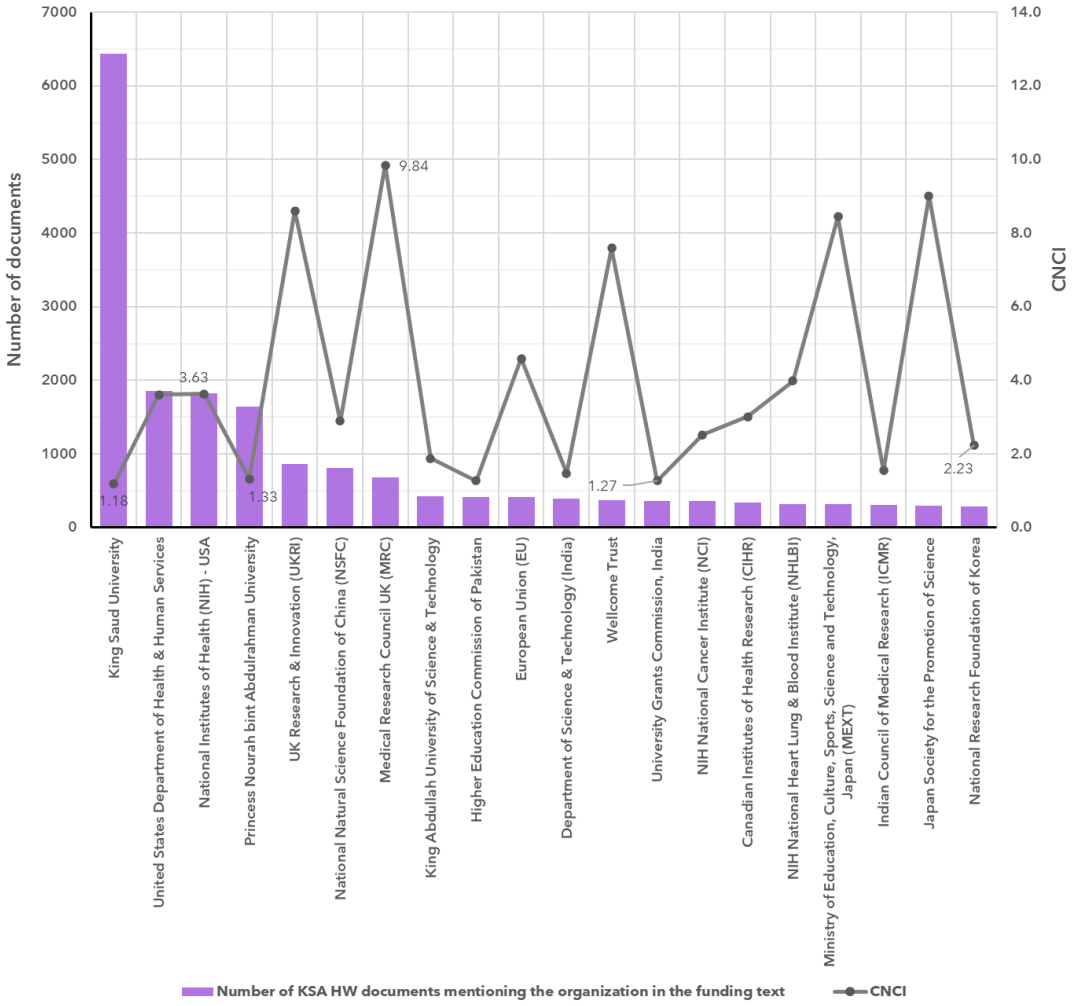

Figure 33: Top 20 funding organizations mentioned in the funding text of Saudi Arabia Health and Wellness papers in the period 2014-2023

3.3.5 International collaboration dynamics analysis

In the area of Health and Wellness the percentage of Saudi Arabia papers with an international collaboration of ~70% is higher than that of all considered benchmark countries/regions except for that of GCC excluding Saudi Arabia as shown in Figure 34. At the same time this means that Saudi Arabia has the lowest number of papers with only national affiliations.

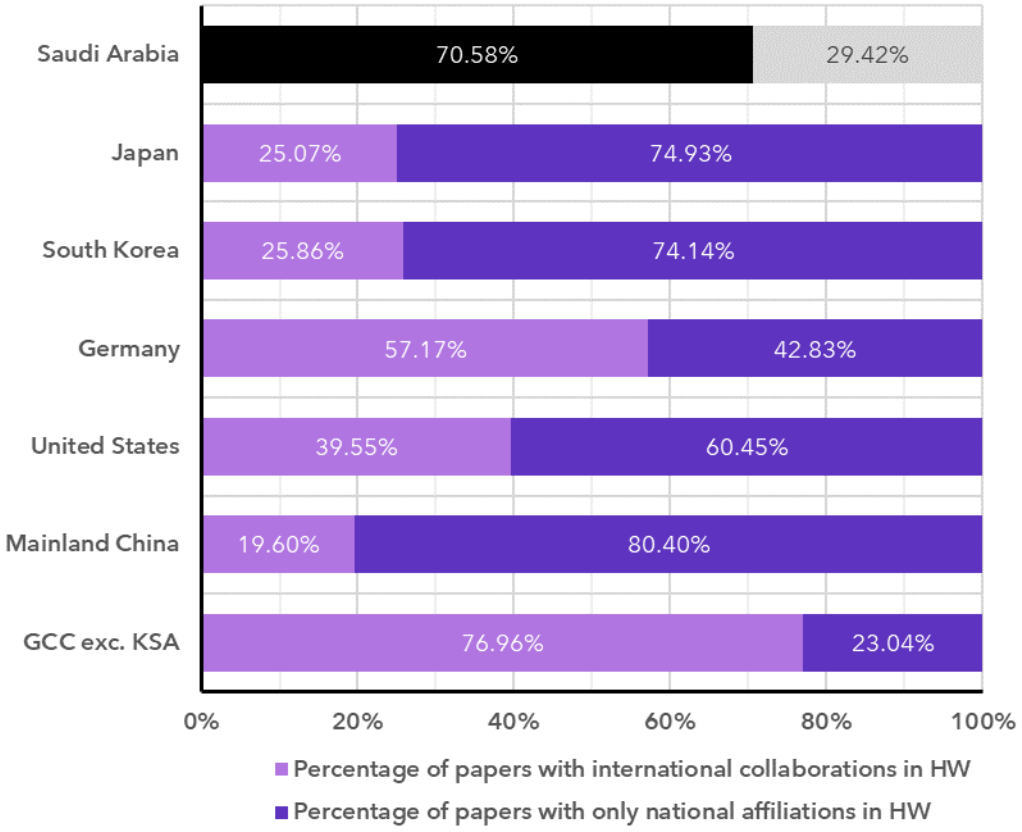

Figure 34: Percentage of papers with an international collaboration or only national affiliations in the area Health and Wellness and in the period 2014-2023

Egypt, followed by India and USA, had the highest number of documents in collaboration with Saudi Arabia affiliated researchers in the national priority area Health and Wellness in the period 2014-2023 with 14,691, 10,002 and 9,700 documents respectively as shown in Figure 35 and Figure 36.

In terms of citation impact measured by the CNCI, papers in collaboration with Netherlands followed by Spain and Japan had the highest CNCI among the top 20 collaborating countries with a CNCI of 7.48, 7.21, and 6.87, respectively. Nevertheless, research with all the top 20 collaborating countries with Saudi Arabia in this area resulted in a CNCI higher than the global average performance.

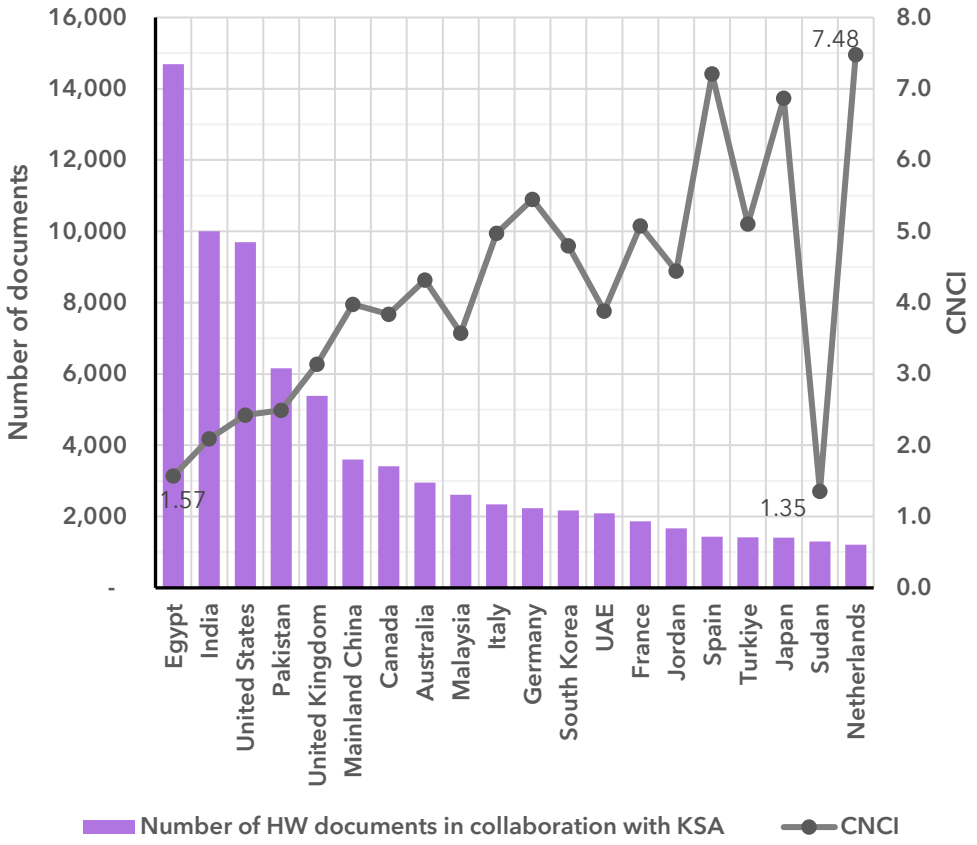

Figure 35: Top 20 collaborating countries with Saudi Arabia in the area Health and Wellness in the period 2014-2023

Figure 36: Top 10 collaborating countries with Saudi Arabia in the area Health and Wellness in the period 2014-2023

3.3.6 Open access publications analysis

In the area Health and Wellness over the period 2014-2023 the number as well as the percentage of open access documents increased continuously reaching 9,799 documents and 73.8% from overall research output in the area Health and Wellness in 2023. The percentage achieved in 2023 is higher than the one observed from the overall research output of 63.7%. Accordingly, this reflects a relatively high percentage of open access documents which could lead to higher visibility of Saudi Arabia's research output in this area and for possibly more citations.

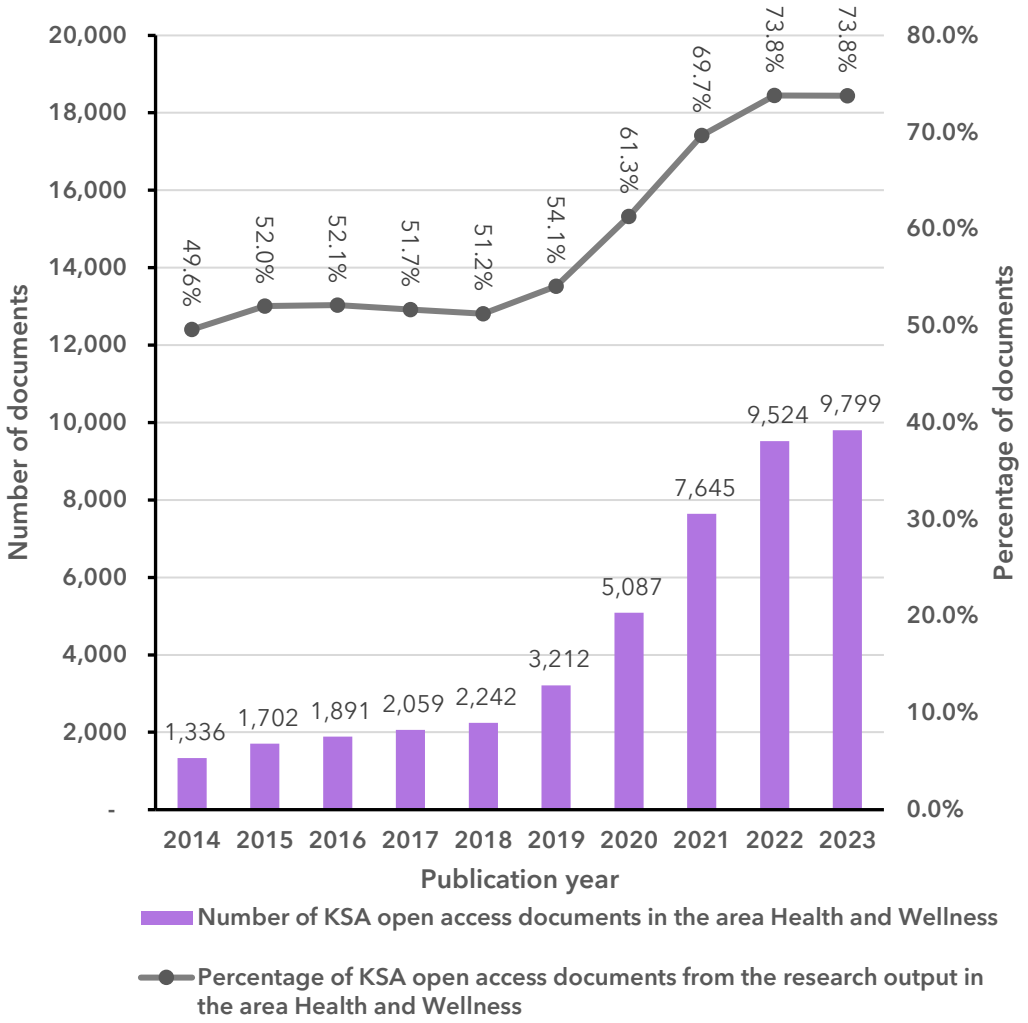

Figure 37: Number and percentage of Saudi Arabia's open access documents in the area Health and Wellness and in the period 2014-2023

3.3.7 Top 20 organizations in terms of number of publications

The top 20 organizations in Saudi Arabia in terms of number of documents published in the area Health and Wellness and in the period 2014-2023 are King Saud University with 16,554 documents followed by King Abdulaziz University with 11,579 and King Saud Bin Abdulaziz University for Health Sciences with 4,937 documents as shown in Figure 38.

Alfaisal University achieved the highest CNCI of 3.15, followed by University Ha'il and Jazan University with CNCI's of 2.53 and 2.05, respectively.

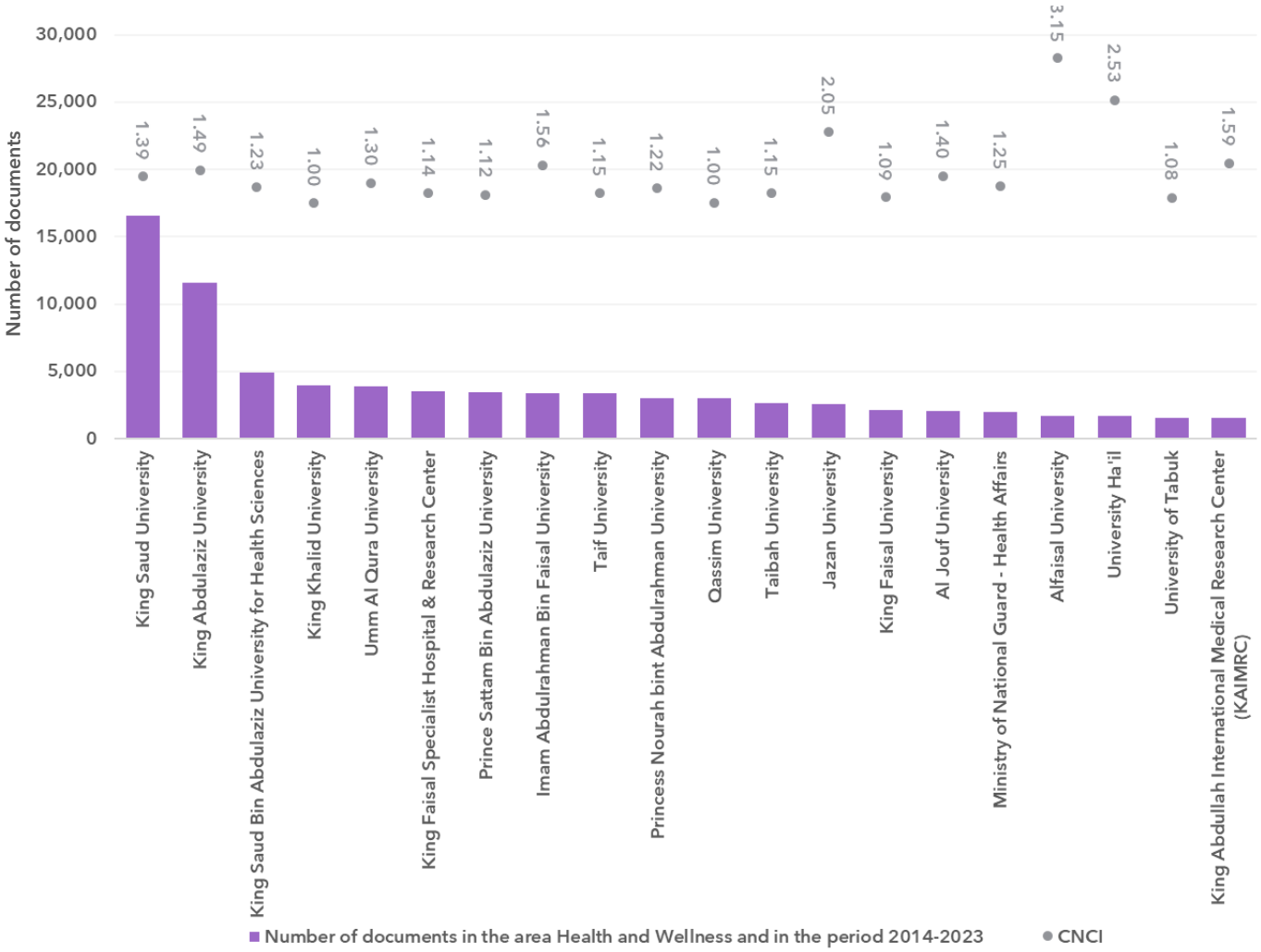

Figure 38: Top 20 Saudi organizations in terms of documents published in the area Health and Wellness and in the period 2014-2023

3.3.8 Top 20 Saudi affiliated researchers in terms of number of publications in the area Health and Wellness

The top 3 Saudi affiliated researchers in terms of number of documents published in the period 2014-2023 and in this area are Abdullah M. Asiri affiliated to King Abdulaziz University with 320 documents followed by Ziad Ahmed Memish affiliated to King Saud Medical City with 218 documents and Shafiul Haque affiliated to Jazan University with 186 documents as shown in Table 2.

Among the top 20, Ziad Ahmed Memish had the highest CNCI with 14.37, the highest number of Top 1% documents with 49 documents and the highest number of Top 10% documents with 94 documents.

Table 2: Top 20 Saudi affiliated researchers in the period 2014-2023 in terms of number of documents published in the area Health and Wellness

Name	Affiliation	Web of Science Publications	CNCI	Documents in Top 1%	Documents in Top 10%
Asiri, Abdullah M.	King Abdulaziz University	320	1.39	6	54
Memish, Ziad Ahmed	King Saud Medical City	218	14.37	49	94
HAQUE, SHAFIUL	Jazan University	186	2.61	9	24
Azhar, Esam	King Abdulaziz University	185	1.21	2	34
Abdel-Daim, Mohamed M.	Batterjee Medical College	183	1.63	2	39
Rahman, Mohammed M.	King Abdulaziz University	182	1.35	2	23
Alkuraya, Fowzan	King Faisal Specialist Hospital & Research Center	180	1.78	4	54
Aljurf, Mahmoud	King Faisal Specialist Hospital & Research Center	172	1.66	5	45
Patil, Shankargouda	Roseman Univ Hlth Sci	170	0.75	1	13
Al-Daghri, Nasser	King Saud University	169	1.38	1	32
Al-Qahtani, Mohammed Hussain	King Khalid University	168	1.06	1	23
Rabaan, Ali	Johns Hopkins Aramco Healthcare	160	1.71	3	36
Kazmi, Imran	King Abdulaziz University	148	1.90	7	37
Almatroudi, Ahmad	Qassim University	145	1.55	2	33
Al-Tawfiq, Jaffar	Johns Hopkins Aramco Healthcare	145	1.60	6	37
Al-Dhabi, Naif	King Saud University	145	1.27	2	26
Ahmed, Nehad	Prince Sattam Bin Abdulaziz University	143	0.27	0	3
Ahmad, Sheikh Fayaz	King Saud University	143	1.24	0	22
Ghoneim, Mohammed M.	Almaarefa University	138	1.44	1	28
Alkahtani, Saad	King Saud University	135	1.10	0	20

3.3.9 SWOT analysis of the underlying research topics

This section provides a more granular analysis of Saudi Arabia's research performance in the underlying categories that constitute the national priority area Health and Wellness. The research topics constituting the area, and the selection of those research topics is described in Dataset Description.

To do this, we perform a Strength, Weakness, Opportunity and Threat (SWOT) analysis. For a description of the analysis see the section Strengths, Weakness, Opportunities and Threats Analysis (SWOT).

When investigating Saudi Arabia's performance in the research topics in the national priority area Health and Wellness we notice out of the 47 research topics there are 23 strength research topics listed in Table 3, 17 opportunity research topics listed in Table 4, three weakness research topics listed in Table 5 and four threat research topics listed in Table 6, as also shown in Figure 39.

Given that these research topics align with national priorities, RDIA might consider focusing on sustaining high performance in areas of established strength, enhancing productivity in opportunity areas by capitalizing on the demonstrated expertise, as evidenced by a CNCI exceeding 1. Additionally, efforts should be directed toward improving research quality and citation impact in threat categories, while simultaneously addressing productivity and quality gaps in areas identified as weaknesses.

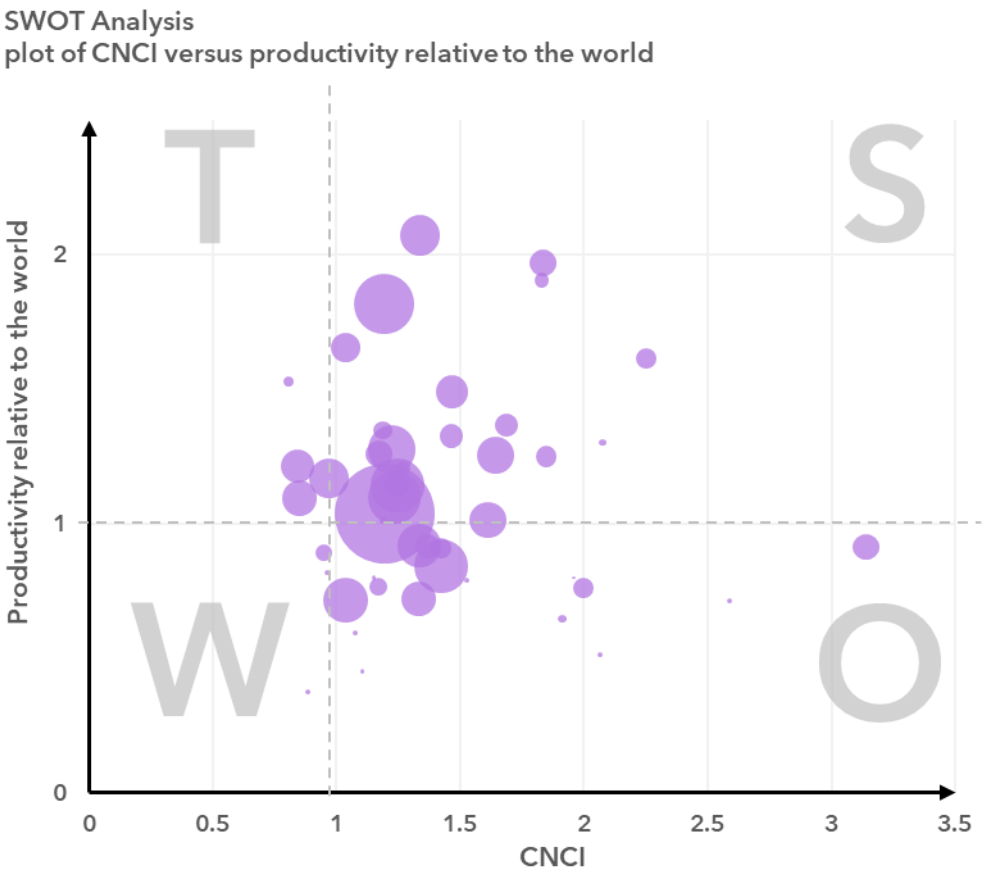

Figure 39: SWOT analysis of the national priority area Health and Wellness. The y-axis shows the productivity relative to the world (share of Saudi Arabia from the global productivity in the research topic normalized by Saudi Arabia share from global productivity when considering overall research). The x-axis shows the impact relative to the global average.

Table 3: Saudi Arabia strength research topics in the national priority area Health and Wellness

Research topic	CNCI	Productivity relative to the world
Cancer	1.2	1.0
Nutrition & Obesity	1.2	1.1
Cognition & Memory	1.2	1.1
Diabetes	1.2	1.8
Biopharmaceuticals	1.2	1.3
Neurological	1.6	1.0
Vaccines	1.6	1.3
Antimicrobial Resistance	1.3	2.1
Biosensors/MEMS	1.5	1.5
Heart Health	1.2	1.3
Implants	1.0	1.7
Hepatitis	1.2	1.1
Telehealth	1.5	1.3
Tuberculosis	1.7	1.4
Nanomedicine	1.7	2.6
Influenza	1.8	1.3
AI/ML Imaging	1.8	2.0
Malaria	2.2	1.6
Eyesight	1.2	1.3
Mobile Health	1.3	1.2
Dengue	1.8	1.9
Neurodegenerative Gene Therapy	1.2	1.0
Wearables	2.1	1.3

Table 4: Saudi Arabia opportunity research topics in the national priority area Health and Wellness

Research topic	CNCI	Productivity relative to the world
Cardiovascular Diseases	1.4	0.8
Immunotherapy	1.0	0.7
Chronic Respiratory	1.3	0.9
Precision Medicine	1.3	0.7
Skin Health	3.1	0.9
Gene/ RNA Therapy	1.4	0.9
Gut Health	2.0	0.8
eHealth	1.4	0.9
Immunity Boosting	1.2	0.8
Lab-on-a-Chip / microfluidics	1.9	0.6
CAR-T Cell Therapy	2.1	0.5
Phage therapy	1.1	0.6
Exoskeleton	1.1	0.5
Medical Robots	1.2	0.8
Robotic Prosthetics	2.6	0.7
Telesurgery	1.5	0.8
Congenital Gene Therapy	2.0	0.8

Table 5: Saudi Arabia weakness research topics in the national priority area Health and Wellness

Research topic	CNCI	Productivity relative to the world
Stem cells therapies	0.9	0.9
Healthcare/Surgical Robots	0.9	0.4
Blood Disorder Gene Therapy	1.0	0.8

Table 6: Saudi Arabia threat research topics in the national priority area Health and Wellness

Research topic	CNCI	Productivity relative to the world
Genomics	1.0	1.2
Gastrointestinal	0.8	1.1
Electronic Health Records	0.8	1.2
Health Data and IT Management	0.8	1.5

3.4 Saudi Arabia research output performance analysis in Sustainability and Essential Needs (SE)

3.4.1 Research volume analysis

The number of Saudi Arabia papers published in the national priority area Sustainability and Essential Needs grew continuously from 569 papers in 2014 to 4007 papers in 2023 as shown in Figure 40.

This reflects a double digit-growth for all years, for some years the growth rate was above 50%, and a much higher growth rate than the global rate in the same area. It is worth highlighting that although globally there was a negative growth rate between 2022 and 2023, in Saudi Arabia we still observe a double-digit growth rate of 10.5%.

In the considered period Saudi Arabia had a yearly average growth rate not only three times of the average global rate but also higher than all of the other considered benchmark countries/regions as shown in Figure 41. All the above indicates, the focus nationally of increasing the research activity in this national priority area.

In Figure 42 the number of active Saudi affiliated researchers per year in the area Sustainability and Essential Needs is shown. For more information on the methodology used to investigate the number of active researchers see the section Number of active researchers.

In Figure 42 the number of active Saudi affiliated researchers per year in the area Sustainability and Essential Needs is shown. For more information on the methodology used to investigate the number of active researchers see the section Number of active researchers.

As we have seen earlier the number of Saudi Arabia papers in the area Sustainability and Essential Needs increased continuously in the last 10 years 2014-2023. Similarly, the number of active researchers in this area also increased continuously. This reflects an 8.1x increase in this period indicating the growing number of researchers in this national priority area.

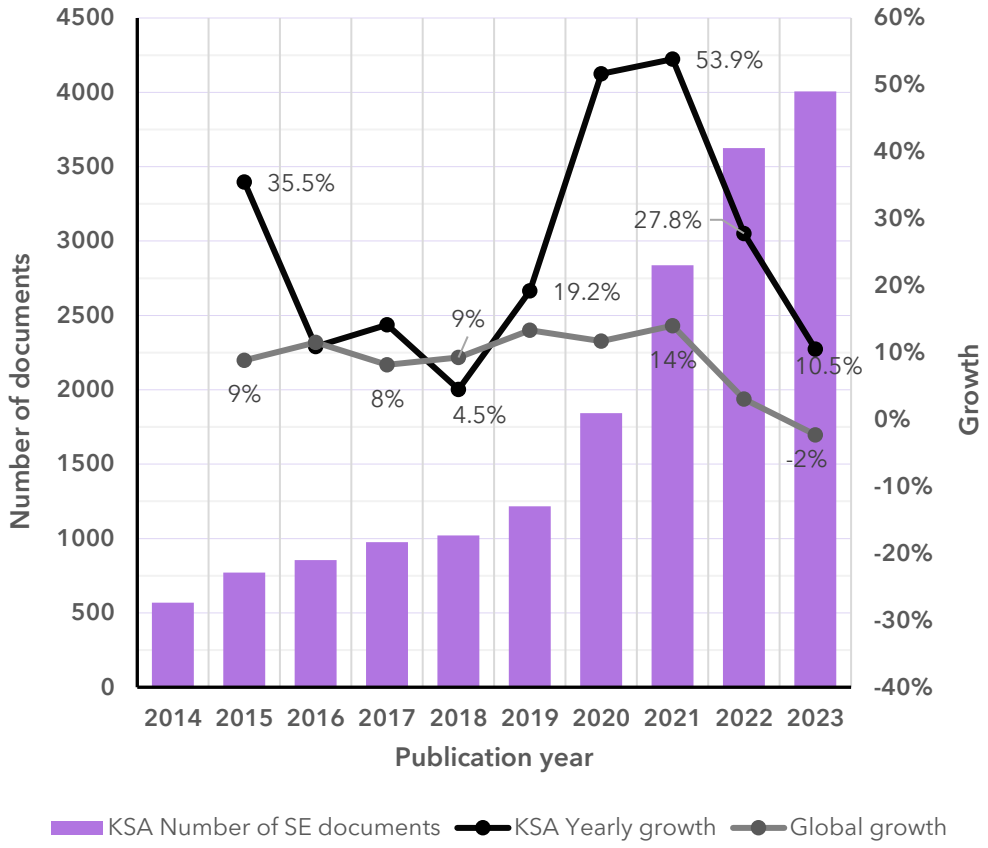

Figure 40: Saudi Arabia number of papers and growth in the national priority area Sustainability and Essential Needs

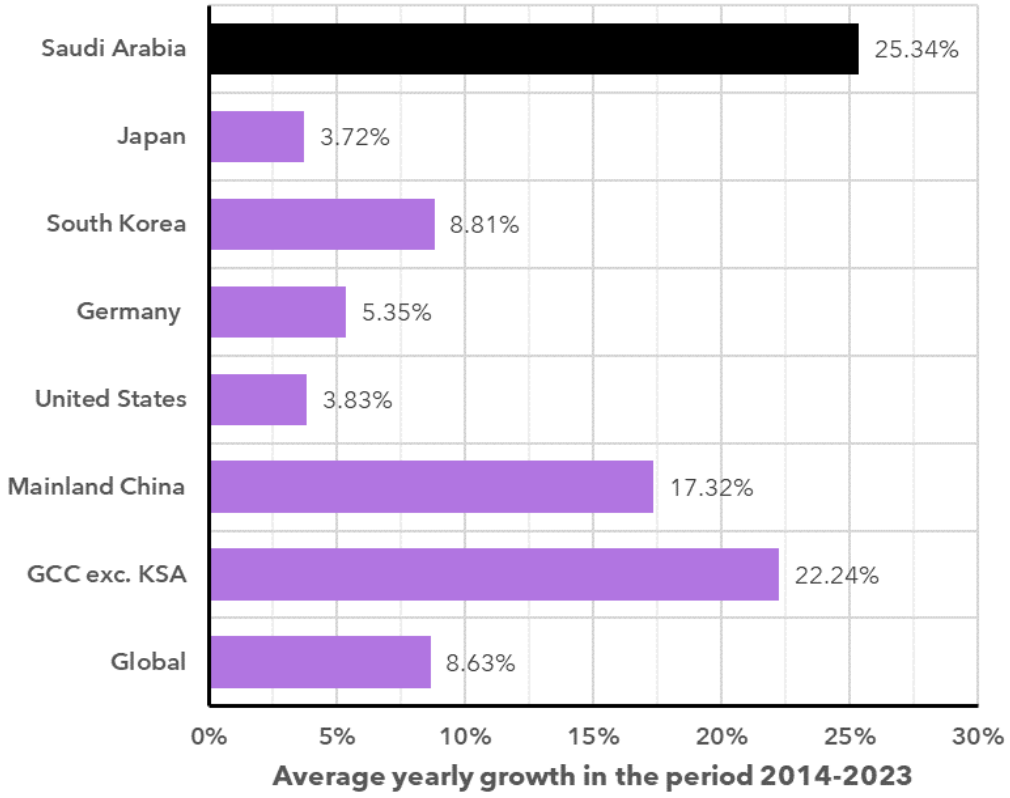

Figure 41: Average yearly growth of number of papers in the area Sustainability and Essential Needs in the period 2014-2023

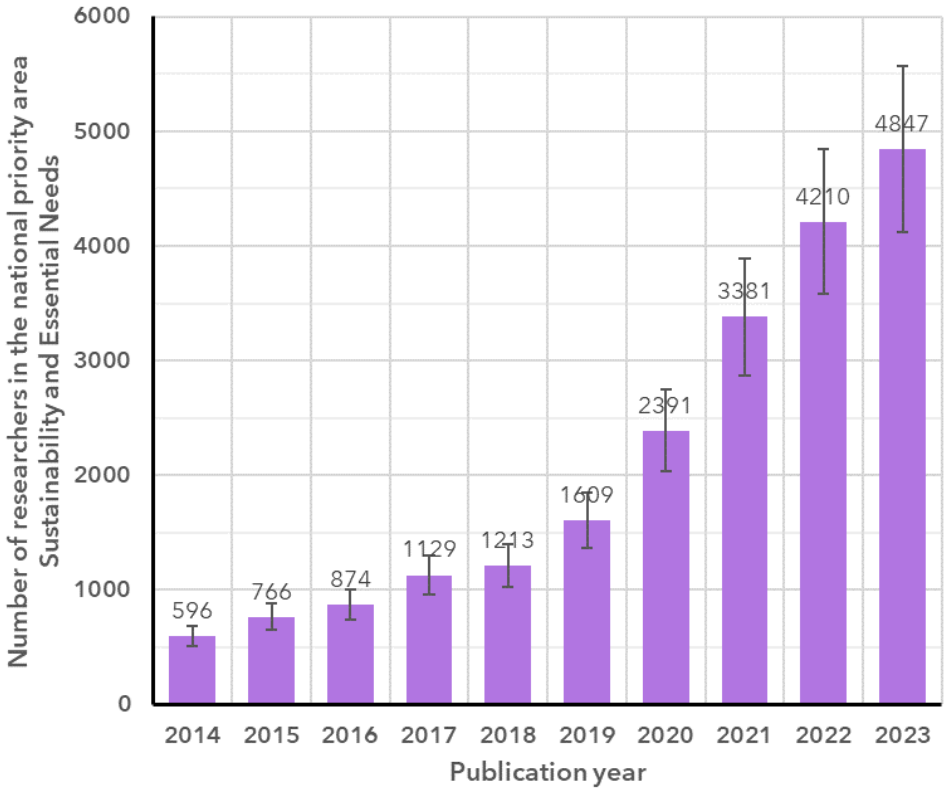

Figure 42: Number of active Saudi affiliated researchers in the area Sustainability and Essential Needs

3.4.2 Citation impact analysis

The category normalized citation impact (CNCI) of Saudi Arabia in the period 2014-2023 was always above 1.4 indicating a citation impact performance at least 40% higher than the global average as shown in Figure 43.

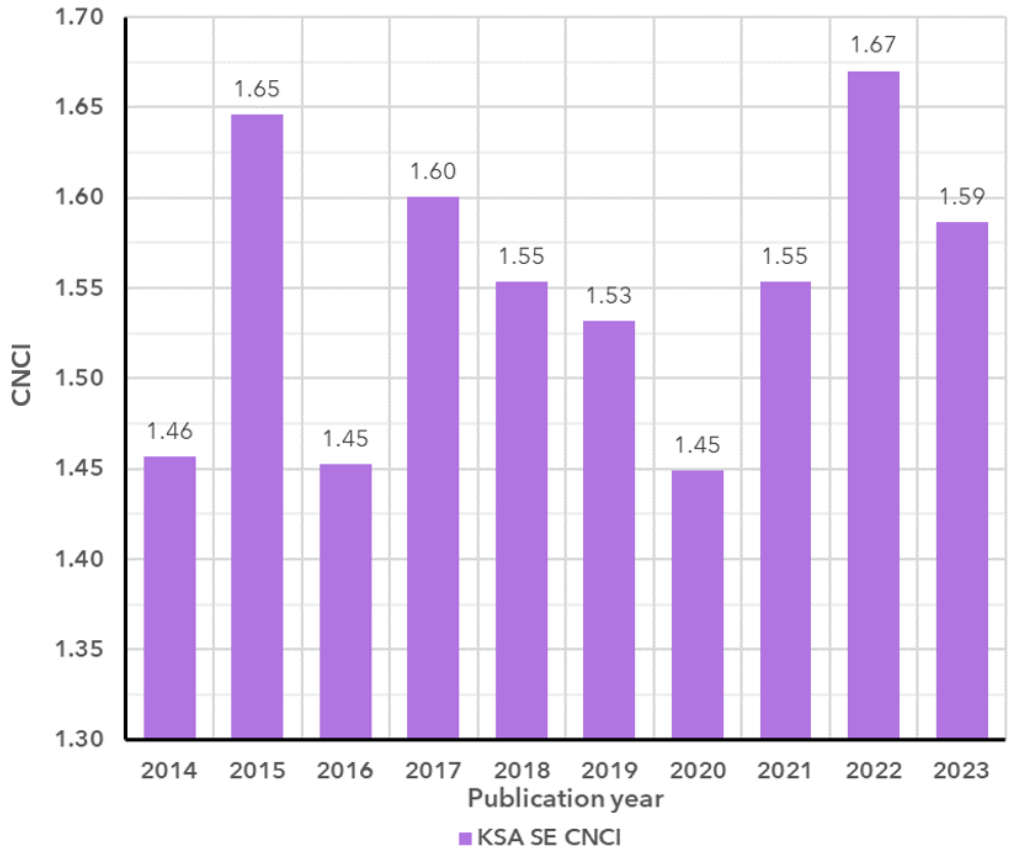

Figure 43: Saudi Arabia yearly category normalized citation impact in the area Sustainability and Essential Needs

The CNCI fluctuated slightly in this period between 1.4 and 1.67. Saudi Arabia also achieved a CNCI in this period and in this area higher than that of all the considered benchmark countries/regions as shown in Figure 44.

This indicates a very high citation impact performance. It is also worth noting that the high citation impact footprint was maintained during a high research output growth period.

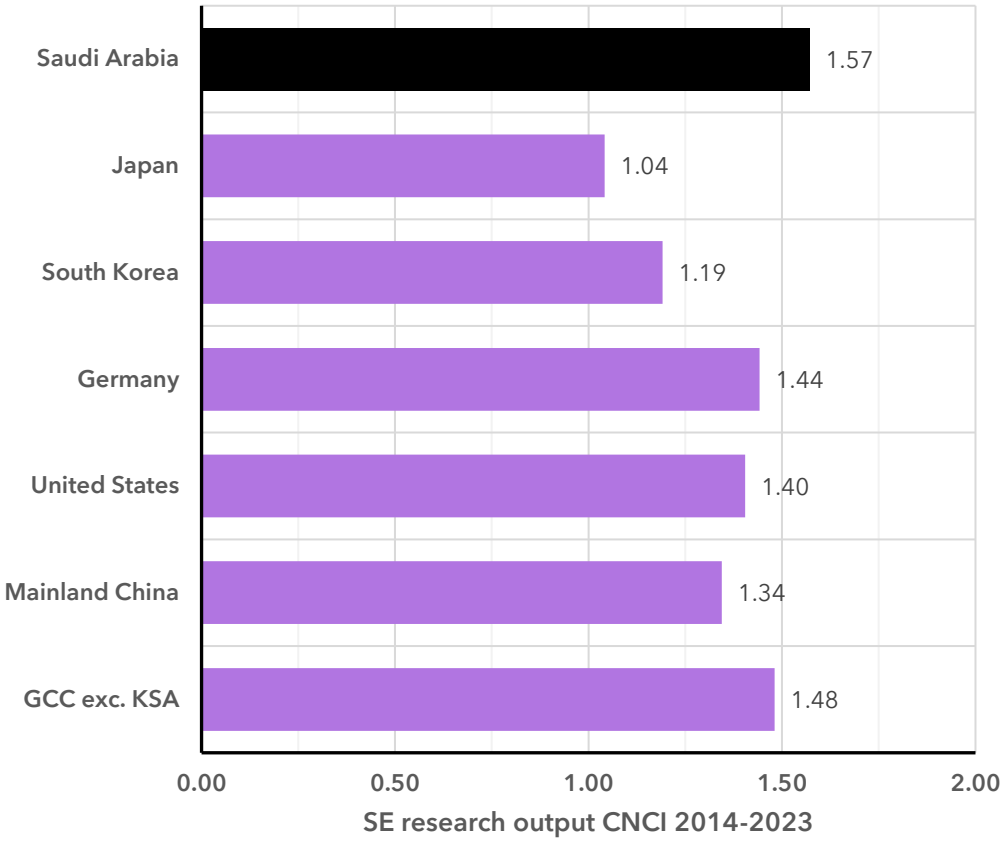

Figure 44: Sustainability and Essential Needs research output CNCI in the period 2014-2023

3.4.3 Research excellence analysis

The percentage of Saudi Arabia's Top 1% documents in the area Sustainability and Essential Needs decreased from 3.16% in 2014 to 2.59% in 2015 to then increase continuously to 3.7% in 2019 as shown in Figure 45.

Afterwards the percentage decreased to 3.09% in 2020 and increased continuously to reach 3.78% in 2022 and then decrease to 2.87% in 2023. On the other hand, the number of Top 1% documents increased continuously from 18 documents in 2014 to 137 documents in 2022 and then decreased to 115 documents in 2023. In general, the percentage of Saudi Arabia's documents in the area Sustainability and Essential Needs fluctuated between 2.59% and 3.78%.

Considering that the global average performance is ~1.5% as shown in Figure 46, this shows that for all years the performance of Saudi Arabia in this area was at least 100% higher than the global average.

Additionally, when considering Sustainability and Essential Needs research output over the whole period 2014-2023, Saudi Arabia had a higher percentage of Top 1% documents than all the other considered countries/regions.

This is in alignment with the analysis of CNCI showing high citation impact footprint of Saudi Arabia in this area and leading to high research excellence performance when considering the Top 1% documents.

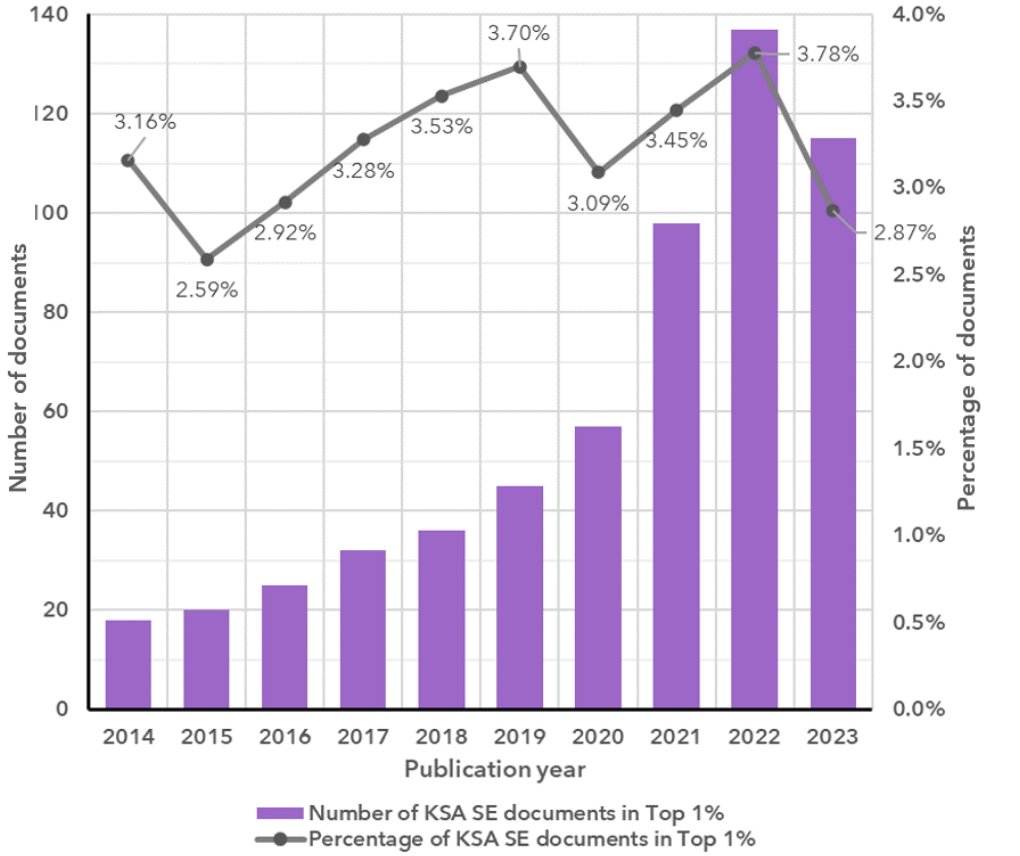

Figure 45: Number and percentage of Saudi Arabia Top 1% documents in the Sustainability and Essential Needs area

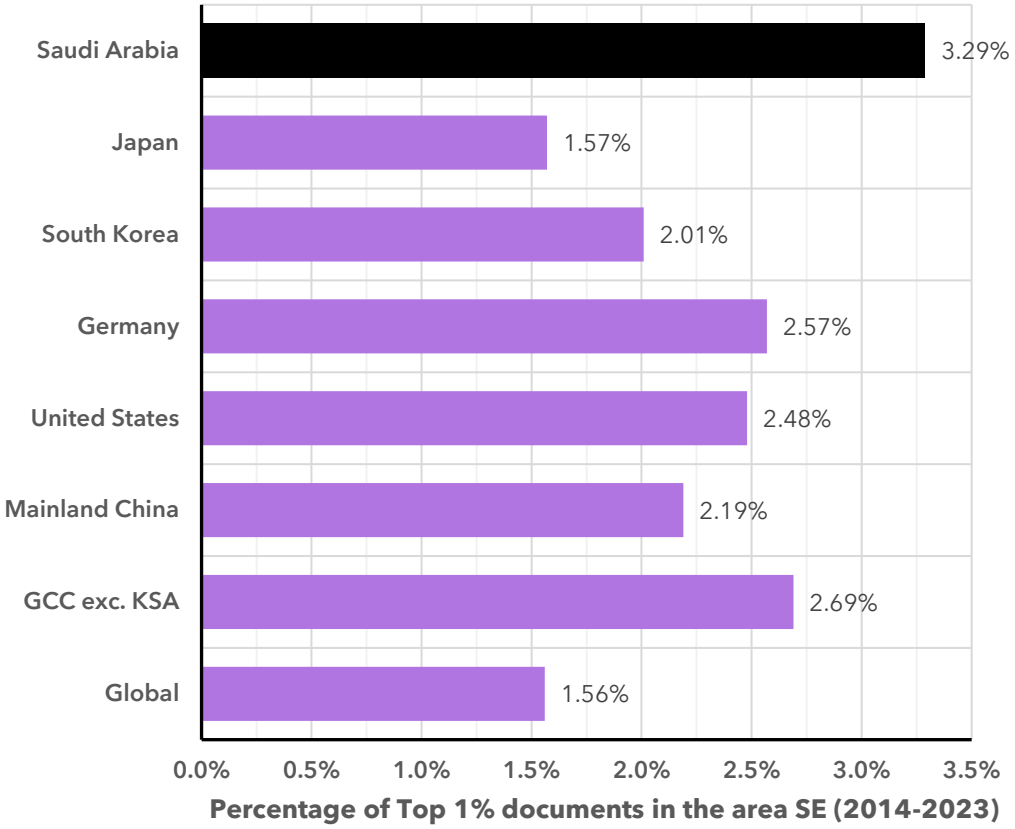

Figure 46: Percentage of Top 1% documents in the area Sustainability and Essential Needs area during the period 2014-2023

The number of Saudi Arabia Top 10% documents increased continuously from 111 documents in 2014 to 821 documents in 2022 and then decreased slightly to 791 documents in 2023 as shown in Figure 47.

In the same period, the percentage of Top 10% documents fluctuated between 19.5% and 22.3%. When considering the overall research output in the area Sustainability and Essential Needs in the period 2014-2023, the global average percentage of Top 10% documents was 13.6%.

In comparison, Saudi Arabia had in all years at least a 42% higher percentage of Top 10% documents than the global percentage. Additionally, the percentage of Saudi Arabia Top 10% documents in the area Sustainability and Essential Needs was higher than that of the global average as well as all considered countries/regions as shown in Figure 48.

Overall, when considering the Top 1% and Top 10%, we observe a relatively high and consistent research excellence performance of Saudi Arabia in this national priority area in the last 10 years (2014-2023).

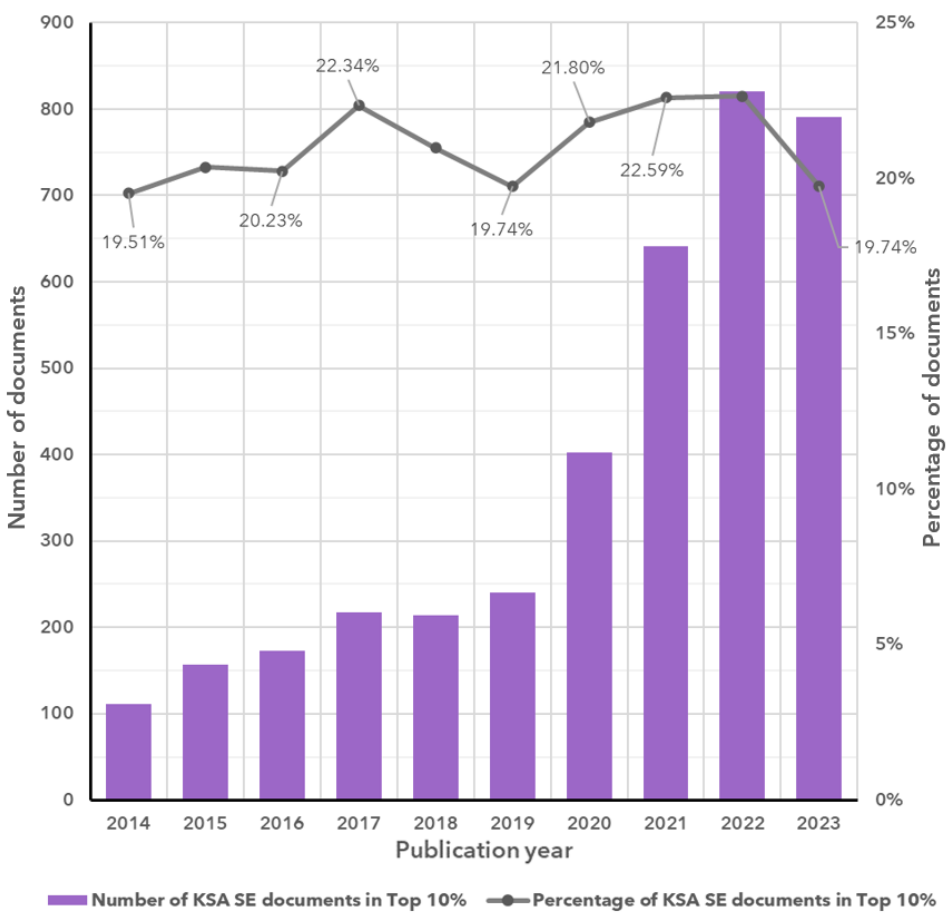

Figure 47: Number and percentage of Saudi Arabia Top 10% documents in the Sustainability and Essential Needs area

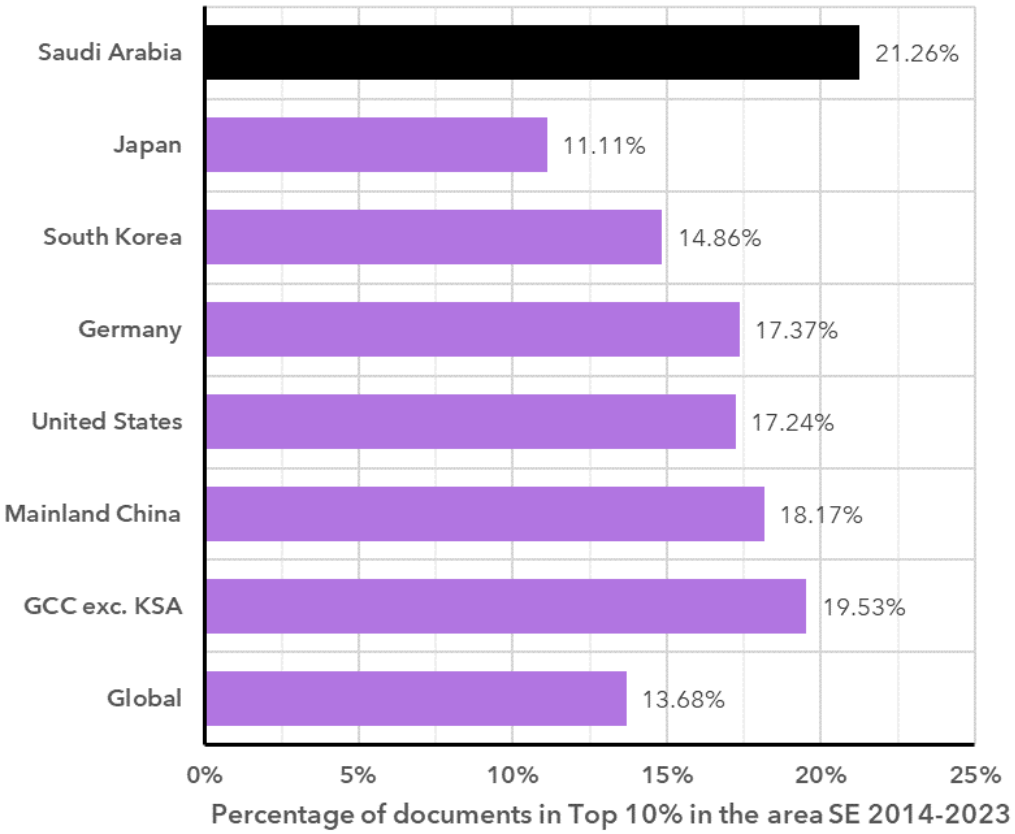

Figure 48: Percentage of Top 10% documents in 2014-2023 in the Sustainability and Essential Needs area

3.4.4 Funding dynamics analysis

The percentage of Saudi Arabia papers in the Sustainability and Essential Needs area with funding acknowledgement is higher than that of GCC excluding Saudi Arabia, Japan and the global baseline. Also, it is slightly higher than that of Germany and USA but lower than that South Korea and Mainland China as shown in Figure 49.

Additionally, we notice that the percentage of articles with funding in the area Sustainability and Essential Needs is higher than that from the total articles for the global baseline as well as for all considered countries/regions.

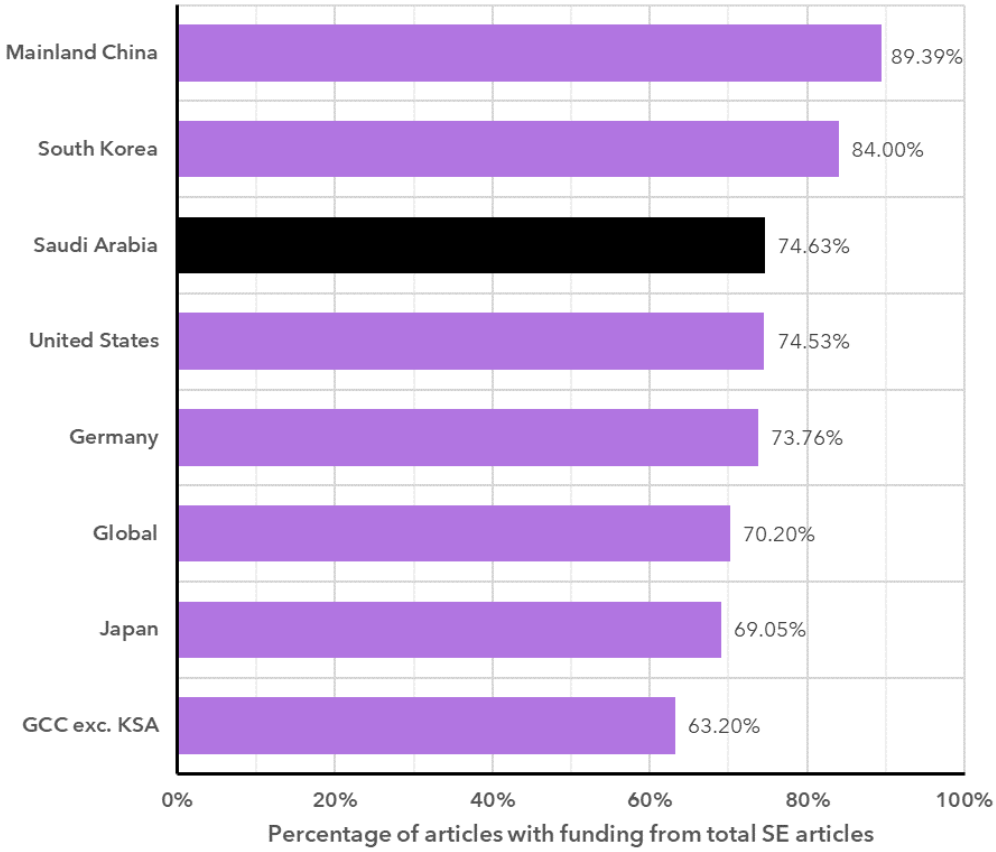

Figure 49: Percentage of publications with funding acknowledgment from overall Sustainability and Essential Needs publications in the period 2014-2023

The top 3 funding organizations mentioned in the funding section of Saudi Arabia documents in the area Sustainability and Essential Needs during the period 2014-2023 are King Saud University, National Natural Science Foundation of China (NSFC) and King Abdullah University of Science & Technology with 2408, 823 and 681 documents respectively as shown in Figure 50.

Research in collaboration with Saudi Arabia in the area Sustainability and Essential Needs that was funded by Japan Society for the Promotion of Science resulted in the highest citation impact measured by CNCI followed by Ministry of Education, Culture, Sports, Science and Technology, Japan (MEXT) and UK Research & Innovation (UKRI) with a CNCI of 4.8, 4.4 and 4.1, respectively.

The lowest CNCI is observed in papers funded by King Saud University, though the CNCI is still 50% higher than the global average and one should also take into consideration the high volume of funded papers relative to the other organizations.

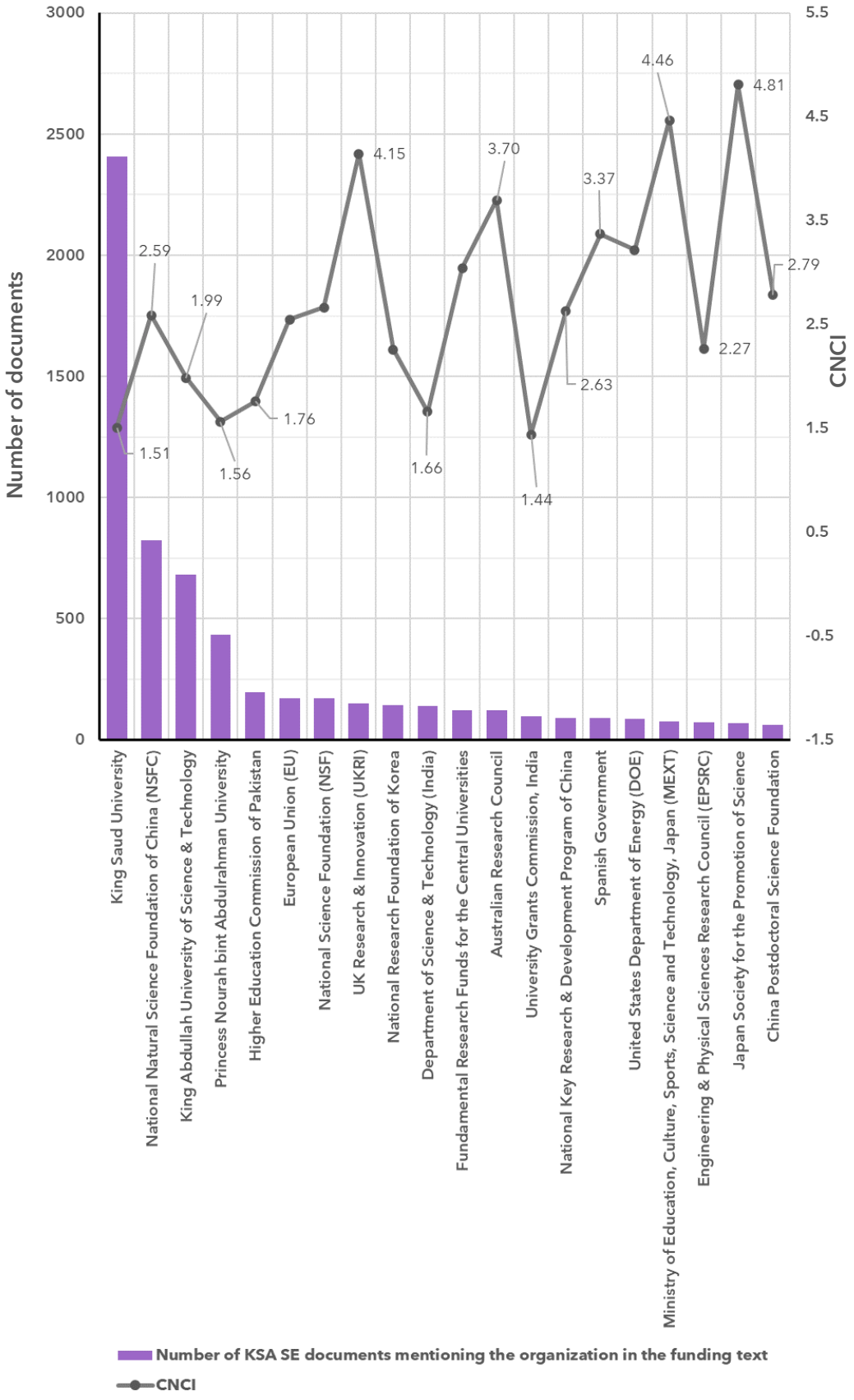

Figure 50: Top 20 funding organizations mentioned in the funding text of Saudi Arabia Sustainability and Essential Needs papers in the period 2014-2023

3.4.5 International collaboration dynamics analysis

In the area Sustainability and Essential Needs, the percentage of Saudi Arabia papers with an international collaboration of ~82% is higher than that of all considered benchmark countries/regions as shown in Figure 51.

At the same time this means that Saudi Arabia has the lowest number of papers with only national affiliations.

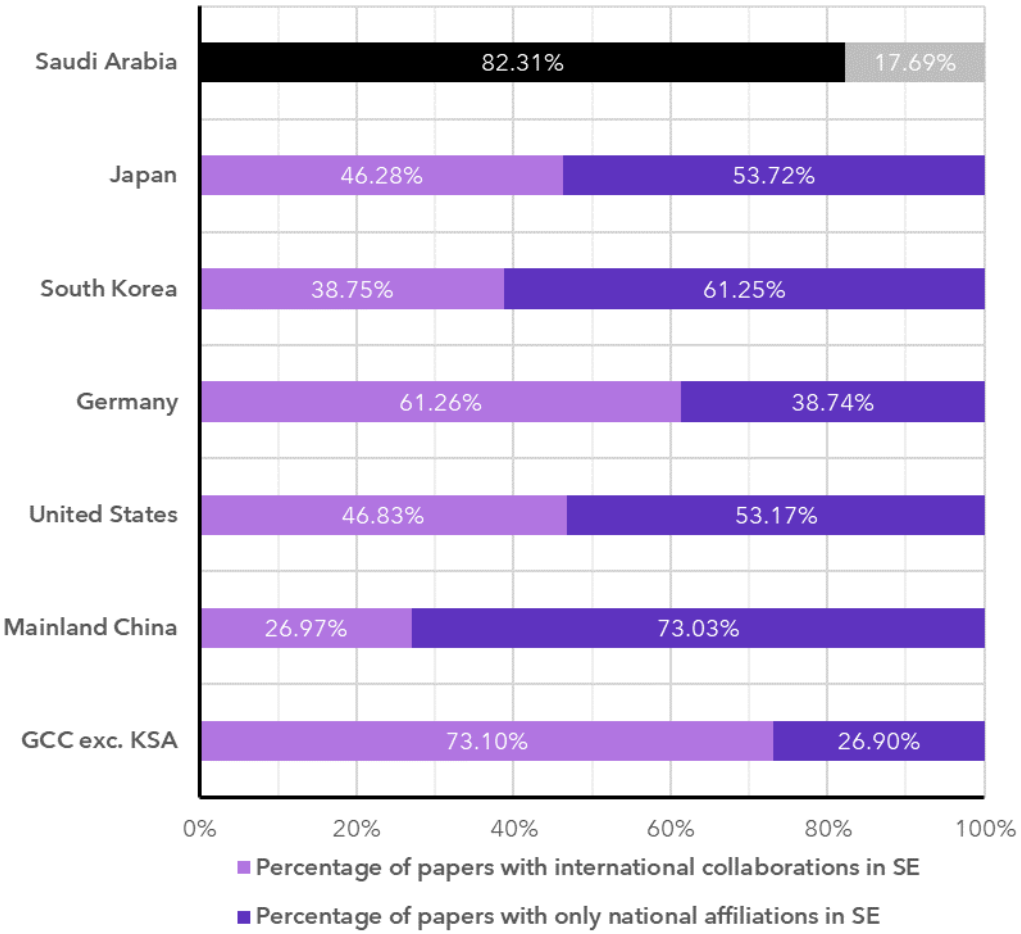

Figure 51: Percentage of papers with an international collaboration or only national affiliations in the area Sustainability and Essential Needs and in the period 2014-2023

Egypt, followed by India and Pakistan had the highest number of documents in collaboration with Saudi Arabia affiliated researchers in the national priority area Sustainability and Essential Needs in the period 2014-2023 with 4051, 2882 and 2549 documents respectively as shown in Figure 52 and Figure 53.

In terms of citation impact measured by the CNCI, papers in collaboration with Japan followed by Spain and Germany had the highest CNCI among the top 20 collaborating countries with a CNCI of 3.37, 2.86, and 2.6, respectively.

Nevertheless, research with all the top 20 collaborating countries with Saudi Arabia in this area resulted in a CNCI higher than the global average citation impact performance.

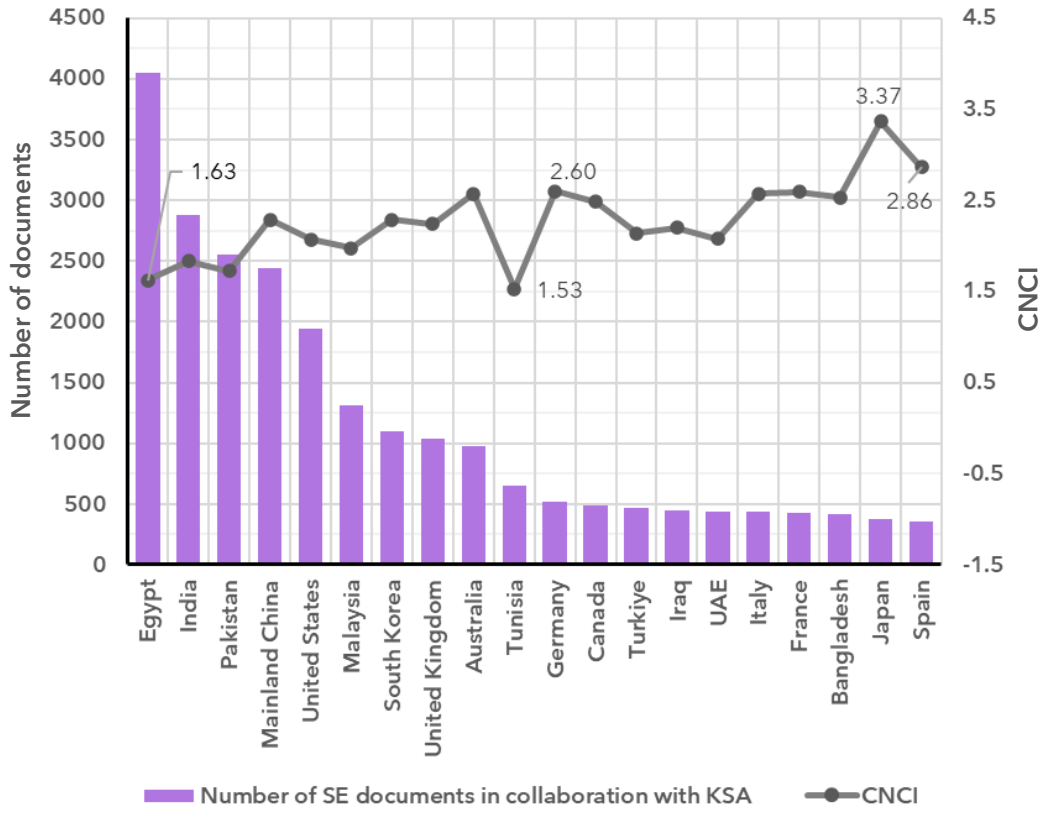

Figure 52: Top 20 collaborating countries with Saudi Arabia in the area Sustainability and Essential Needs in the period 2014-2023

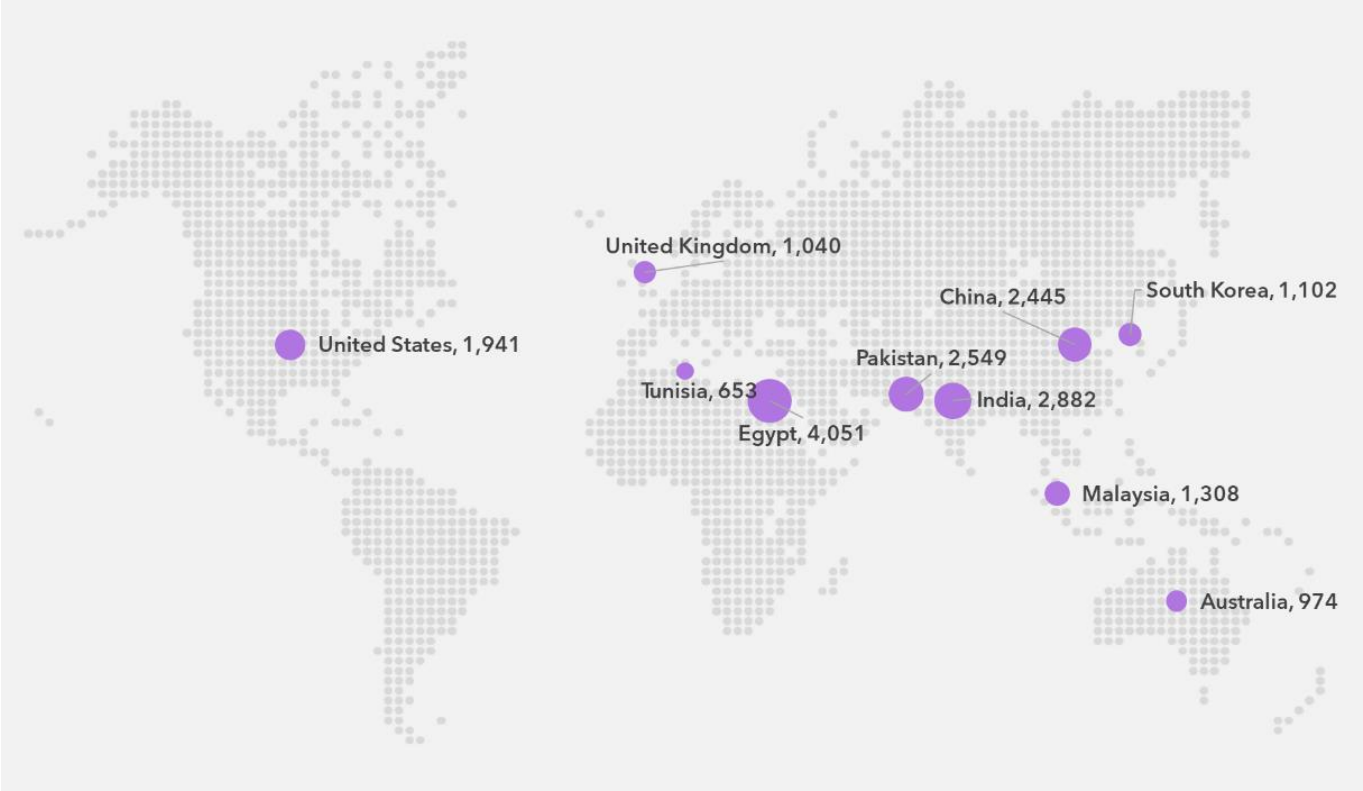

Figure 53: Top 10 collaborating countries with Saudi Arabia in the area Sustainability and Essential Needs in the period 2014-2023

3.4.6 Open access publication analysis

In the area Sustainability and Essential Needs over the period 2014-2023 the number of open access documents increased continuously reaching 2,312 documents in 2023 as shown in Figure 54.

On the other hand, the percentage of open access documents in this area increased almost continuously till 2022 followed by slight decrease to 57.8% in 2023.The percentage achieved in 2023 is slightly lower than the one observed from the overall research output of 63.7%.

Nevertheless, this still reflects a relatively high percentage of open access documents which could lead to higher visibility of Saudi Arabia research output in this area and for possibly more citations.

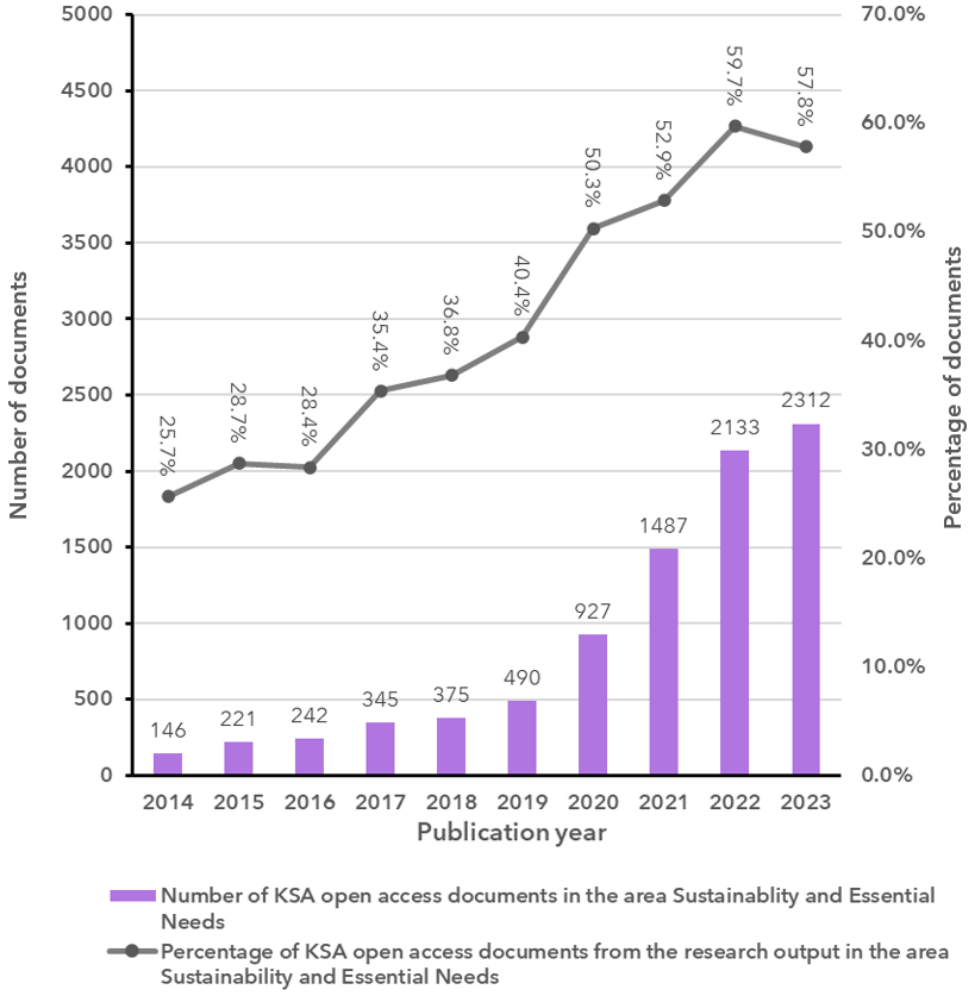

Figure 54: Number and percentage of Saudi Arabia open access documents in the area Sustainability and Essential Needs and in the period 2014-2023

3.4.7 Top 20 organizations in terms of number of publications

The top 20 organizations in Saudi Arabia in terms of number of documents published in the area Sustainability and Essential Needs during the period 2014-2023 are King Saud University with 4,270 documents followed by King Abdulaziz University with 2,610 and King Abdullah University of Science & Technology with 1,803 documents as shown in Figure 55.

In terms of citation impact measured by the CNCI, the highest CNCI is achieved by King Abdullah University of Science & Technology followed by Jazan University and University of Tabuk with a CNCI of 2.03, 1.85 and 1.79 respectively.

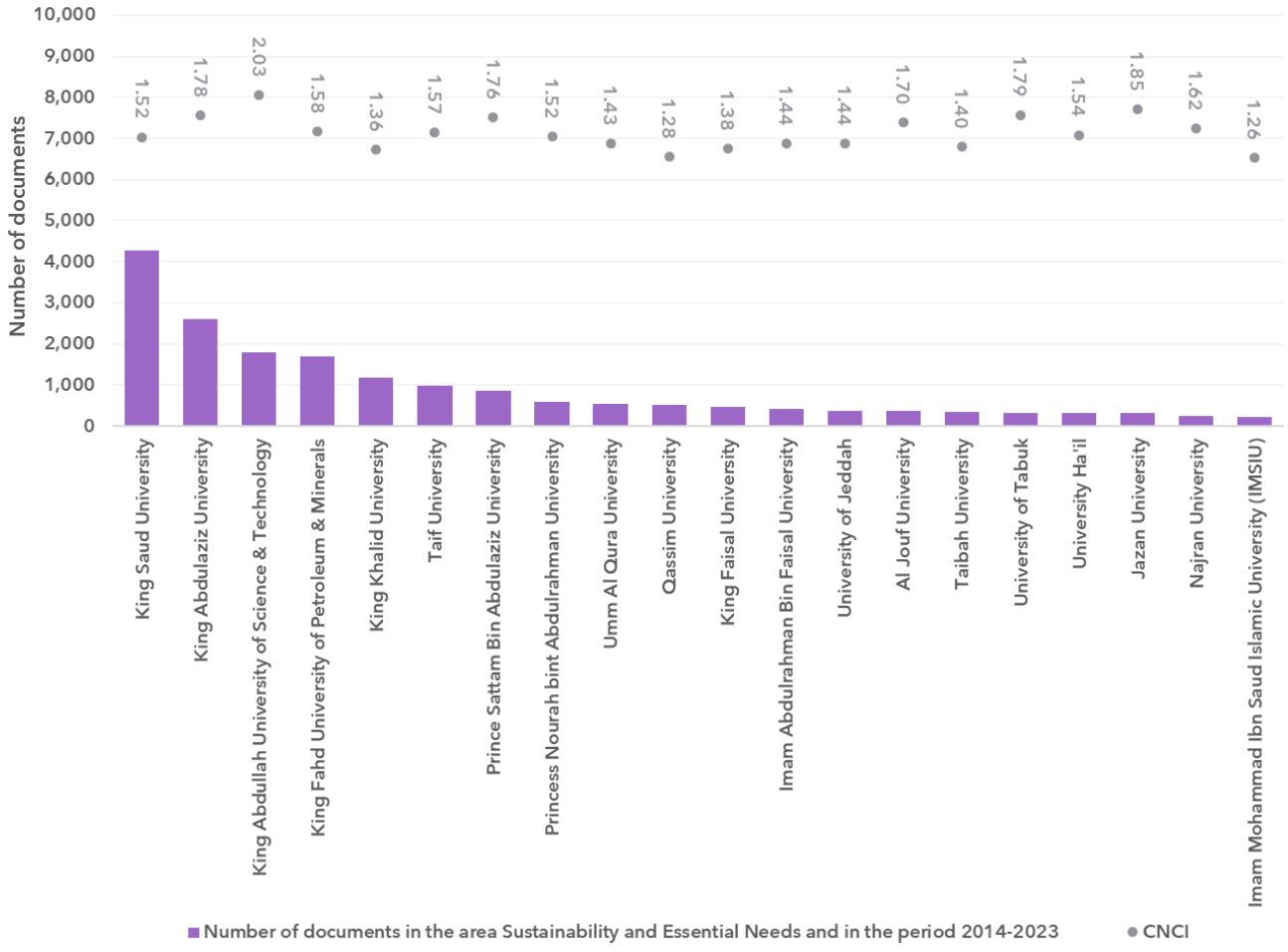

Figure 55: Top 20 Saudi organizations in terms of documents published in the area Sustainability and Essential Needs during the period 2014-2023

3.4.8 Top 20 Saudi affiliated researchers in terms of number of publications in the area Sustainability and Essential Needs

The top 3 Saudi affiliated researchers in terms of number of documents published in the period 2014-2023 and in this area are Noreddine Ghaffou affiliated to King Abdullah University of Science & Technology with 167 documents followed by M. Naushad affiliated to King Saud University with 108 documents and Johannes Vrouwenvelder affiliated to King Abdullah University of Science & Technology with 90 documents as shown in Table 7.

Among the top 20, Carlos M Duarte affiliated to King Abdullah University of Science & Technology had the highest CNCI with 4.26 and the highest number of Top 1% documents with 16 documents. The highest number of Top 10% documents with 52 documents is achieved by Noreddine Ghaffour.

Table 7: Top 20 Saudi affiliated researchers in the period 2014-2023 in terms of number of documents published in the area of Sustainability and Essential Needs

Name	Affiliation	Web of Science Publications	CNCI	Documents in Top 1%	Documents in Top 10%
Ghaffour, Noreddine	King Abdullah University of Science & Technology	167	1.85	7	52
NAUSHAD, M.	King Saud University	108	2.99	12	47
Vrouwenvelder, Johannes	King Abdullah University of Science & Technology	90	1.48	2	22
ALOthman, Zeid A.	King Saud University	90	2.31	10	30
Asiri, Abdullah M.	King Abdulaziz University	88	2.26	8	25
Saleh, Tawfik	King Fahd University of Petroleum & Minerals	86	2.60	7	35
Duarte, Carlos M	King Abdullah University of Science & Technology	77	4.26	16	50
Zubair, Syed M.	King Fahd University of Petroleum & Minerals	72	1.65	1	22
Elshikh, Mohamed S	King Saud University	63	1.23	1	10
Antar, Mohamed	King Fahd University of Petroleum & Minerals	62	1.47	2	16
Rehan, Mohammad	King Abdulaziz University	61	3.50	6	28
Al-Dhabi, Naif	King Saud University	60	1.41	1	13
Leiknes, T.	King Abdullah University of Science & Technology	60	1.82	2	19
Alsaedi, Ahmed	King Abdulaziz University	59	2.25	2	24
Abd_Allah, Elsayed Fathi	King Saud University	58	1.42	0	12
Umar, Ahmad	Najran University	56	1.35	2	10
Orfi, Jamel	King Saud University	54	0.64	0	4
Qasem, Naef A.A.	King Fahd University of Petroleum & Minerals	51	1.81	1	11
Rezk, Hegazy	Prince Sattam Bin Abdulaziz University	51	1.78	2	14
Ali, Emadadeen	King Saud University	50	0.67	0	4

3.4.9 SWOT analysis of the underlying research topics

In this part we have a more granular look by analyzing the research performance of Saudi Arabia in the underlying categories the constitute the national priority area Sustainability and Essential Needs.

The research topics constituting the area and the selection of those research topics is described in Dataset Description. For a description of the SWOT analysis please see the section Strengths, Weakness, Opportunities and Threats Analysis (SWOT).

When investigation Saudi Arabia's performance in the research topics in the national priority area Sustainability and Essential Needs we notice out of the 38 research topics there are 23 strength research topics listed in Table 8, 14 opportunity research topics listed in Table 9 and one threat area Water Leakage with a high productivity relative to the global productivity (1.83) and low CNCI (0.89) as also shown in Figure 56.

As all of these research topics are of national priority, it would be important to conserve the high performance in the strength research topics, increase the productivity in the opportunity areas by leveraging on the gained expertise that is evident with the CNCI being higher than 1 and improve the quality and accordingly the citation impact in the research topic Water Leakage.

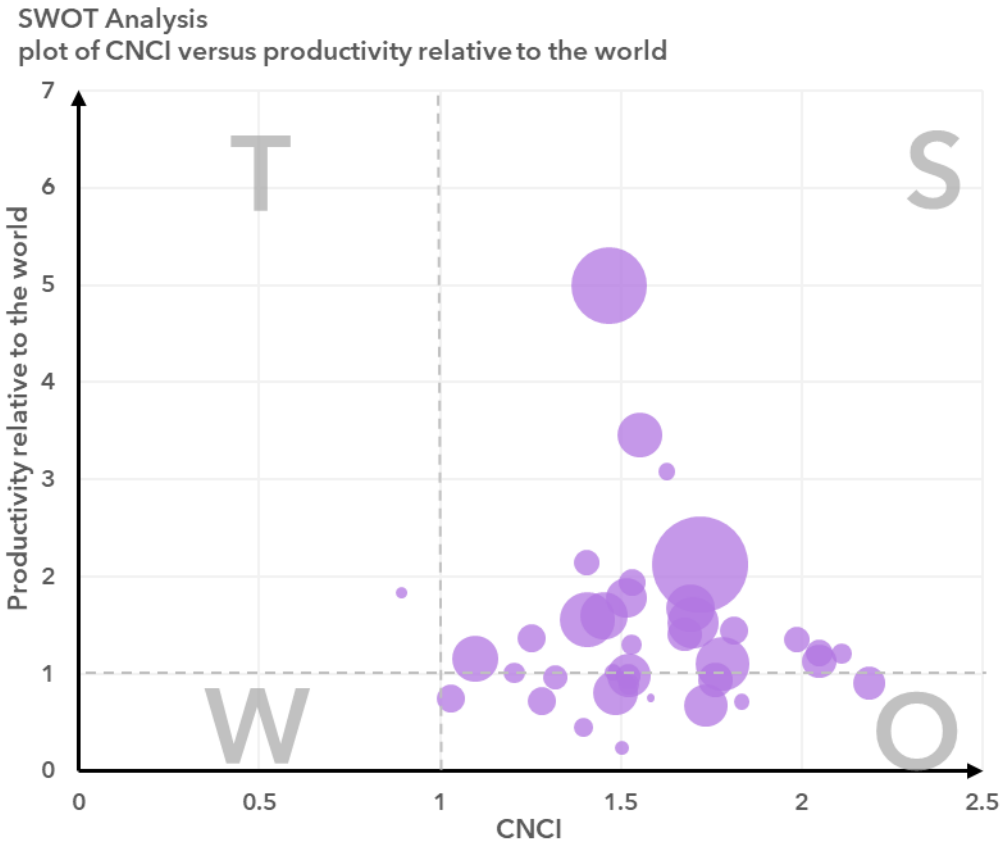

Figure 56: SWOT analysis of the national priority area Sustainability and Essentials. The y-axis shows the productivity relative to the global productivity (share of Saudi Arabia from the global productivity in the research topic normalized by Saudi Arabia share from global productivity when considering overall research). The x-axis shows the impact relative to the world.

Table 8: Saudi Arabia strength research topics in the national priority area Sustainability and Essentials

Research topic	CNCI	Productivity relative to the global productivity
Wastewater Purification/ Treatment	1.7	2.1
Electric Vehicles	1.8	1.1
Food-Borne Hazard Control	1.4	1.6
Pest Management	1.1	1.2
Bioenergy	1.7	1.5
Water - Domestic Purification	1.5	1.6
Carbon (CO2) Capture	1.7	1.7
Water Desalination	1.5	5.0
Carbon (CO2) Transport	2.0	1.1
Carbon (CO2) Utilization	1.5	1.8
Waste - Smart Management	1.7	1.4
Eco-Agrochemicals	1.3	1.4
Precision Agriculture	2.0	1.2
Resources from Wastewater	1.6	3.5
Waste-to-Energy	1.8	1.4
Intelligent Packaging	2.0	1.4
Air Purification	1.2	1.0
Waste Management	1.5	1.9
Water - Conservation Management	2.1	1.2

Hydroponics	1.5	1.3
Geothermal Energy	1.4	2.2
Food Alternatives	1.5	1.0
Brine mining	1.6	3.1

Table 9: Saudi Arabia opportunity research topics in the national priority area Sustainability and Essentials

Research topic	CNCI	Productivity relative to the global productivity
Aquaculture	1.7	0.7
Soil Preservation	1.5	0.8
Plant Breeding	1.5	1.0
Food Traceability & Distribution	1.8	0.9
Carbon (CO2) Storage	2.2	0.9
Emergency Communications	1.3	0.7
Seismology/Meteorology Event Detection	1.0	0.8
Urban Heat Island	1.4	0.5
Afforestation	1.5	0.2
Flood Protection	1.3	1.0
Sustainable Packaging	1.5	1.0
Waste Landfill	1.5	0.9
Shore Protection	1.8	0.7
Precision Livestock	1.6	0.8

3.5 Saudi Arabia research output performance analysis in Energy and Industrials (EI)

3.5.1 Research volume analysis

The number of Saudi Arabia papers published in the national priority area Energy and Industrials grew continuously from 621 papers in 2014 to 3816 papers in 2023 as shown in Figure 57.

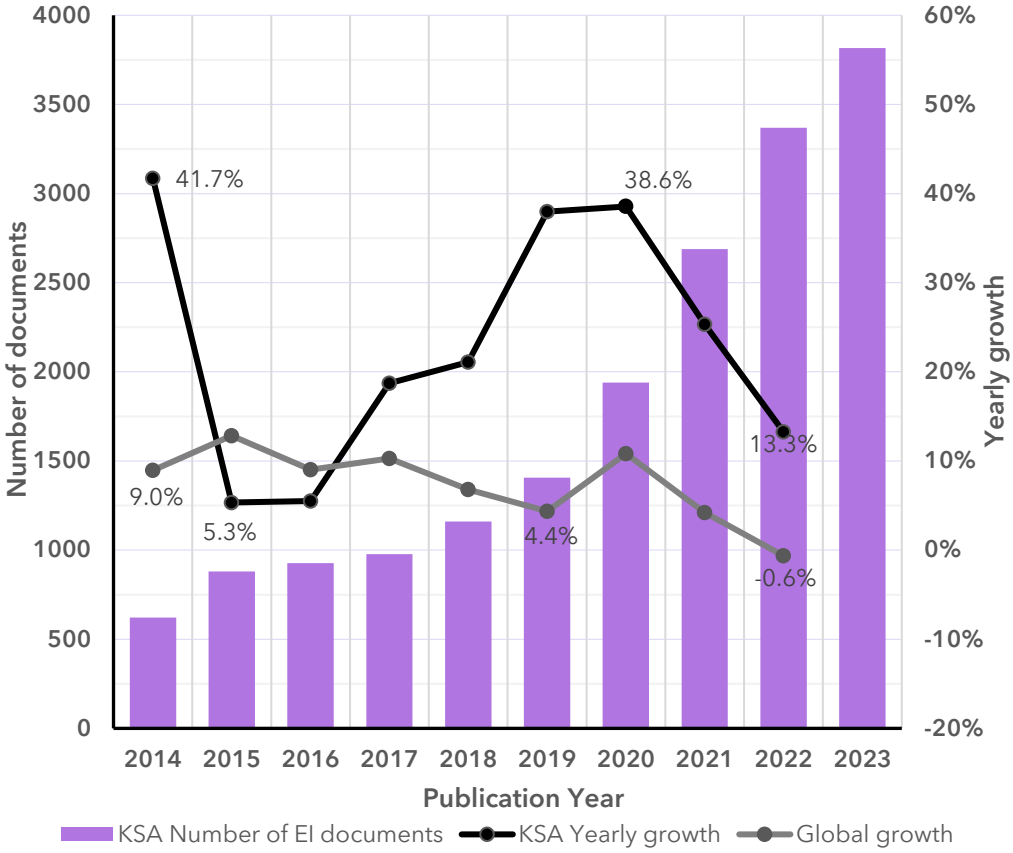

Figure 57: Saudi Arabia number of papers and growth in the national priority area Energy and Industrials

This reflects a double digit-growth for almost all years, for some years the growth rate was above 40%, and a much higher growth rate than the global rate in the same area. It is worth highlighting that although globally there was a negative growth rate between 2023 and 2024, in Saudi Arabia we still observe a double-digit growth rate of 13.3%.

In the considered period, Saudi Arabia had a yearly average growth rate not only three times of the average global rate but also higher than all of the other considered benchmark countries/regions as shown in Figure 58. All the above indicates, the focus nationally of increasing the research activity in this national priority area. In Figure 59 we the number of active Saudi affiliated researchers per year in the area Energy and Industrials is shown.

For more information on the methodology used to investigate the number of active researchers please see the section Number of active researchers.

As observed in the figure, the number of active Saudi researchers in this area increased continuously during the period 2014-2023. This reflects a x7.2 increase in this period indicating the growing number of researchers in this national priority area.

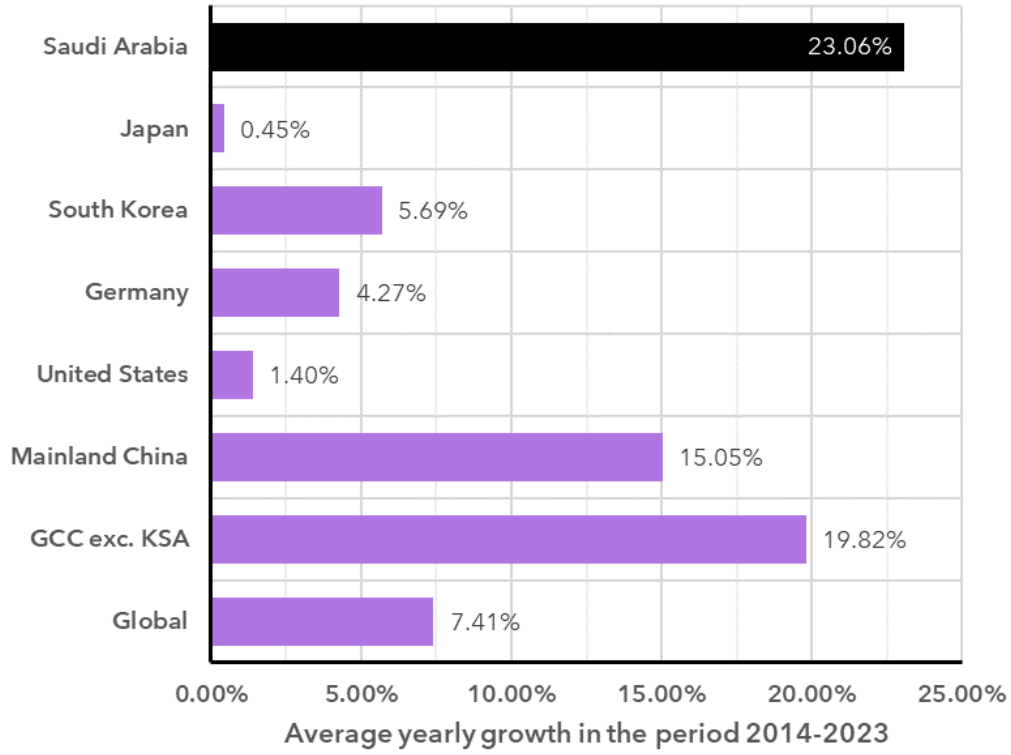

Figure 58: Average yearly growth of number of papers in the area Energy and Industrials in the period 2014-2023

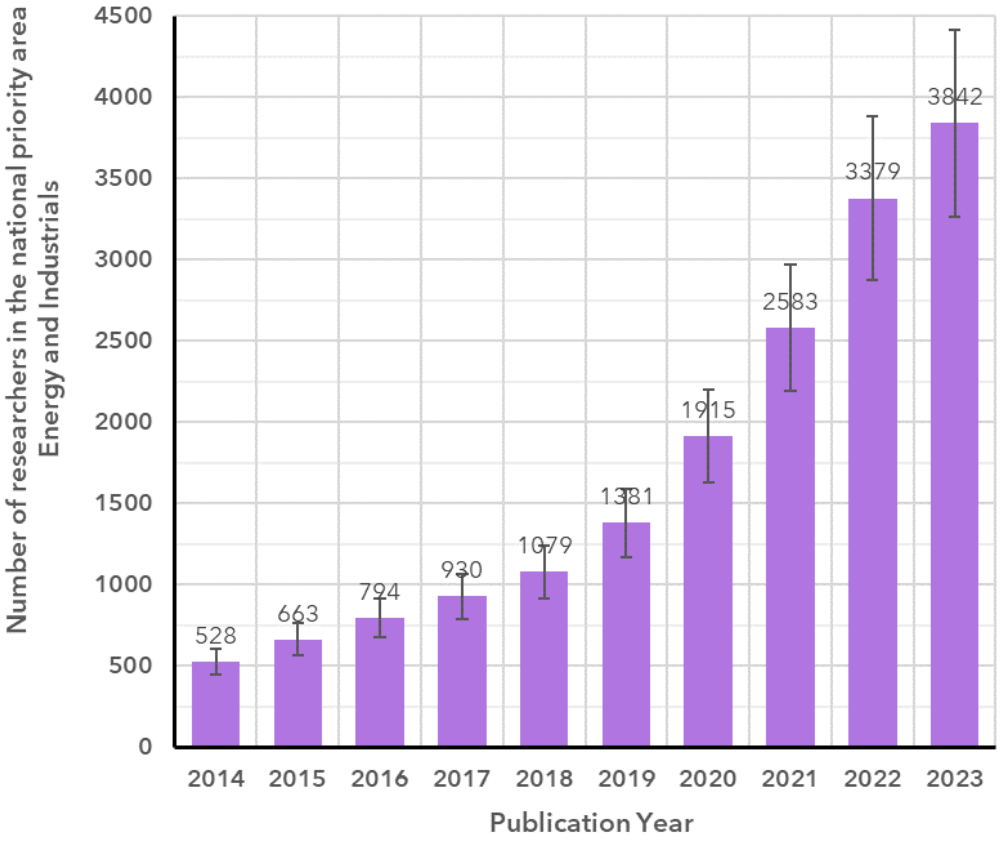

Figure 59: Number of active Saudi affiliated researchers in the area Energy and Industrials

3.5.2 Citation impact analysis

The category normalized citation impact (CNCI) of Saudi Arabia in the period 2014-2023 was always above 1.4 indicating a citation impact performance at least 40% higher than the global average as shown in Figure 60.

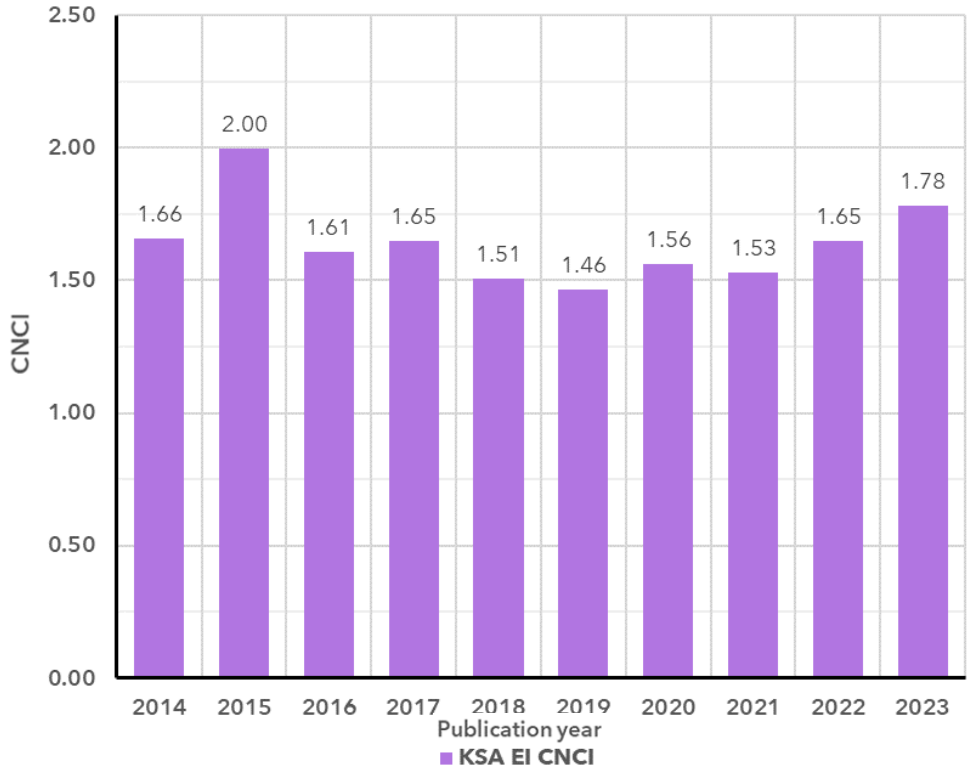

Figure 60: Saudi Arabia yearly category normalized citation impact in the area Energy and Industrials

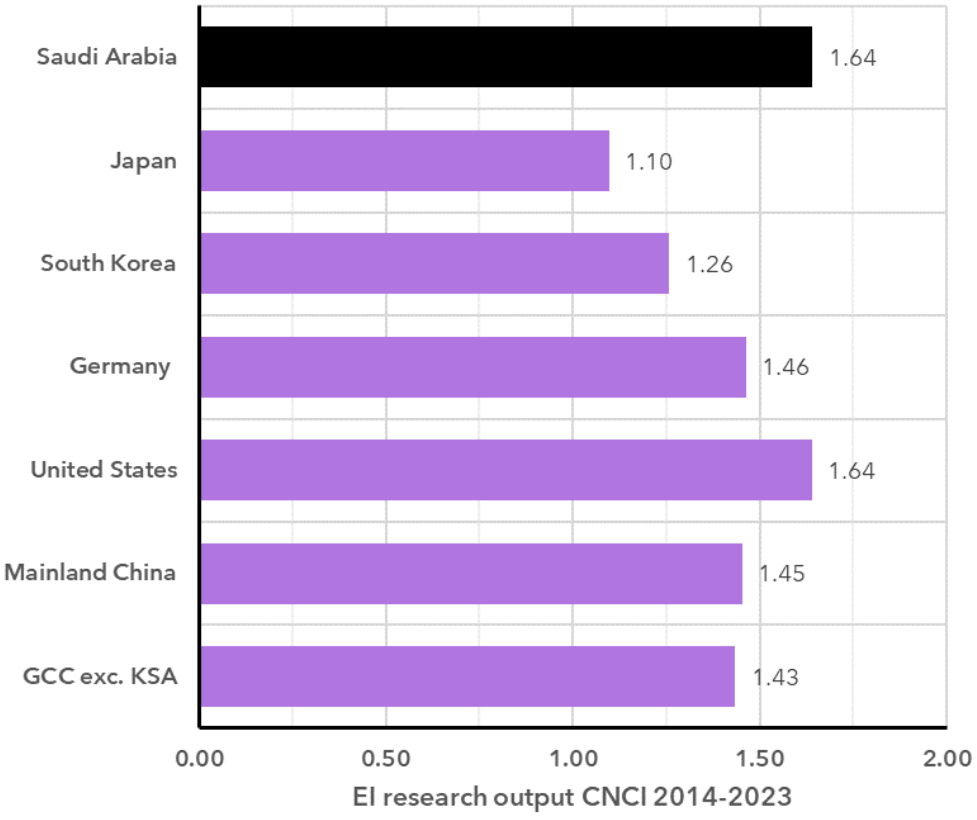

Figure 61: Energy and Industrials research output CNCI in the period 2014-2023

The CNCI fluctuated slightly in this period between 1.46 and 2.0. Saudi Arabia also achieved a CNCI in this period and in this area on par with the USA and higher than that of all the considered benchmark countries/regions as shown in Figure 61. This indicates a very high citation impact performance.

It is also important to highlight that the high citation impact footprint was sustained even during a period of significant growth in research output.

3.5.3 Research excellence analysis

The percentage of Saudi Arabia Top 1% documents in the area Energy and Industrials increased from 3.7% in 2014 to 4.89% in 2015 to then decrease continuously to 2.84% in 2020 as shown in Figure 62.

Afterwards the percentage increased continuously to reach 3.43% in 2023. On the other hand, the number of Top 1% documents increased almost continuously from 23 documents in 2014 to 131 documents in 2023. In general, the percentage of Saudi Arabia documents in the area Energy and Industrials fluctuated between 2.84% and 4.89%. Considering that the global average performance is ~1.9% as shown in Figure 63, this shows that for all years the performance of Saudi Arabia in this area was at least 50% higher than the global average.

Additionally, when considering the research output in the area Energy and Industrials during the period 2014-2023, Saudi Arabia had a higher percentage of Top 1% documents than all the other considered countries/regions.

This is in alignment with the analysis of CNCI showing high citation impact footprint of Saudi Arabia in this area and leading to high research excellence performance when considering the Top 1% documents.

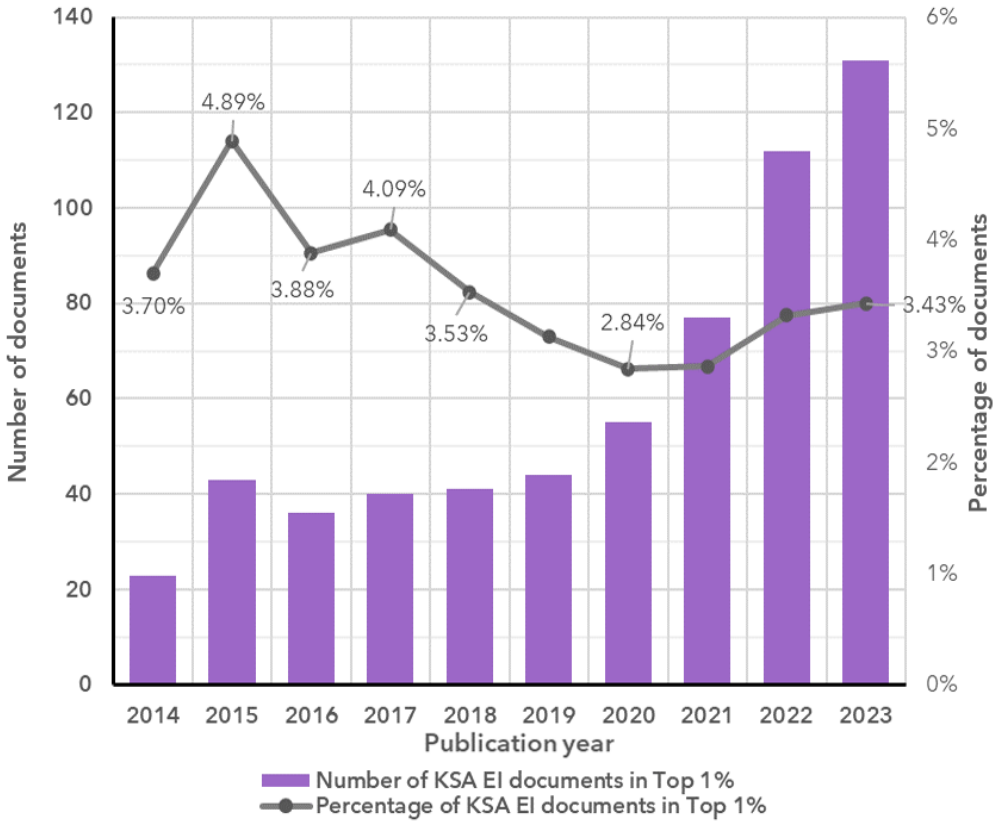

Figure 62: Number and percentage of Saudi Arabia Top 1% documents in the area Energy and Industrials

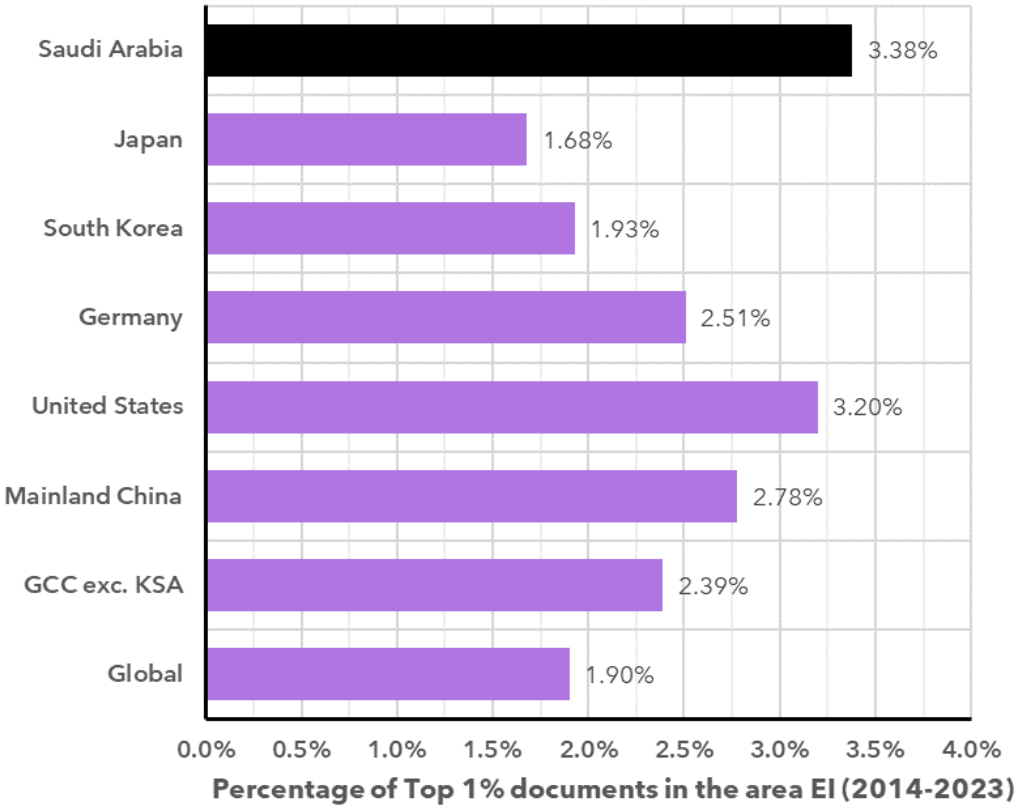

Figure 63: Percentage of Top 1% documents in the area Energy and Industrials during the period 2014-2023

The number of Saudi Arabia Top 10% documents increased almost continuously from 125 documents in 2014 to 854 documents in 2023 as shown in Figure 64. In the same period, the percentage of Top 10% documents fluctuated between 19.29% and 23.3%. The global average percentage of Top 10% documents in the area Energy and Industrials was 15%.

In comparison, Saudi Arabia had in all years at least a 28% higher percentage of Top 10% documents than the global percentage in this area. Additionally, the percentage of Saudi Arabia Top 10% documents in the area Energy and Industrials was higher than that of the global average as well as all considered countries/regions as shown in Figure 65.

Overall, when considering the Top 1% and Top 10% metrics, we observe a relatively high and consistent research excellence performance of Saudi Arabia in this national priority area in the last 10 years (2014-2023).

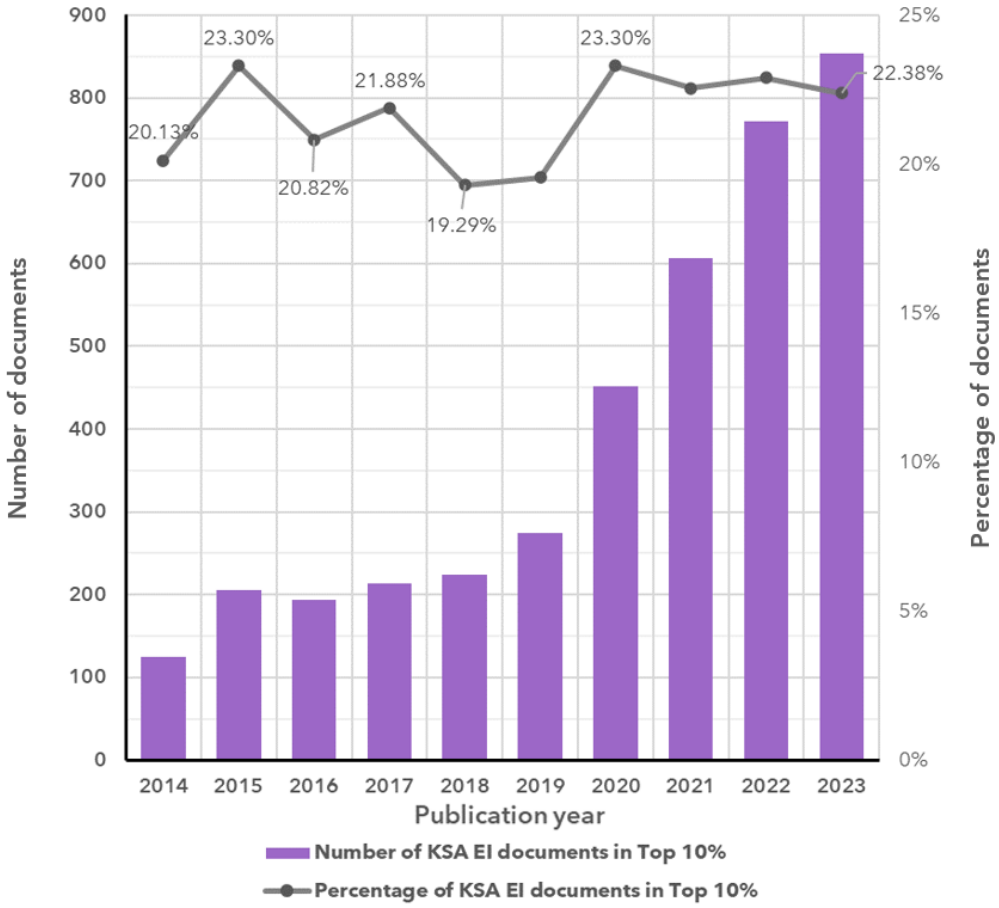

Figure 64: Number and percentage of Saudi Arabia Top 10% documents in the area Energy and Industrials

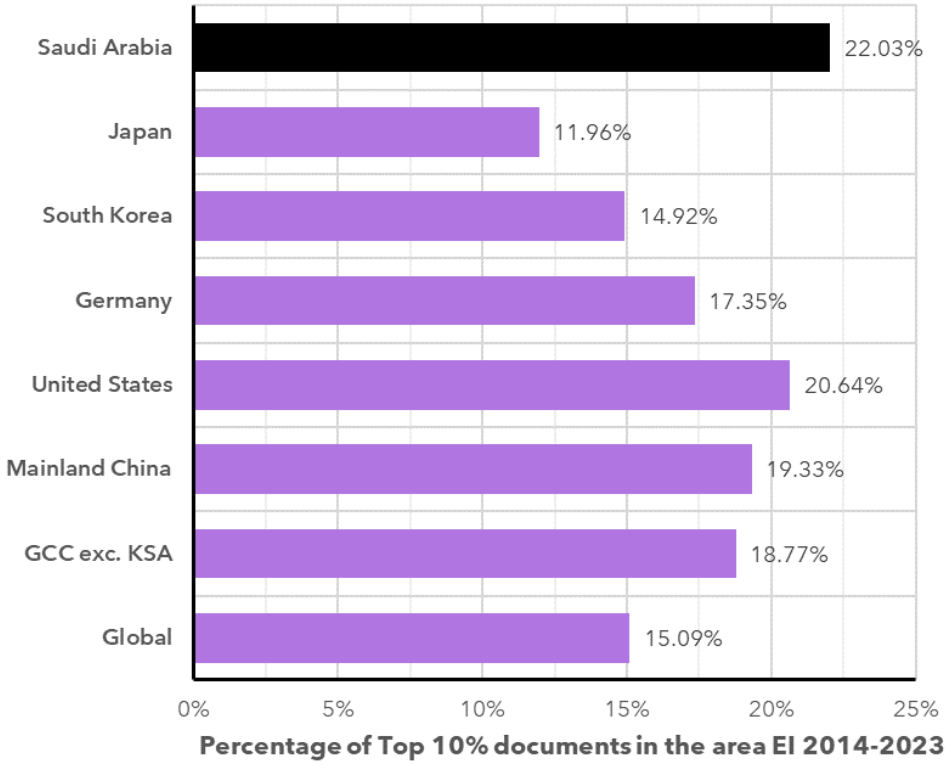

Figure 65: Percentage of Top 10% documents in the area Energy and Industrials during the period 2014-2023

3.5.4 Funding dynamics analysis

The percentage of Saudi Arabia documents with funding acknowledgement in the area Energy and Industrials is higher than that of GCC excluding Saudi Arabia, Japan, Germany, USA and the global baseline. Though it is lower than that South Korea and Mainland China as shown in Figure 66.

Moreover, the percentage of Saudi Arabia documents in the area Energy and Industrials with funding acknowledgment is higher than the percentage of total Saudi Arabia papers with funding acknowledgement.

Additionally, we notice that the percentage of articles with funding acknowledgement in the area Energy and Industrials is higher than that observed when considering the overall research output for the global baseline as well as for all considered countries/regions except for GCC excluding Saudi Arabia.

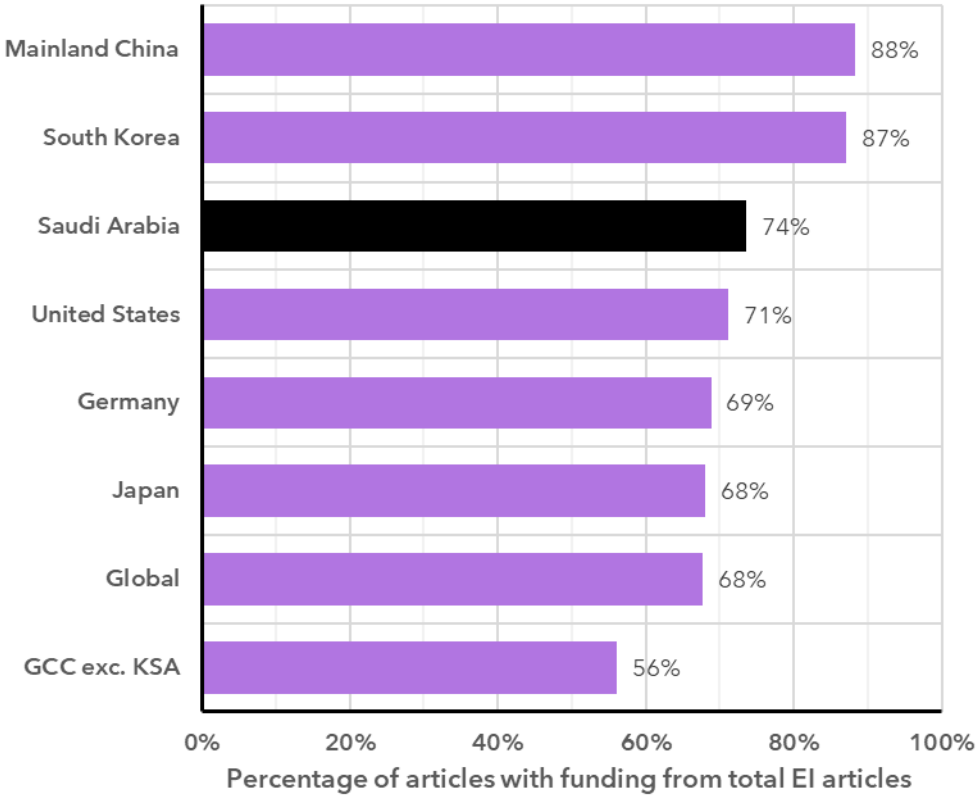

Figure 66: Percentage of publications with funding acknowledgment from overall Energy and Industrials publications in the period 2014-2023

The top 3 funding organizations mentioned in the funding text of Saudi Arabia documents in the area of Energy and Industrials during the period 2014-2023 are King Saud University, National Natural Science Foundation of China (NSFC) and King Abdullah University of Science & Technology with 1610, 1057 and 766 documents respectively as shown in Figure 67.

Research in collaboration with Saudi Arabia in the area Energy and Industrials that was funded by the National Basic Research Program of China resulted in the highest citation impact measured by the CNCI followed by National Key Research & Development Program of China and United States Department of Energy (DOE) with a CNCI of 4.8, 3.72 and 3.67 respectively.

The lowest CNCI is observed in papers funded by Higher Education Commission of Pakistan, with a CNCI of 0.95 reflecting a performance 5% lower than the global average.

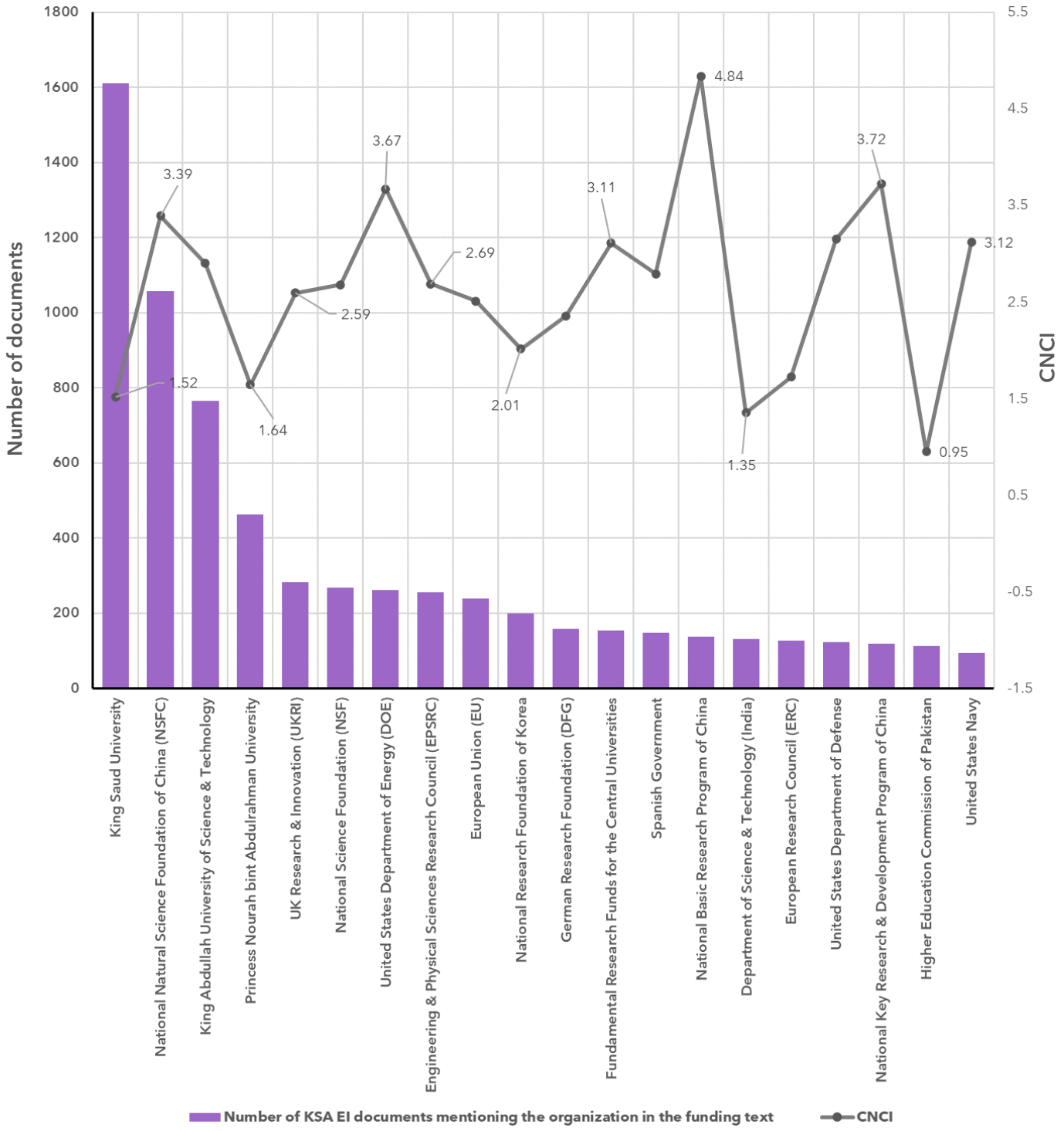

Figure 67: Top 20 funding organizations mentioned in the funding text of Saudi Arabia Energy and Industrials papers in the period 2014-2023

3.5.5 International collaboration dynamics analysis

In the area Energy and Industrials, the percentage of Saudi Arabia papers with an international collaboration (82%) is higher than that of all considered benchmark countries/regions as shown in Figure 68.

At the same time this means that Saudi Arabia has the lowest number of papers with only national affiliations.

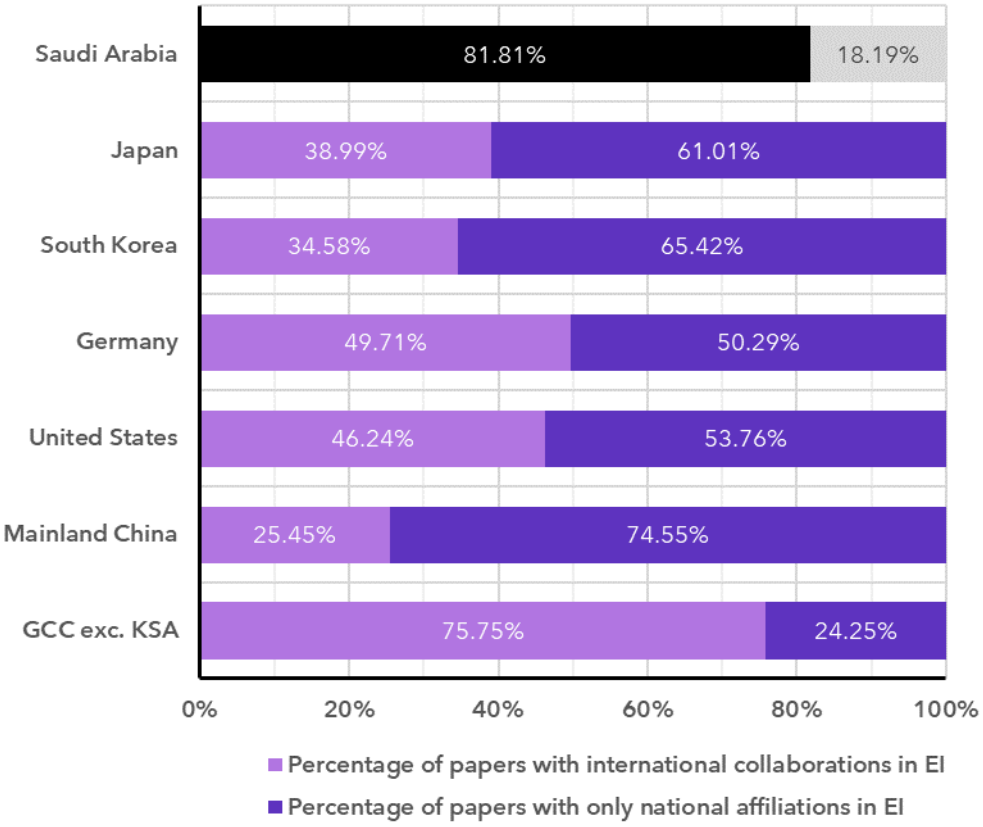

Figure 68: Percentage of papers with an international collaboration or only national affiliations in the area Energy and Industrials during the period 2014-2023

Egypt, followed by Mainland China and India had the highest number of documents in collaboration with Saudi Arabia affiliated researchers in the national priority area Energy and Industrials in the period 2014-2023 with 3381, 2410 and 2323 documents respectively as shown in Figure 69.

In terms of citation impact measured by the CNCI, papers in collaboration with Canada followed by Mainland China and Australia had the highest CNCI among the top 20 collaborating countries with a CNCI of 2.78, 2.68, and 2.33, respectively.

Nevertheless, research with all the top 20 collaborating countries with Saudi Arabia in this area resulted in a CNCI higher than 1, reflecting a citation impact higher than the global average.

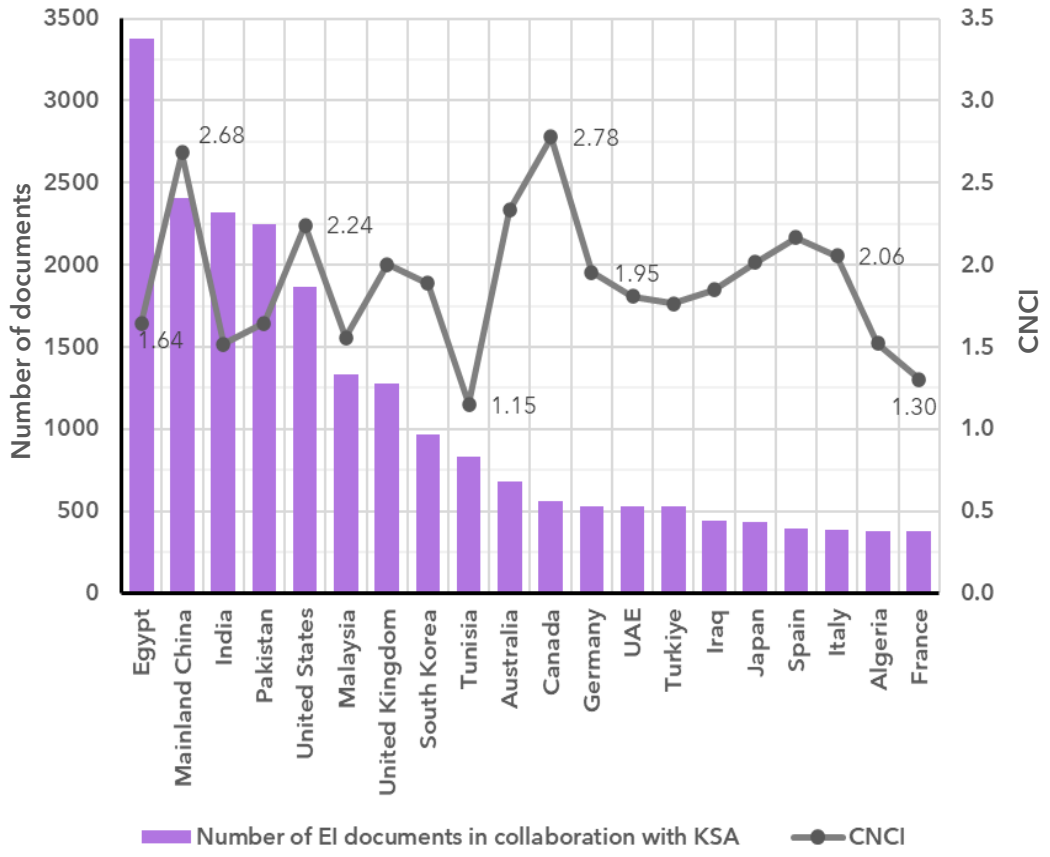

Figure 69: Top 20 collaborating countries with Saudi Arabia in the area Energy and Industrials in the period 2014-2023

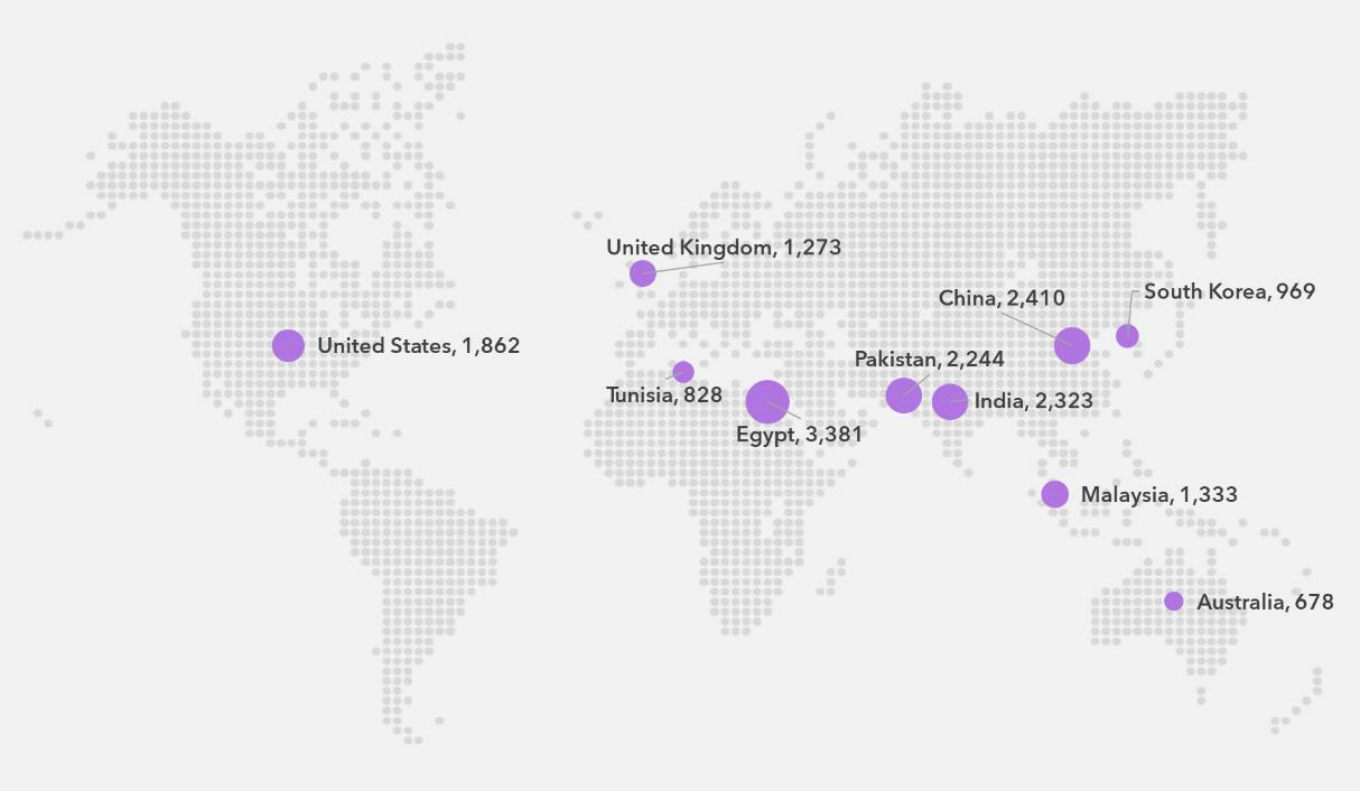

Figure 70: Top 10 collaborating countries with Saudi Arabia in the area Energy and Industrials in the period 2014-2023

3.5.6 Open access publications analysis

In the area Energy and Industrials over the period 2014-2023 the number of open access documents increased continuously reaching 1,856 documents in 2023 as shown in Figure 71.

On the other hand, the percentage of open access documents in this area increased almost continuously till 2022 and then slightly decreased to 48.7% in 2023.The percentage achieved in 2023 is lower than the one observed from the overall research output of 63.7%.

Although, in different disciplines there could be different dynamics regarding open access documents, one could further increase the percentage of open access documents in this area. This could lead to higher visibility of Saudi Arabia research output in this area and for possibly more citations.

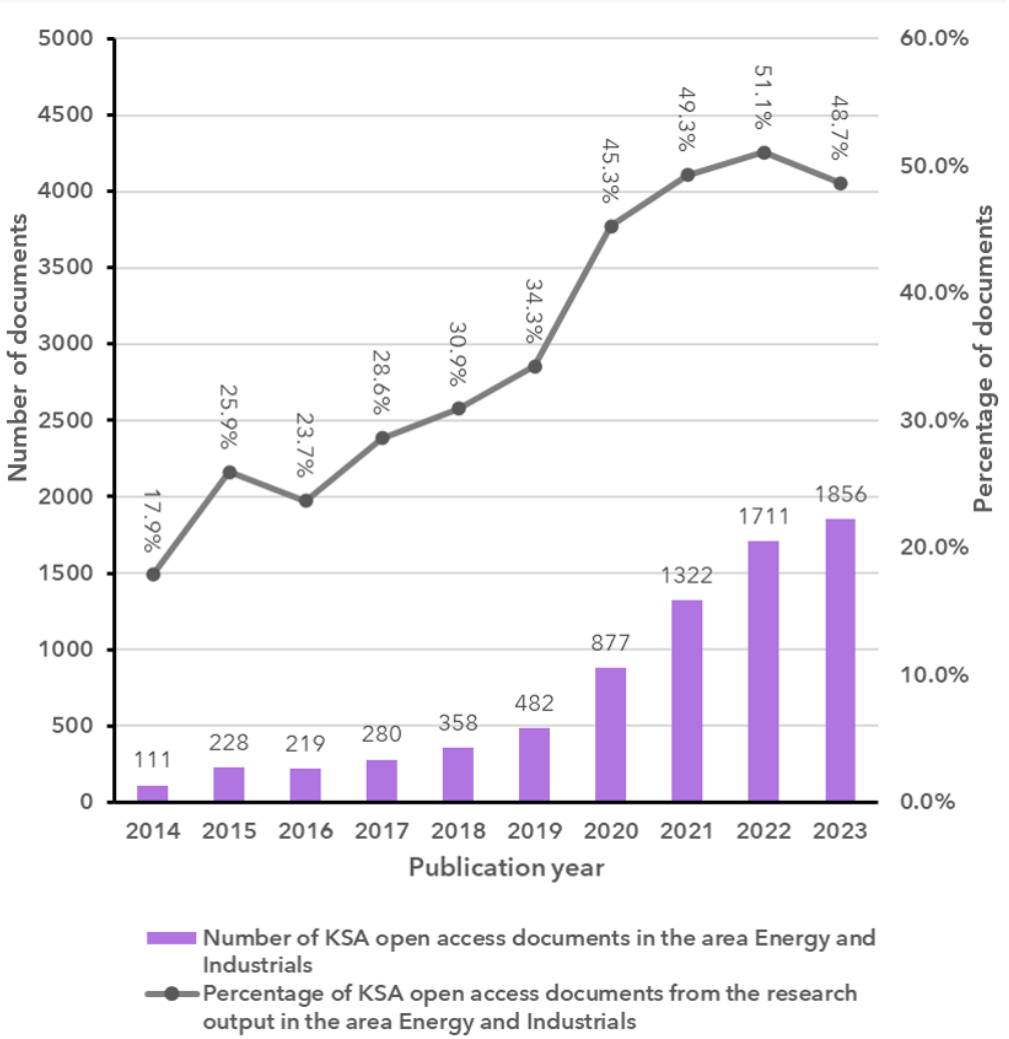

Figure 71: Number and percentage of Saudi Arabia open access documents in the area Energy and Industrials in the period 2014-2023

3.5.7 Top 20 organizations in terms of number of publications

The top 20 organizations in Saudi Arabia in terms of number of documents published in the area Energy and Industrials during the period 2014-2023 are King Saud University with 2,989 documents followed by King Abdulaziz University with 2,804 and King Abdullah University of Science & Technology with 2,168 documents as shown in Figure 72.

In terms of citation impact measured by the CNCI, the highest CNCI is achieved by King Abdullah University of Science & Technology followed by King Abdulaziz University and Imam Abdulrahman Bin Faisal University with a CNCI of 2.36, 2.06, and 1.88, respectively.

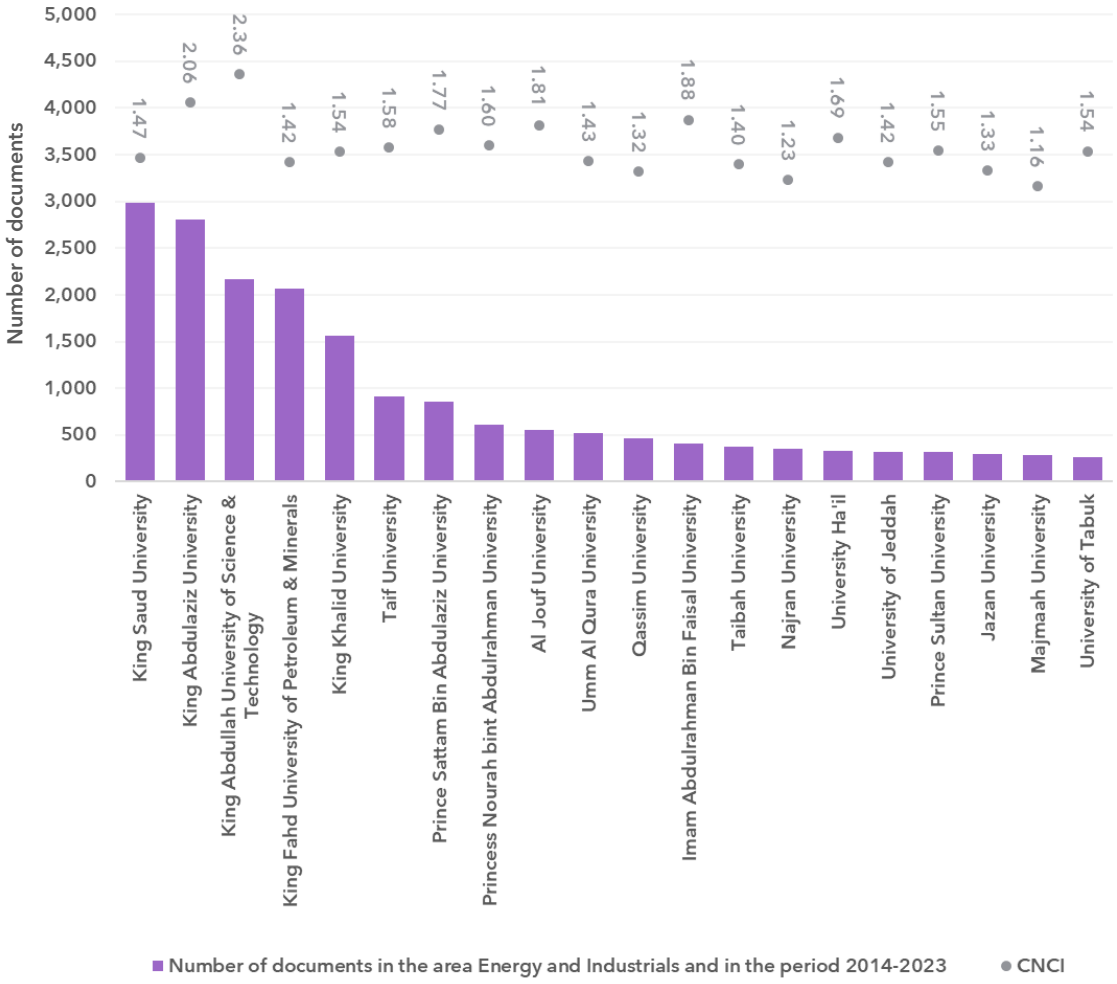

Figure 72: Top 20 Saudi organizations in terms of documents published in the area Energy and Industrials during the period 2014-2023

3.5.8 Top 20 Saudi affiliated researchers in terms of number of publications in the area Energy and Industrials

The top 3 Saudi affiliated researchers in terms of number of documents published in the period 2014-2023 and in this area are Abdullah M. Asiri affiliated to King Abdulaziz University with 231 documents followed by Stefaan De Wolf affiliated to King Abdullah University of Science & Technology with 140 documents and Ibrahim Sayed Yahia affiliated to King Khalid University with 136 documents as shown in Table 10.

Among the top 20, Osman M. Bakr affiliated to King Abdullah University of Science & Technology had the highest CNCI with 5.78. The highest number of Top 1% documents with 30 documents and the highest number of Top 10% documents with 103 documents is achieved by Abdullah M. Asiri.

Table 10: Top 20 Saudi affiliated researchers in the period 2014-2023 in terms of number of documents published in the area Energy and Industrials

Name	Affiliation	Web of Science Publications	CNCI	Documents in Top 1%	Documents in Top 10%
Asiri, Abdullah M.	King Abdulaziz University	231	3.58	30	103
De Wolf, Stefaan	King Abdullah University of Science & Technology	140	3.49	17	64
Yahia, Ibrahim Sayed	King Khalid University	136	1.13	0	20
Bakr, Osman M.	King Abdullah University of Science & Technology	134	5.78	29	77
Rezk, Hegazy	Prince Sattam Bin Abdulaziz University	132	2.14	6	47
Mohammed, Omar F.	King Abdullah University of Science & Technology	132	4.63	20	59
Anthopoulos, Thomas D.	King Abdullah University of Science & Technology	124	3.74	21	53
Laquai, Frédéric	King Abdullah University of Science & Technology	124	3.08	13	48
Al-fatesh, Ahmed S	King Saud University	111	1.22	0	19
Khalid, Muhammad	King Fahd University of Petroleum & Minerals	105	1.75	4	28
Alsaedi, Ahmed	King Abdulaziz University	103	1.21	0	16
Fakeeha, Anis H.	King Saud University	101	1.17	0	15
Kamal, Muhammad Shahzad	King Fahd University of Petroleum & Minerals	99	1.21	1	14
Baran, Derya	King Abdullah University of Science & Technology	97	3.51	12	45
Al-Ghamdi, Ahmed	King Abdulaziz University	85	1.54	4	12
Eltamaly, Ali M.	King Saud University	82	1.38	1	18
Rehman, Shafiqur	King Fahd University of Petroleum & Minerals	81	1.01	1	8
Abasaeed, Ahmed	King Saud University	79	1.14	0	12
Abido, M. A.	King Fahd University of Petroleum & Minerals	76	1.68	3	12
Al Faify, Salem	King Khalid University	75	1.07	0	9

3.5.9 SWOT analysis of the underlying research topics

In this part we have a more granular look by analyzing the research performance of Saudi Arabia in the underlying categories the constitute the national priority area Energy and Industrials.

The research topics constituting the area and the selection of those research topics is described in Dataset Description. To do this we perform a Strength, Weakness, Opportunity and Threat (SWOT) analysis. For more information on the SWOT analysis please see the section Strengths, Weakness, Opportunities and Threats Analysis (SWOT).

When investigation Saudi Arabia performance in the research topics constituting the national priority area Energy and Industrials, we notice that out of the 37 research topics there are 22 strength research topics listed in Table 11, 12 opportunity research topics listed in Table 12, two weakness research topics listed in Table 13 and one threat area as shown in Table 14 as also shown in Figure 73.

As all of these research topics are of national priority, one should try to conserve the high performance in the strength research topics, increase the productivity in the opportunity areas by leveraging on the gained expertise that is evident with the CNCI being higher than 1, improve the quality and accordingly the citation impact in the threat areas as well as increase the citation impact and productivity in the weakness research topics.

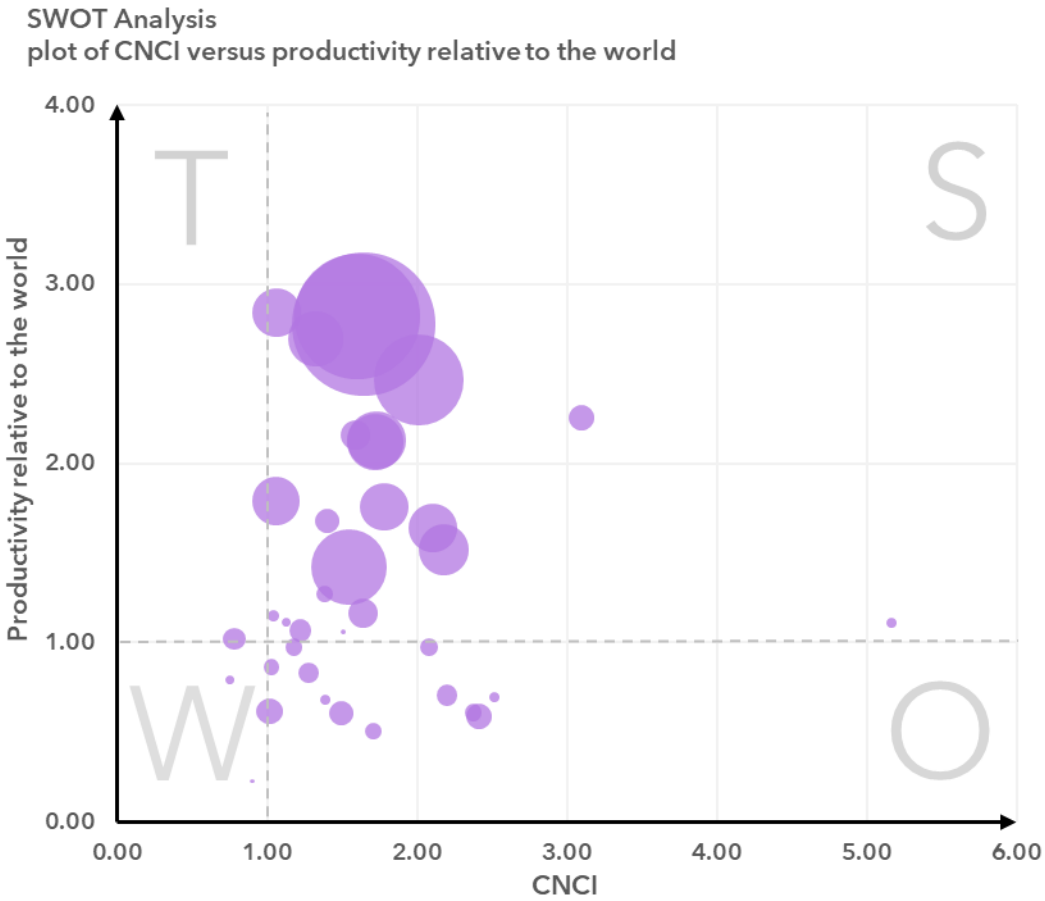

Figure 73: SWOT analysis of the national priority area Energy and Industrials. The y-axis shows the productivity relative to the global productivity (share of Saudi Arabia from the world productivity in the research topic normalized by Saudi Arabia share from global productivity when considering overall research). The x-axis shows the impact relative to the global average.

Table 11: Saudi Arabia strength research topics in the national priority area Energy and Industrials

Research topic	CNCI	Productivity relative to the global productivity
PV Modules	1.64	2.78
Solar Farms	1.60	2.82
Hydrogen Production	2.01	2.47
Wind Turbines	1.54	1.42
Grid Integration	1.73	2.13
Smart Grids	1.72	2.12
COTC Products	1.32	2.69
Lithium-Sulphur Battery	2.18	1.52
Hydrogen Storage and Transportation	1.78	1.76
Intelligent Manufacturing	2.10	1.64
COTC Processes	1.06	1.79
Oil Reuse	1.06	2.84
Rare-Earth Use	1.59	2.16
Battery Management	1.64	1.16
Energy from Ammonia	3.10	2.25
Mining Automation Software	1.22	1.07
Sustainable Mining Waste Management	1.40	1.68
Autonomous Mining - Smart Drilling	1.38	1.27
Bladeless Wind Turbines	1.04	1.15

Rare-Earth Recovery	5.16	1.11
Smart HVAC	1.13	1.11
Sodium-Sulphur Battery	1.51	1.06

Table 12: Saudi Arabia opportunity research topics in the national priority area Energy and Industrials

Research topic	CNCI	Productivity relative to the global productivity
Industry Predictive maintenance	1.01	0.62
Solid State Battery	2.42	0.59
Tidal/Wave Energy	1.50	0.61
Sodium Ion Battery	2.20	0.71
Autonomous Mining - Remotely Operated Equipment	1.27	0.83
Industrial Emissions	2.08	0.98
Vehicle Emissions	1.18	0.98
Digital Twins	2.38	0.61
Industrial Robots	1.70	0.51
Small Modular Nuclear Reactor (SMR)	1.03	0.86
Sustainable Mining - Water Conservation	1.39	0.68
Sustainable Mining - Low Emissions	2.52	0.69

Table 13: Saudi Arabia weakness research topics in the national priority area Energy and Industrials

Research topic	CNCI	Productivity relative to the global productivity
Autonomous Mining - Self-driving Vehicles	0.75	0.79
Construction Robots	0.90	0.23

Table 14: Saudi Arabia threat research topics in the national priority area Energy and Industrials

Research topic	CNCI	Productivity relative to the global productivity
Production Planning & Lean Manufacture	0.78	1.02

3.6 Saudi Arabia research output performance analysis in Economies of the Future (EF)

3.6.1 Research volume analysis

The number of Saudi Arabia papers published in the national priority area Economies of the Future grew continuously from 1,311 papers in 2014 to 11,305 papers in 2023 as shown in Figure 74.

This reflects a double digit-growth for almost all years, for some years the growth rate was above 40%, and a much higher growth rate than the global rate in the same area. It is worth highlighting, that although globally there was a negative growth rate between 2023 and 2024, in Saudi Arabia we still observe a positive growth rate of 4.3%.

In the considered period, Saudi Arabia had a yearly average growth rate not only double the average global rate but also higher than all of the other considered benchmark countries/regions as shown in Figure 75. All of the above indicates, the focus nationally of increasing the research activity in this national priority area.

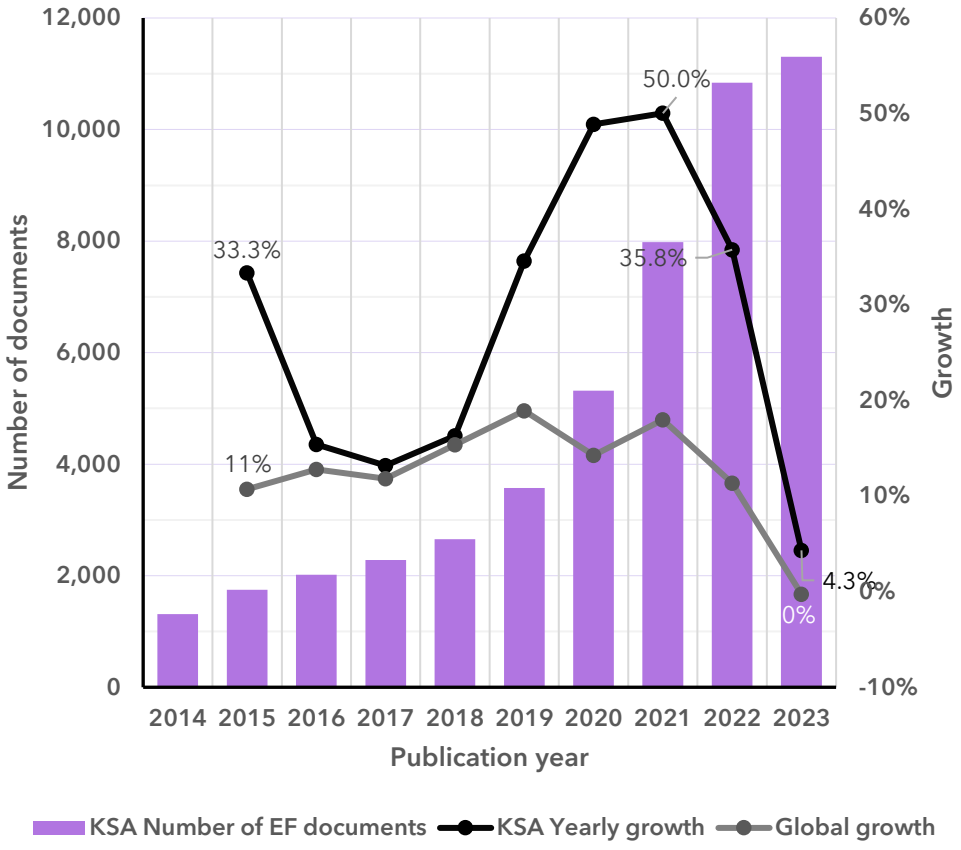

Figure 74: Saudi Arabia number of papers and growth in the national priority area Economies of the Future

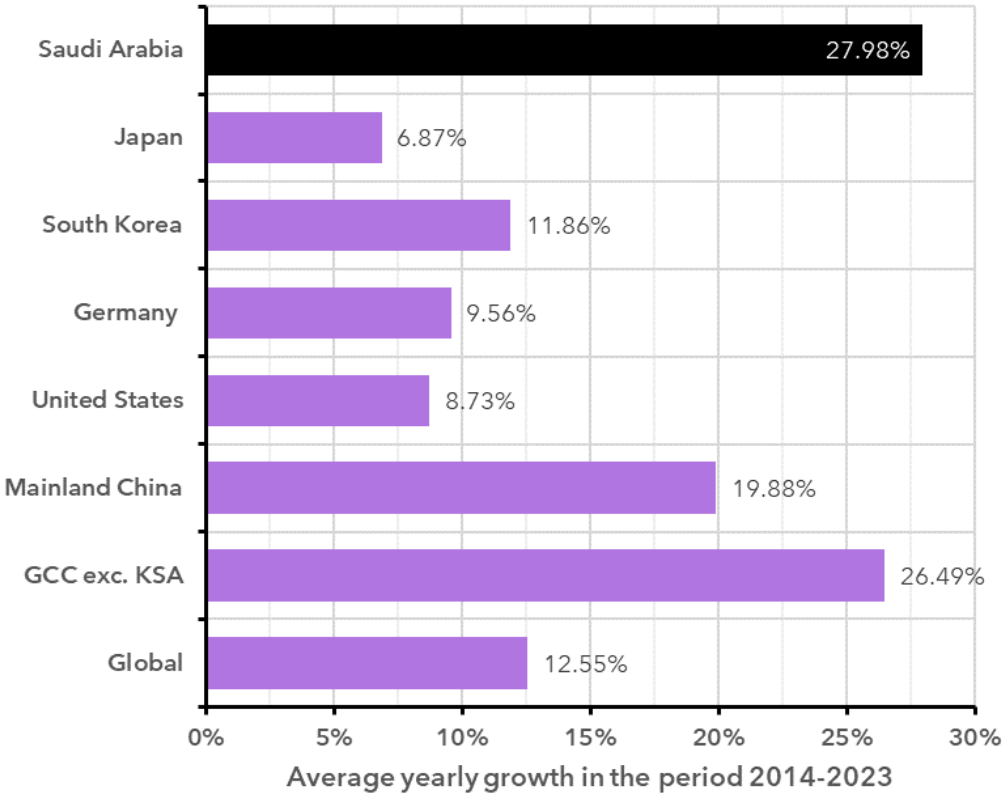

Figure 75: Average yearly growth of number of papers in the area Economies of the Future in the period 2014-2023

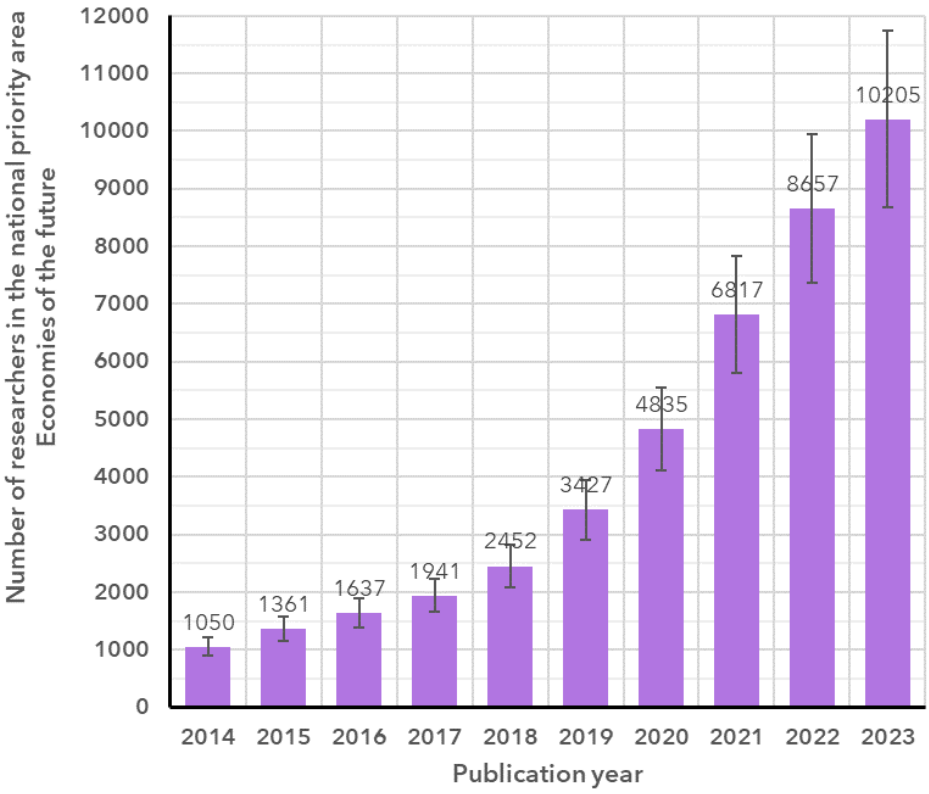

Figure 76: Number of active Saudi affiliated researchers in the area Economies of the Future

In Figure 76 the number of active Saudi affiliated researchers per year in the area Economies of the Future is shown. For more information on the methodology used to investigate this metric please see the section Number of active researchers.

As we have seen earlier the number of Saudi Arabia papers in the area Economies of the Future increased continuously in the last 10 years 2014-2023. In parallel, as well as the number of active researchers in this area also increased continuously. This reflects a x9.7 increase in this period.

3.6.2 Citation impact analysis

The CNCI of Saudi Arabia in the period 2014-2023 was always above 1.47 indicating a citation impact performance at least 47% higher than the global average as shown in Figure 77.

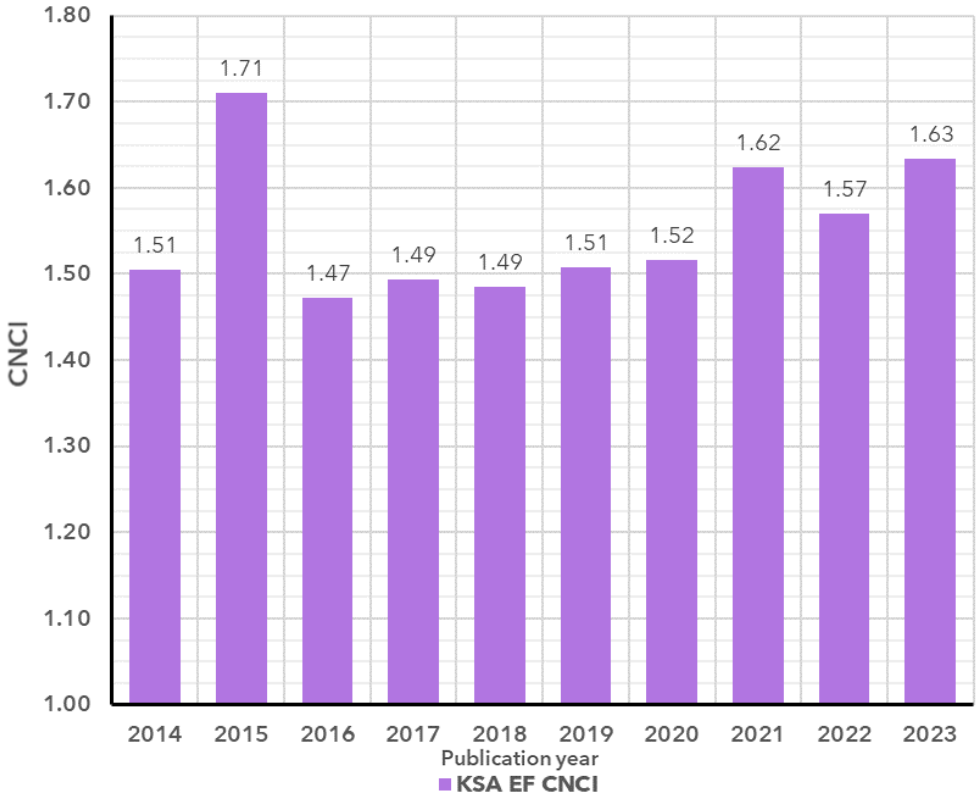

Figure 77: Saudi Arabia yearly category normalized citation impact in the area Economies of the Future

The CNCI fluctuated slightly in this period between 1.42 and 1.71. Saudi Arabia also achieved a CNCI in this period and in this area higher than that of all the considered benchmark countries/regions except for that of USA and GCC excluding Saudi Arabia as shown in Figure 78.

This indicates a very high citation impact performance. It is important to emphasize that the high citation impact was maintained despite a period of rapid growth in research output.

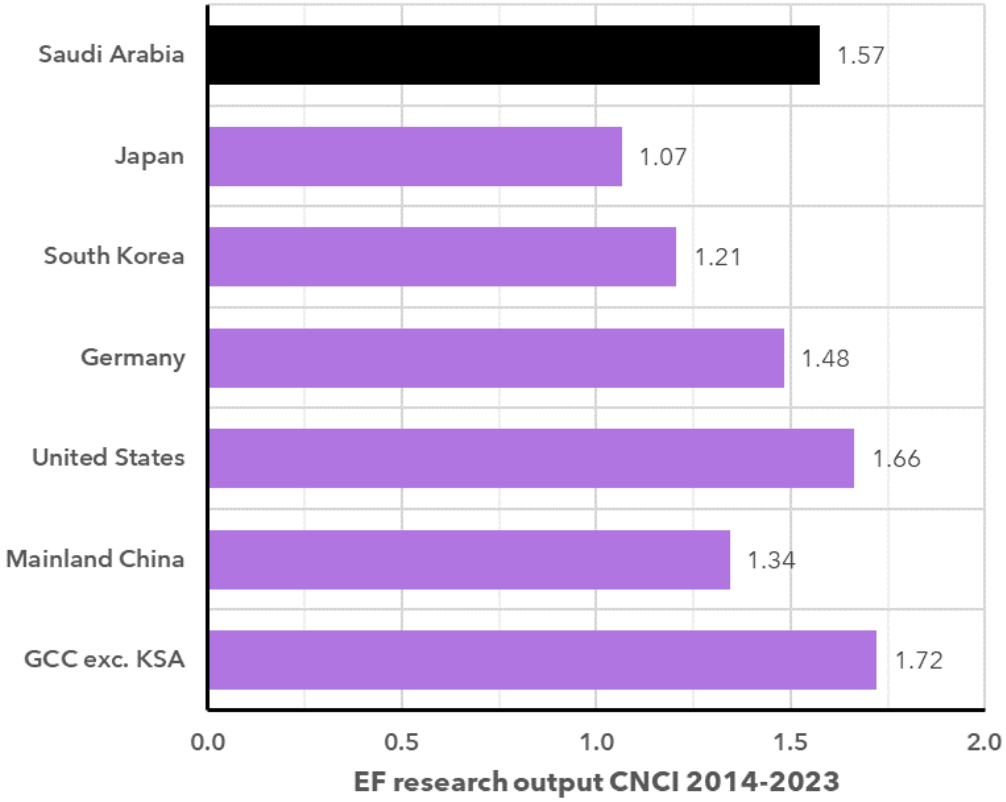

Figure 78: Economies of the Future research output CNCI in the period 2014-2023

3.6.3 Research excellence analysis

The percentage of Saudi Arabia Top 1% documents in the area Economies of the Future fluctuated between 2.6% and 3.66% as shown in Figure 79.

On the other hand, the number of Top 1% documents increased almost continuously from 37 documents in 2014 to 316 documents in 2022 and then decreased slightly to 293 in 2023.

Considering that the global average performance is ~1.79% as shown in Figure 80, this shows that for all years the performance of Saudi Arabia in this area was at least 45% higher than the global average.

Additionally, when considering the research output in the area Economies of the Future over the whole period 2014-2023, Saudi Arabia had a higher percentage of Top 1% documents than all the other considered countries/regions and a close percentage to that of USA and GCC excluding Saudi Arabia.

This is in alignment with the analysis of CNCI showing high citation impact footprint of Saudi Arabia in this area and leading to high research excellence performance when considering the Top 1% documents.

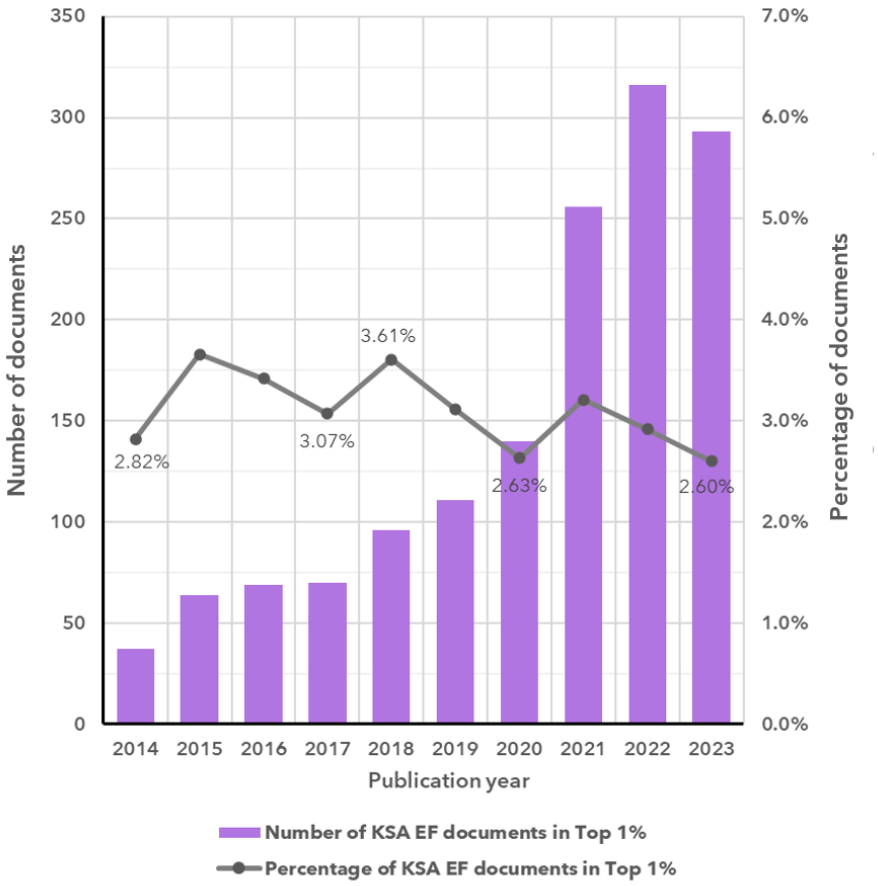

Figure 79: Number and percentage of Saudi Arabia Top 1% documents in the area Economies of the Future

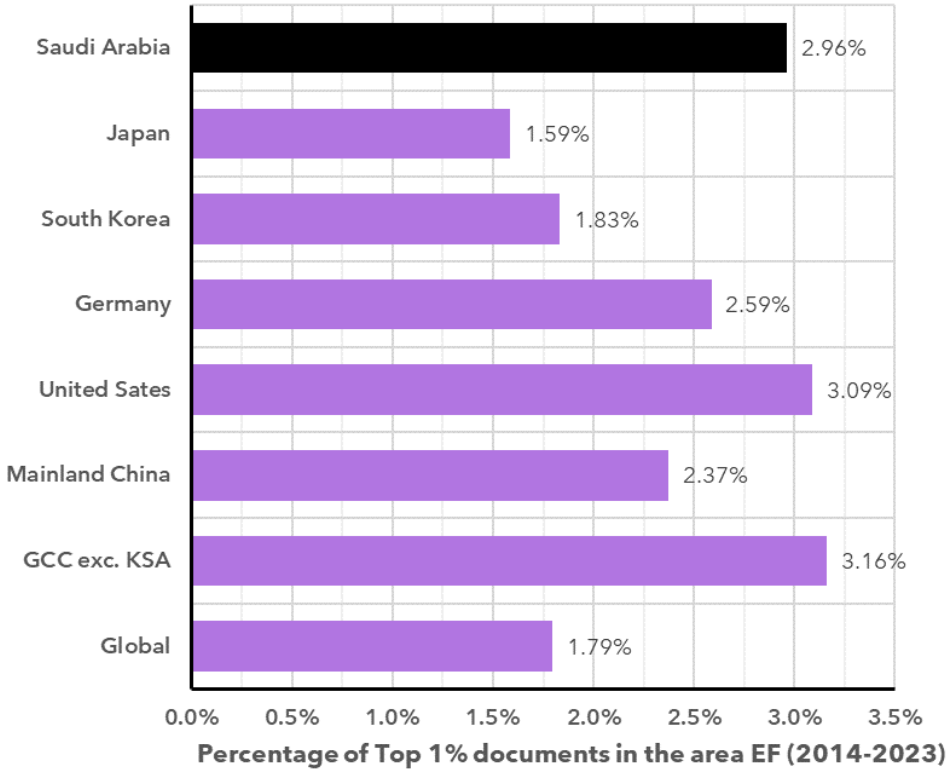

Figure 80: Percentage of Top 1% documents in the area Economies of the Future and the period 2014-2023

The number of Saudi Arabia Top 10% documents increased almost continuously from 239 documents in 2014 to 2264 documents in 2022 and then decreased slightly to 2162 in 2023 as shown in Figure 81. In the same period, the percentage of Top 10% documents fluctuated between 18.23% and 21.82%.

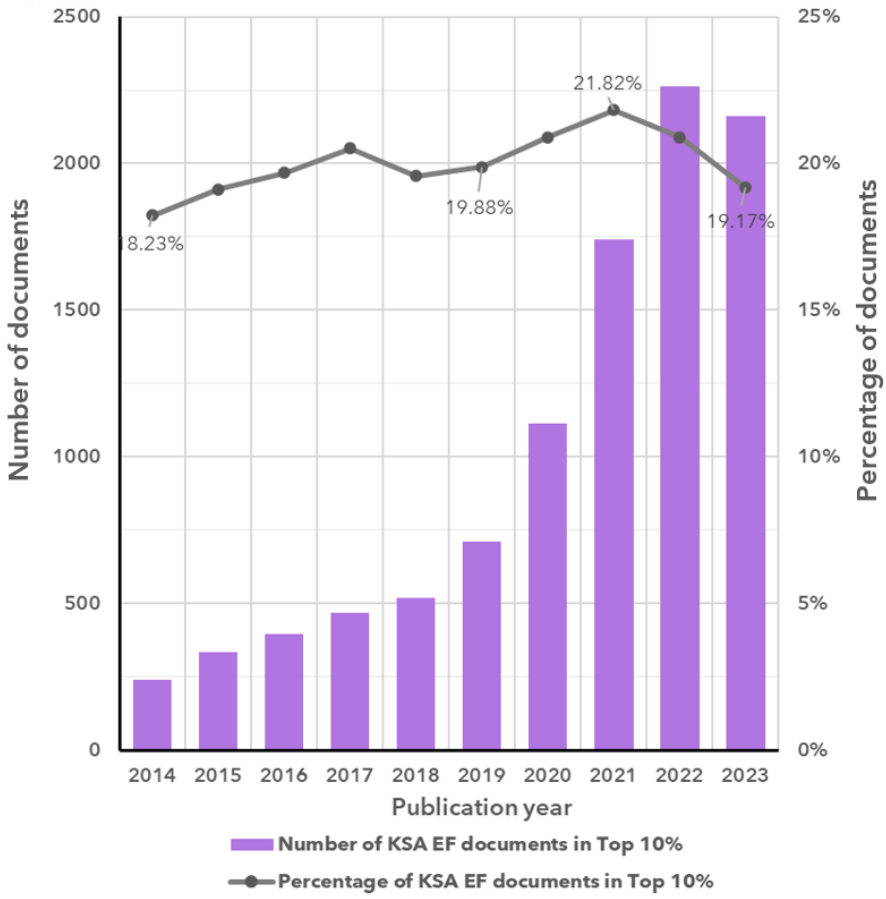

Figure 81: Number and percentage of Saudi Arabia Top 10% documents in the area Economies of the Future

The global percentage of Top 10% documents in this area and in the same period was 13.88%. In comparison, Saudi Arabia had in all years at least a 31% higher percentage of Top 10% documents.

Additionally, the percentage of Saudi Arabia Top 10% documents in the area Economies of the Future was higher than that of the global average as well as all considered countries/regions except for GCC excluding Saudi Arabia, which achieved a slightly higher percentage as shown in Figure 82.

Overall, when considering the Top 1% and Top 10%, we observe a relatively high and consistent research excellence performance of Saudi Arabia in this national priority area in the last 10 years (2014-2023).

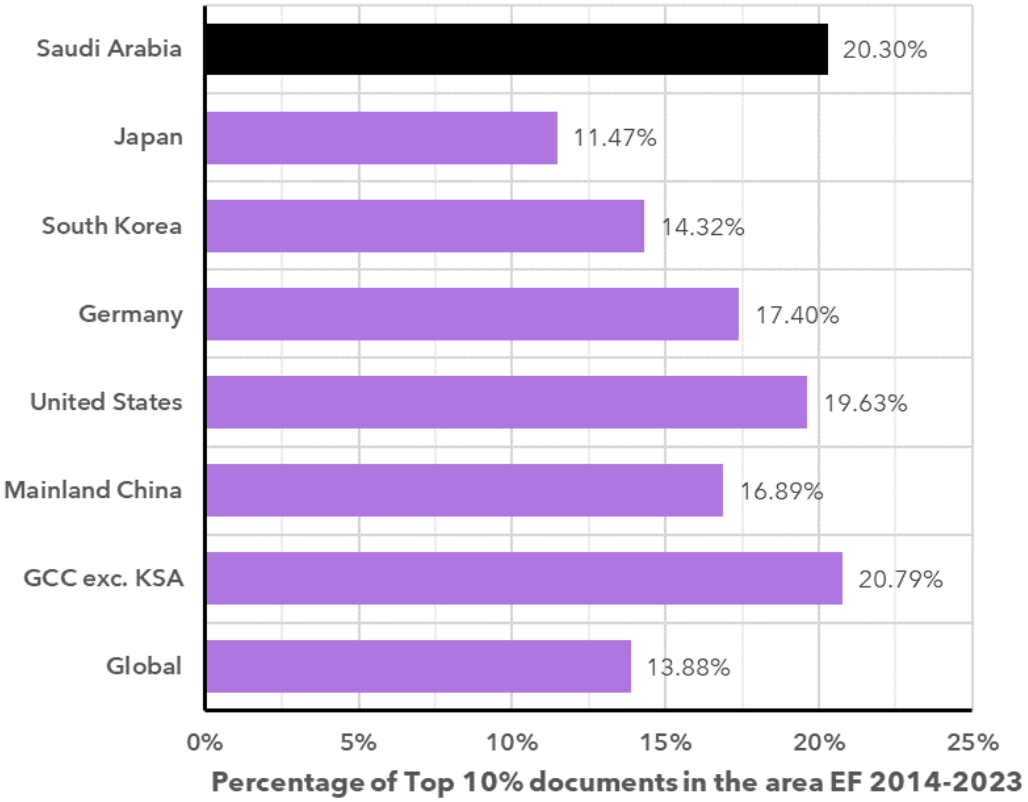

Figure 82: Percentage of Top 10% documents in 2014-2023 in the area Economies of the Future

3.6.4 Funding dynamics analysis

The percentage of Saudi Arabia papers in the area Economies of the Future with funding acknowledgement is higher than that of GCC excluding Saudi Arabia and the global baseline. It is slightly lower but close to that of Japan, USA and Germany. Though, it is lower than that of Mainland China and South Korea as shown in Figure 83.

Moreover, the percentage of Saudi Arabia documents in the area Economies of the Future with funding acknowledgment is higher than the percentage of total Saudi Arabia papers with funding acknowledgment.

Additionally, we notice that the percentage of articles with funding acknowledgment in the area Economies of the Future is higher than observed when considering the overall research output for the global baseline as well as for all considered countries/regions.

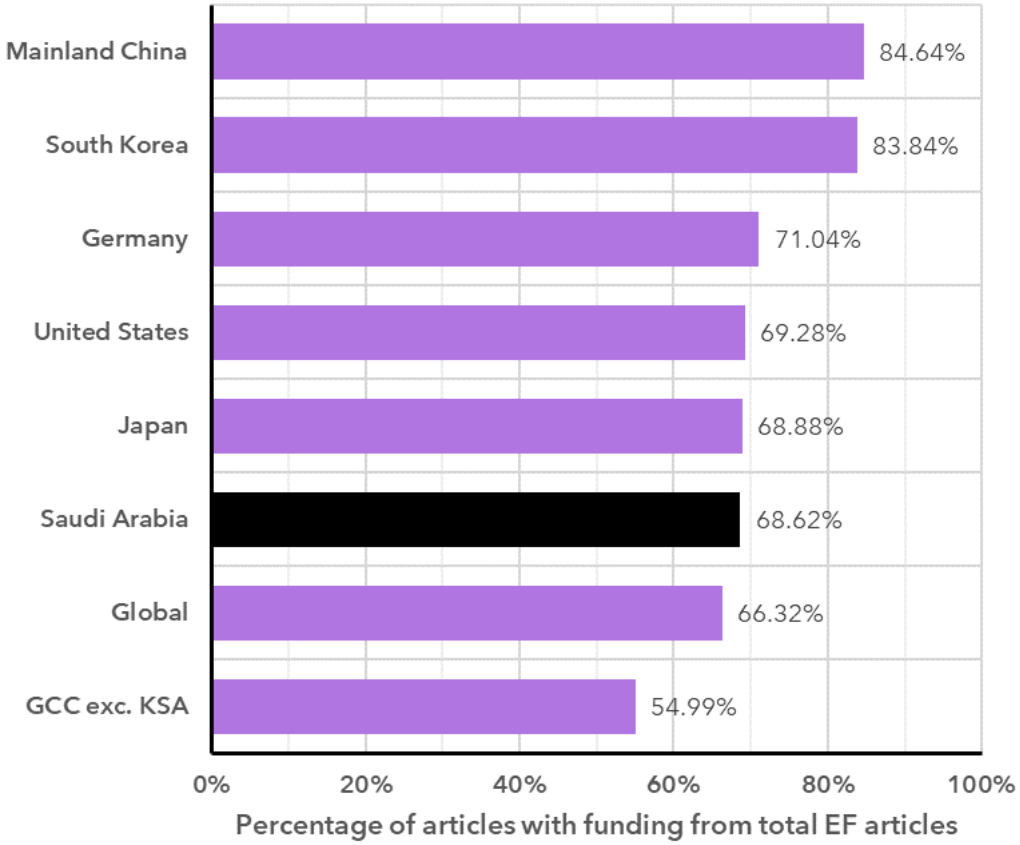

Figure 83: Percentage of publications with funding acknowledgement from overall Economies of the Future publications in the period 2014-2023

The top 3 funding organizations mentioned in the funding text of Saudi Arabia documents in the area Economies of the Future and in the period 2014-2023 are King Saud University, National Natural Science Foundation of China (NSFC) and Princess Nourah bint Abdulrahman University with 4206, 2742 and 1765 documents respectively as shown in Figure 84.

Saudi Arabia's research in the area Economies of the Future that was funded by the National Institutes of Health (NIH) - USA resulted in the highest citation impact measured by CNCI followed by United States Department of Health & Human Services and National Science Foundation (NSF) with a CNCI of 5.48, 5.38 and 3.27 respectively.

The lowest CNCI is observed in papers funded by Princess Nourah bint Abdulrahman University, with a CNCI of 1.48. Though the CNCI is still 48% higher than the global average and one should also take into consideration the high volume of funded papers relative to the other organizations.

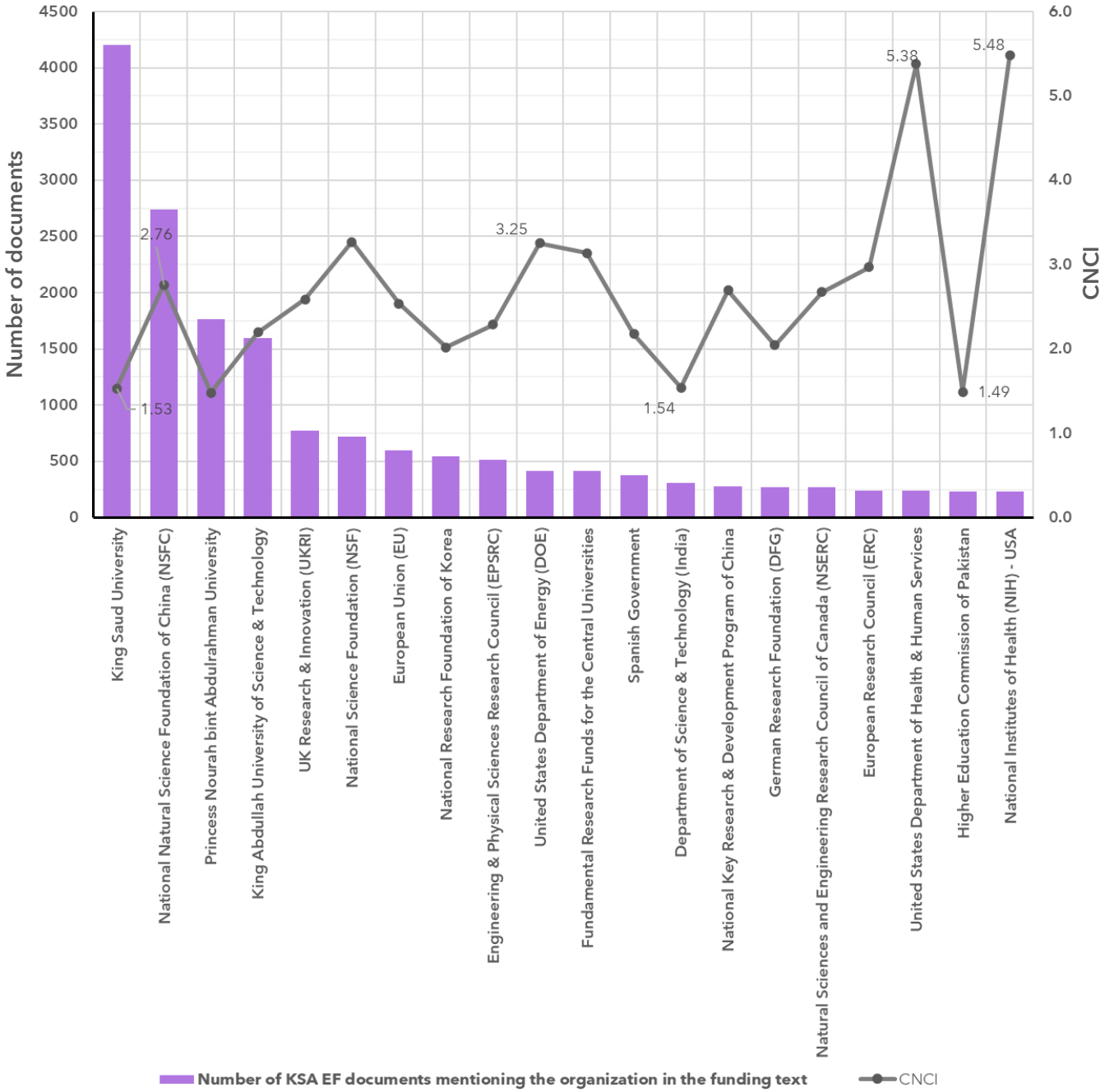

Figure 84: Top 20 funding organizations mentioned in the funding text of Saudi Arabia Economies of the Future papers in the period 2014-2023

3.6.5 International collaboration dynamics analysis

In the area Economies of the Future the percentage of Saudi Arabia papers with an international collaboration (80%) is higher than that of all considered benchmark countries/regions as shown in Figure 85.

At the same time this means that Saudi Arabia has the lowest number of papers with only national affiliations.

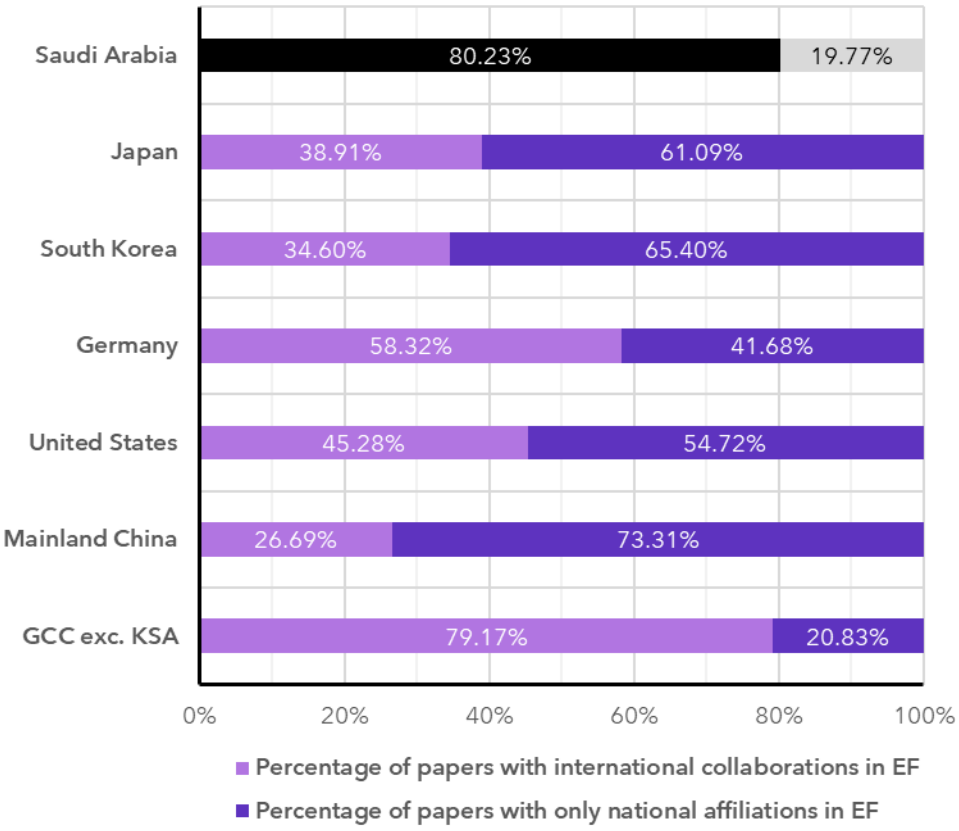

Figure 85: Percentage of papers with an international collaboration or only national affiliations in the area Economies of the Future and in the period 2014-2023

Egypt, followed by Pakistan and India had the highest number of documents in collaboration with Saudi Arabia affiliated researchers in the national priority area Economies of the Future in the period 2014-2023 with 7610, 7425 and 7399 documents respectively as shown in Figure 86 and Figure 87.

In terms of citation impact measured by the CNCI, papers in collaboration with Taiwan followed by Spain and Italy had the highest CNCI among the top 20 collaborating countries with a CNCI of 2.97, 2.79, and 2.71, respectively.

Nevertheless, research with all the top 20 collaborating countries with Saudi Arabia in this area resulted in a CNCI higher Than 1, reflecting a citation impact performance higher than the global average.

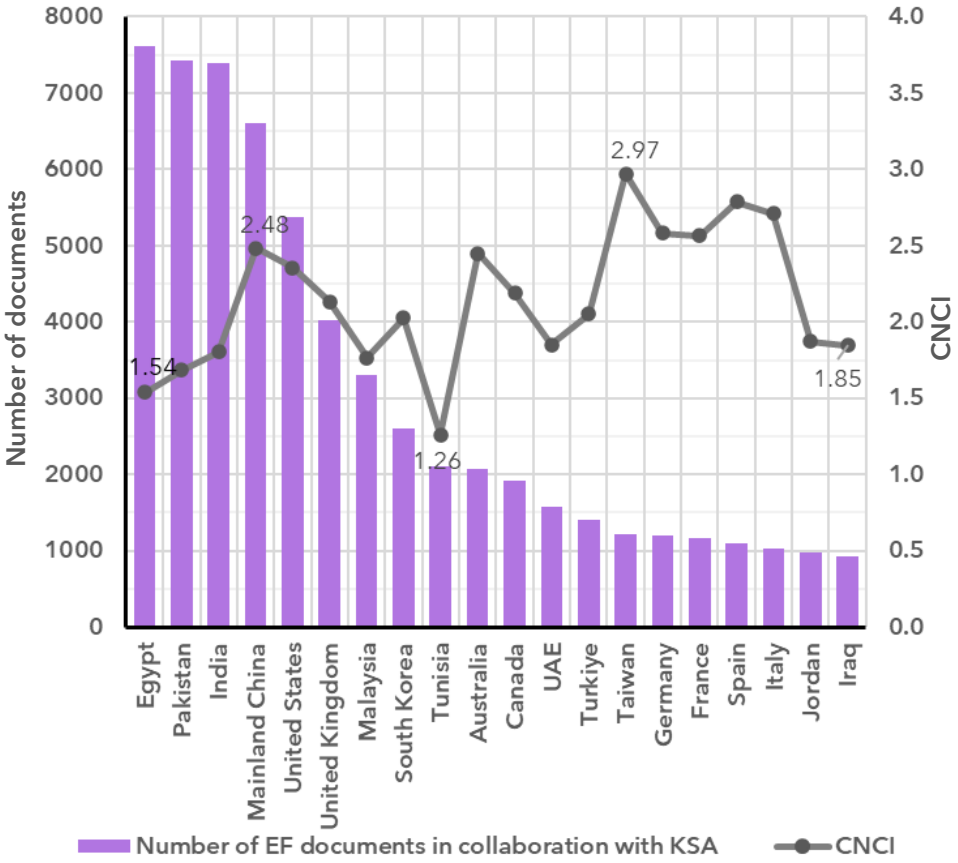

Figure 86: Top 20 collaborating countries with Saudi Arabia in the area Economies of the Future in the period 2014-2023

Figure 87: Top 10 collaborating countries with Saudi Arabia in the area Economies of the Future in the period 2014-2023

3.6.6 Open access publications analysis

In the area Economies of the Future over the period 2014-2023 the number as well as the percentage of open access documents increased continuously reaching 7,190 documents and 63.7% in 2023 as shown in Figure 88.

The percentage achieved in 2023 is the same as the one observed from the overall research output of 63.7%. Accordingly, this reflects a relatively high percentage of open access documents which could lead to higher visibility of Saudi Arabia research output in this area and for possibly more citations.

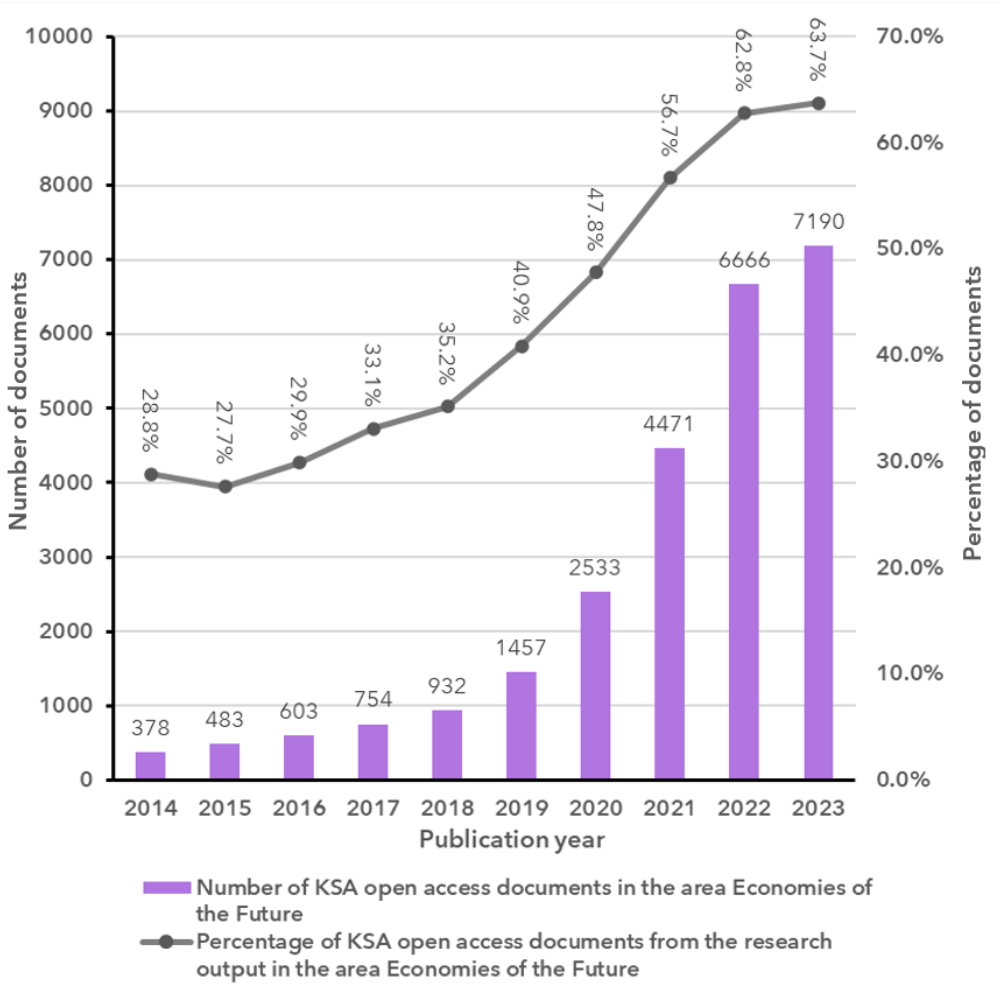

Figure 88: Number and percentage of Saudi Arabia open access documents in the area Economies of the Future in the period 2014-2023

3.6.7 Top 20 organizations in terms of number of publications

The top 20 organizations in Saudi Arabia in terms of number of documents published in the area Economies of the Future during the period 2014-2023 are King Saud University with 8,431 documents followed by King Abdulaziz University with 8,140 and King Abdullah University of Science & Technology with 4,594 documents as shown in Figure 89.

In terms of citation impact measured by the CNCI, the highest CNCI is achieved by King Abdullah University of Science & Technology followed by King Abdulaziz University and Prince Sultan University with a CNCI of 2.03, 1.92, and 1.88, respectively.

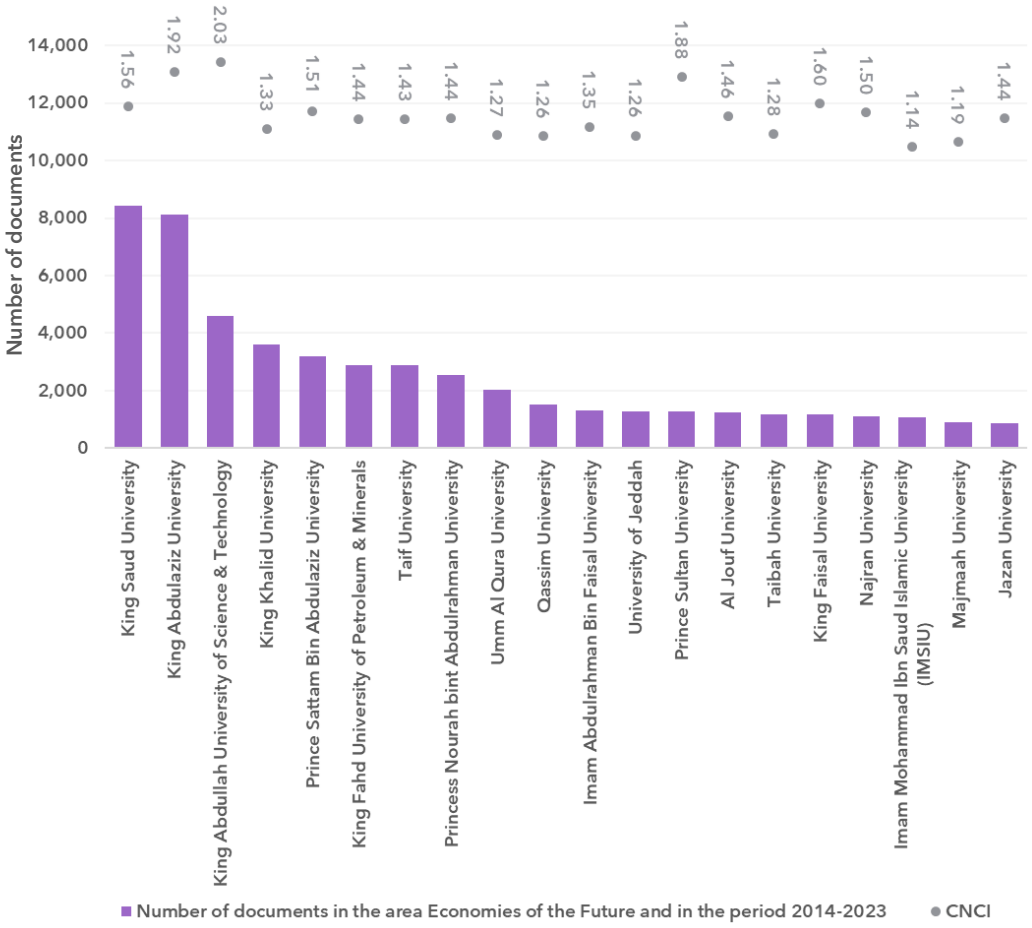

Figure 89: Top 20 Saudi organizations in terms of documents published in the area Economies of the Future during the period 2014-2023

3.6.8 Top 20 Saudi affiliated researchers in terms of number of publications in the area Economies of the Future

The top 3 Saudi affiliated researchers in terms of number of documents published in the period 2014-2023 and in this area are Abdullah M. Asiri affiliated to King Abdulaziz University with 295 documents followed Mohamed-Slim Alouini affiliated to King Abdullah University of Science & Technology with 286 documents and M. Shamim Hossain affiliated to King Saud University with 218 documents as shown in Table 15.

Among the top 20, Mohamed-Slim Alouini affiliated to King Abdullah University of Science & Technology had the highest CNCI with 3.44 and the highest number of Top 1% documents with 24 documents sharing this position with Tanzila Saba affiliated to Prince Sultan University.

Mohamed-Slim Alouini had also the highest number of Top 10% documents with 114 documents.

Table 15: Top 20 Saudi affiliated researchers in the period 2014-2023 in terms of number of documents published in the area Economies of the Future

Name	Affiliation	Web of Science Publications	CNCI	Documents in top 1%	Documents in top 10%
Asiri, Abdullah M.	King Abdulaziz University	295	1.52	9	56
Alouini, Mohamed-Slim	King Abdullah University of Science & Technology	286	3.44	24	114
Hossain, M. Shamim	King Saud University	218	3.14	21	95
Hassan, Mohammad Mehedi	King Saud University	209	2.24	9	69
Saba, Tanzila	CCIS Prince Sultan Univ	207	2.70	24	83
Muhammad, Ghulam	King Saud University	192	3.26	17	94
Alsaedi, Ahmed	King Abdulaziz University	187	2.14	9	67
Rehman, Amjad	CCIS Prince Sultan Univ	176	2.80	22	65
Umar, Ahmad	Najran University	171	1.41	4	39
Khan, Muhammad Khurram	King Saud University	166	2.66	11	61
Al-Ghamdi, Ahmed	King Abdulaziz University	163	1.43	6	23
Anthopoulos, Thomas D.	King Abdullah University of Science & Technology	161	2.03	9	46
Ooi, Boon S	King Abdullah University of Science & Technology	156	2.24	9	54
Ng, Tien Khee	King Abdullah University of Science & Technology	154	2.01	9	44
Yahia, Ibrahim Sayed	King Khalid University	152	0.99	0	16
Masud, Mehedi	Taif University	147	1.79	6	43
Rahman, Mohammed M.	King Abdulaziz University	143	1.33	1	20
Salama, Khaled Nabil	King Abdullah University of Science & Technology	139	1.52	3	31
Abdel-Khalek, Sayed	Taif University	137	0.71	0	8
Almogren, Ahmad S	King Saud University	132	2.19	6	43

3.6.9 SWOT analysis of the underlying research topics

In this part we have a more granular look by analyzing the research performance of Saudi Arabia in the underlying research topics that constitute the national priority area Economies of the Future. The research topics constituting the area and the selection of those research topics is described in Dataset Description. For more information on SWOT analysis please see the section Strengths, Weakness, Opportunities and Threats Analysis (SWOT).

When investigation Saudi Arabia performance in the research topics in the national priority area Economies of the Future we notice that out of the 45 research topics there are 26 strength research topics listed in Table 16, 16 opportunity research topics listed in Table 17 and three weakness research topics listed in Table 18, as also shown in Figure 90.

Since all these research topics are of national importance, it is essential to maintain the high performance in the strength research topics, increase the productivity in the opportunity areas by leveraging on the gained expertise that is evident with the CNCI being higher than 1, and increase the citation impact and productivity in the weakness research topics.

We also notice that the research topic Open RAN has very few documents globally (158) in the period 2014-2023, from which none were published by Saudi affiliated researchers.

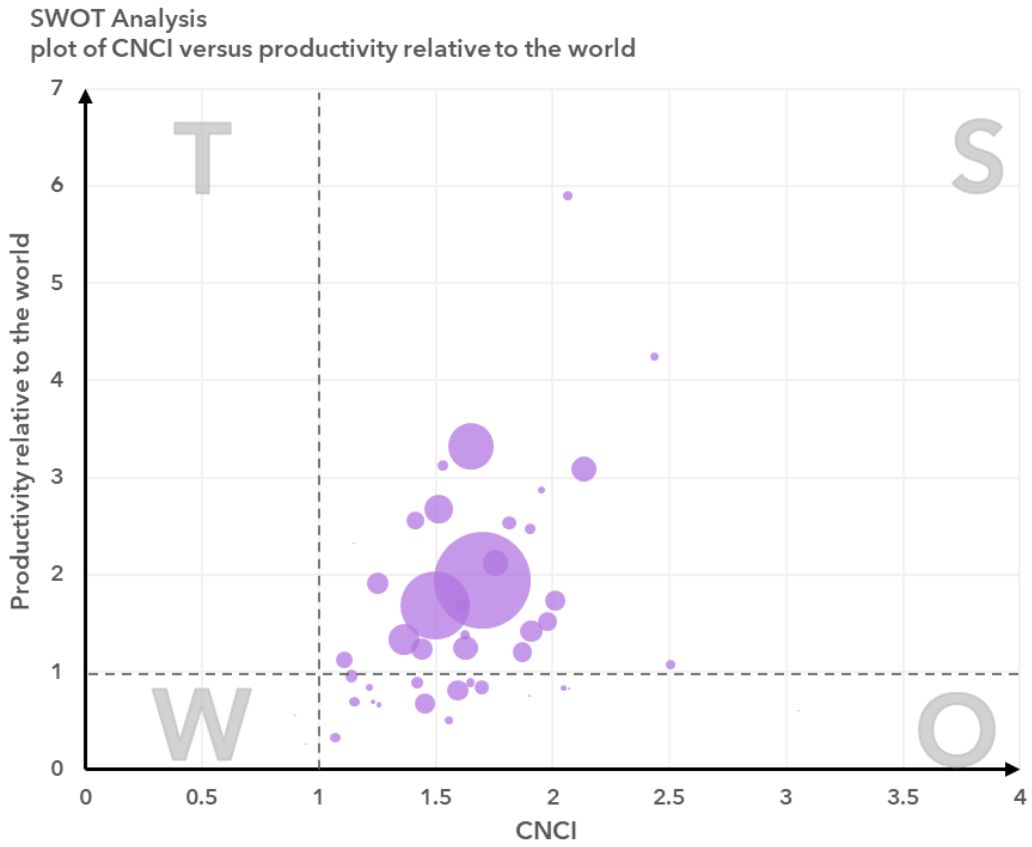

Figure 90: SWOT analysis of the national priority area Economies of the Future. The y-axis shows the productivity relative to the global productivity (share of Saudi Arabia from the global productivity in the research topic normalized by Saudi Arabia share from global productivity when considering overall research). The x-axis shows the impact relative to the global average.

Table 16: Saudi Arabia strength research topics in the national priority area Economies of the Future

Research topic	CNCI	Productivity relative to the global productivity
AI in ICT	1.7	1.9
Semiconductors	1.5	1.7
Quantum Sensing	1.4	1.3
Internet of Things	1.7	3.3
Logistics AI/ML	1.6	1.2
Biorefining	1.4	1.2
Air Quality, Traffic, Energy or Resource Management	1.9	1.4
Sustainable 6G Materials	1.9	1.2
Cloud Computing	1.5	2.7
Predictive Analytics, Decision Algorithms	1.8	2.1
Urban Air Mobility	2.0	1.5
Quantum Computing	1.1	1.1
Smart Agriculture	2.0	1.7
Data Ownership & Privacy	1.3	1.9
Blockchain	2.1	3.1
Smart Textiles	1.4	2.6
Sustainable buildings	1.6	1.7
Neuromorphic	2.5	1.1
Net Zero Aviation	1.6	1.4

Predictive Analytics	1.8	2.5
AGI - Privacy & Security Oriented	1.9	2.5
IoT in Supply Chains	1.5	3.1
AGI - Responsible AI	2.0	2.9
Low Emission Urban Materials	2.4	4.2
Deep Sea Telecoms	2.1	5.9
Sustainable 6G Energy Efficient Edge Infrastructure	1.1	2.3
AI in ICT	1.7	1.9
Semiconductors	1.5	1.7
Quantum Sensing	1.4	1.3
Internet of Things	1.7	3.3
Logistics AI/ML	1.6	1.2

Table 17: Saudi Arabia opportunity research topics in the national priority area Economies of the Future

Research topic	CNCI	Productivity relative to the global productivity
Space Architecture Habitats	1.5	0.7
3D Printing	1.6	0.8
Citizen Engagement	1.1	0.3
Autonomous Vehicles	1.7	0.8
Warehouse Automation	1.4	0.9
Space Architecture Mining	1.1	1.0
Last Mile Delivery	1.2	0.7

Service Robots	1.6	0.5
Deep Sea Microbes	1.6	0.9
Virtual Cities	1.2	0.8
Deep Sea Autonomous Vehicles	1.3	0.7
Deep Sea eDNA Analytics	2.0	0.8
Mobility as a Service	1.2	0.7
Deep Sea Diving Suits	1.9	0.8
Analog AI	2.1	0.8
Sustainable 6G Automatic Management	3.1	0.6

Table 18: Saudi Arabia weakness research topics in the national priority area Economies of the Future

Research topic	CNCI	Productivity relative to the global productivity
Quantum Error Suppression & Correction or Codes (QECCs)	0.9	0.3
Deep Sea - Mapping	0.9	0.6
Open RAN	0	0

4 Global initiatives, policies, and strategies addressing research development

Given the intrinsic relationship between a country's research base and its overall socio-economic development, policymakers and public administrators have increasingly turned their attention to enhancing research productivity, impact, and excellence. In today's knowledge-driven global economy, a robust research infrastructure is not merely an academic asset but a critical driver of innovation, technological advancement, and economic competitiveness. In other words, countries that prioritize research often experience accelerated development, as cutting-edge discoveries translate into new industries, job creation, and improved quality of life for their citizens.

Similarly, individual universities are placing a heightened emphasis on research performance, recognizing it as a major determinant of institutional reputation and a catalyst for attracting top-tier faculty, students, and funding opportunities. Research excellence elevates a university's standing in global rankings, which in turn enhances its ability to secure grants, forge international collaborations, and influence academic and policy discourse on a wider scale. By fostering a culture of innovation and inquiry, universities contribute significantly to societal progress, addressing pressing issues ranging from healthcare disparities to environmental sustainability. The focus on research performance also encourages interdisciplinary studies, leading to holistic solutions that can have a profound impact on both local and global communities.

Over the past four decades, countries in the Middle East and North Africa (MENA) region have made significant strides in expanding their research output and integrating into the global scientific community. The proportion of scholarly articles published within the region has increased markedly, reflecting concerted efforts to build research capacity and foster innovation. For example, in 2019, 15 out of 19 countries in the MENA region had more citations than the global average (Brainard, 2021). Governments have invested heavily in higher education and R&D, establishing new universities, research institutions, and science parks. For example, initiatives like King Abdullah University of Science and Technology (KAUST) in Saudi Arabia and the Qatar National Research Fund have been instrumental in advancing scientific research in the region. These efforts are part of broader strategies to diversify economies traditionally reliant on oil and gas, shifting towards knowledge-based sectors such as renewable energy, biotechnology, and information technology.

However, simply increasing research productivity and the number of publications is not sufficient to stimulate large-scale and sustainable research development at the level of individual countries. For example, research conducted by the Clarivate Institute for Scientific Information has shown that, while publication rates have risen, countries in the MENA have collaborated very little with each other. In 2019, only 5% of articles had a co-author from another country within the region. This low level of regional collaboration indicates a certain dependency on scientific expertise from overseas. Relying heavily on international partnerships outside the region can limit the development of local research networks and hinder the growth of regional expertise.

Furthermore, this situation highlights the need to complement policies and strategies that boost productivity with additional measures to support domestic research capacity. It is important for countries to not only focus on increasing the quantity of research but also to build strong local research communities. Encouraging collaborations among neighboring countries can help address common regional challenges and promote the sharing of knowledge and resources. Investing in local talent, improving research infrastructure, and providing funding opportunities for regional projects are essential steps toward this goal.

By strengthening domestic research capacity and fostering regional cooperation, countries can reduce their dependence on overseas expertise. This approach leads to more sustainable research development, as it empowers local scientists and institutions to contribute effectively to their country's progress. It also enhances the ability to find solutions tailored to regional needs, which can have a more significant impact on social and economic development in the long term.

The following sections provide an overview of approaches implemented around the world to support research development. In addition to boosting research productivity, these measures also address the quality and impact of scientific research, funding mechanisms, and the overall research environment.

4.1 Research productivity

While the provision of grant funding supports research development in the broad sense (see next section), it has also been used as a tool to stimulate research productivity. Jurisdictions such as Mainland China and Brazil have significantly increased their spending on R&D. This increased funding has supported universities, and research institutions, as well as individual researchers, contributing to a higher output of research publications in the long term. In particular, Mainland China has seen a surge in the rate of scientific publications in recent years as a result of these investments, outpacing the rest of the world[5].

In some countries, monetary incentives are offered to researchers based on their publication activities, especially where this concerns high-impact journals. Iran and South Korea are examples of countries where such policies have been implemented (Erfanmanesh et al., 2017). These incentives have been identified as the main driver for the exceptional increase in the number of publications. However, they have also raised concerns regarding the trade-off in terms of quality (Sadeh et al., 2019).

4.1.1 Kazakhstan's reforms of the higher education system

As many of the states became independent after the dissolution of the Soviet Union, one of the crucial reforms introduced in Kazakhstan was the provision of funding for local science and the integration thereof into the international scientific community (Kuzhabekova & Ruby, 2018). Kazakhstan is noteworthy in this regard because it is one of the few post-Soviet countries that successfully built a robust research infrastructure. This includes support through grants, access of researchers to research mobility programs, application of the Bologna processes to ensure comparability in the standards and quality of higher-education qualifications, and other measures to increase its research performance indicators (Narbaev & Amirbekova, 2021).

Kazakhstan was able to build up a comprehensive national research and innovation system by establishing institutions and structures such as a National Innovation Fund, the National Centre for Engineering and Technology Transfer, the National Center for Science and Technology Information, the National Center for Science and Technological Expertise, as well as venture capital funds. Furthermore, a network of technology parks and business incubators, as well as a legal framework to regulate intellectual property rights, were also established.

With regards to universities specifically, shared-use laboratories were established by the state with the aim of renovating the outdated research infrastructure. Furthermore, all universities were given subscriptions to bibliographic databases such as the Web of Science™ and Scopus. Research grants were introduced for faculty members and students, and international mobility programs were funded to help faculty members participate in the global academic community. Regarding the distribution of research grants, a competitive peer review-based system was introduced to allocate funding.

However, these reforms did not immediately result in improved research performance. Despite these efforts, Kazakhstan continued to produce a low volume of publications and average citation counts for these publications were low. The majority of articles were published in low-impact factor journals and very few articles were published in international journals.

[5] World Economic Forum: https://www.weforum.org/agenda/2020/01/top-ten-countries-leading-scientific-publications-in-the-world/

To address these issues in 2011, the Ministry of Education linked faculty promotions to research publications to motivate faculty members. By linking faculty promotion to research productivity, this policy sought to create more incentives for researchers to publish more often and to improve the quality of their articles. Research has shown that this had positive effects on faculty attitudes towards research, motivations to engage in scientific inquiry, motivations to increase publication performance, and helped establish research as a new and important career target in addition to teaching. However, these policies did not address some of the other barriers to research productivity and quality, such as access to research facilities, funding and resources, English proficiency, methodological skills and time available to conduct research.

4.1.2 Lessons learned

The examples of Iran and Kazakhstan show that an **excessive focus on research quantity without considering the implications on research quality should be avoided.** Explicitly linking faculty promotion to research productivity in a strict and quantitative manner, while intended to drive academic excellence, can lead to several undesirable consequences (Kuzhabekova & Ruby, 2018). One of the most concerning outcomes is the potential increase in publications in predatory or low-quality journals. Faculty members under pressure to meet rigid publication quotas may feel compelled to submit their work to journals with questionable peer-review processes or low academic standards just to meet promotion criteria. This not only undermines the credibility of the research but also dilutes the overall quality of academic contributions from the institution. In addition, such a narrow focus on publication numbers can lead to the inefficient use of both time and financial resources. Faculty members may prioritize producing a large volume of publications over conducting high-quality, impactful research. This pressure can result in rushed or repetitive studies, limiting the depth and innovation of the work. Time that could be spent on developing meaningful research projects, mentoring students, or engaging in interdisciplinary collaborations might instead be consumed by efforts to meet publication targets. Moreover, this approach can also have a negative financial impact on institutions. Faculty members might use limited research funds to cover publication fees in questionable or non-reputable journals, diverting resources that could be better used for research development, equipment, or international collaboration. Over time, this can weaken the institution's academic reputation, as faculty members may become more focused on quantity rather than the quality of their contributions. Finally, the strict linking of promotion to research productivity may discourage faculty members from engaging in other valuable academic activities, such as teaching, community service, or developing industry partnerships. These areas are critical to the broader mission of universities, and an overemphasis on publication numbers may lead to a neglect of these important responsibilities.

Therefore, it is essential to develop a more balanced approach to faculty promotion, one that values not only research output but also the quality and impact of the work, as well as contributions to teaching, mentoring, and community engagement. In conclusion, merely setting a publication requirement is not sufficient to stimulate research development. Rather, complementary factors must be in place, such as proper conditions for research, reduced teaching and administrative loads, and good access to research facilities, funding, and resources

An excessive and superficial focus on quantity alone will likely lead to an eradication of qualitative approaches to scientific research and development. It may even lead to undesirable practices or corruption (Sadeh et al., 2019). Therefore, it is important to carefully embed approaches to boosting research productivity with complementary actions to ensure quality is maintained in step and that the preconditions for good research are in place.

4.2 Research impact and excellence

Driving research excellence and impact is a primary focus area within science and technology policy worldwide. Many countries have developed approaches to promote this within their respective research systems.

In the context of research excellence and impact, national evaluation frameworks have been adopted by several countries as a means of assessing research quality in individual universities. Two notable examples of these are the United Kingdom's Research Excellence Framework (REF) and the Excellence in Research for Australia (ERA) framework. The REF is a system used for assessing the quality of research in U.K. higher education institutions and is based on three core components:

- Quality of research outputs: assessment of the originality, significance, and rigor of published research.
- Research impact assessment: evaluation of the societal and economic impact of research beyond academia.
- Environment and sustainability: considerations of the overall research environment and its sustainability within institutions.

The REF has driven U.K. universities to focus on producing high-quality, impactful research and has informed strategic planning and resource allocation. In a similar vein, Australia's ERA comprises a discipline-specific assessment in which research outputs are evaluated by discipline, allowing for targeted improvements in specific areas. Furthermore, ERA provides benchmarking data that universities use to improve their research quality and global competitiveness. The ERA is considered a key factor in improving research quality and international recognition for Australian universities in fields like medical research, environmental science, and engineering.

4.2.1 German Universities Excellence Initiative

Germany launched the Universities Excellence Initiative[6] in 2005. The aims of this initiative were to promote top-level research, improve the quality of German universities and research institutes, make Germany an attractive research location, and make German research more internationally competitive.

The German Research Foundation (DFG) awarded approximately €4.6 billion in funding between 2006 and 2017 through the three core components of the initiative:

- Graduate schools to promote early career researchers,
- Clusters of excellence to promote top-level research,
- And institutional strategies to promote top-level university research.

The initiative is credited with significantly improving the global rankings of several German universities, with institutions like LMU Munich and the University of Heidelberg becoming recognized as world leaders in research.

4.2.2 Mainland China's Double World-Class Project

Mainland China has been implementing a series of research excellence initiatives since the 1990s, including Project 211 launched in 1995, Project 985 launched in 1998, and Double World-Class Project launched in 2015 (Feng et al., 2024).

Project 211 had the following objectives:

- Develop the overall conditions and environment in Chinese universities.
- Improve key disciplines and public service systems within higher education.
- Enhance student development.

[6] See: https://www.dfg.de/en/research-funding/funding-initiative/excellence-initiative

- Raise the international reputation of Chinese HEIs.

Building on this, Project 985 continued similar ambitions by aiming to:

- Develop several world-class universities and world-class disciplines.
- Develop world-class universities with international reputations via governance reform, platform building, conditions support, and international cooperation.
- Strengthen project management, including the selection and evaluation processes at universities.

Most recently, these efforts were combined into the Double World-Class Project (DWCP) of 2015, which aims for Mainland China to become a higher education powerhouse by 2050, leading the number, quality, and capacity of world-class universities and disciplines. The DWCP also encouraged the diversification of universities (e.g., research universities, teaching universities, art and music conservatories, etc.). Its first round was completed in 2020, and 147 new universities were selected for the second round.

Contrary to the first round, the second round no longer distinguishes between world-class universities and universities designated to develop world-class disciplines. Instead, the second round "emphasizes exploring the establishment of diversified development, diversified support, and diversified evaluation, and guides universities to focus on the innovation and breakthrough in relevant fields and directions, so as to create truly world-class universities" (Feng et al., 2024).

As a result of the project, many Chinese universities have seen significant improvements in global university rankings. For example, institutions like Tsinghua University, Peking University, and Fudan University have consistently climbed in rankings like the QS World University Rankings and the Times Higher Education World University Rankings. In particular, Tsinghua University has been recognized as a leading institution globally in engineering and computer science. Furthermore, Chinese universities have significantly increased their research output, particularly in high-impact journals. The quantity and quality of research papers have grown, with Mainland China now leading in certain fields, such as materials science, engineering, and artificial intelligence. The citation impact of research from Chinese institutions has also improved, reflecting not just quantity but also the growing influence and quality of research.

4.2.3 Lessons learned

The approaches reviewed in this section have demonstrated the **pivotal role of national evaluation frameworks** in driving universities to produce high-quality, impactful research, and in guiding their strategic planning and resource allocation. These frameworks are instrumental in setting clear standards and expectations, which not only motivate universities to align their research activities with national priorities but also foster an environment of continuous improvement. By implementing national frameworks that assess research performance, universities are better able to identify areas of strength and weakness. This data-driven approach allows institutions to allocate resources more efficiently and strategically, focusing on areas where they can achieve the most impact. Furthermore, discipline-specific assessments within these frameworks provide valuable benchmarking data, allowing universities to compare their performance to national and international peers. This comparative analysis enables universities to target specific areas for development and improvement, which can lead to enhanced global competitiveness. The focus on specific disciplines ensures that universities are not only improving overall but also excelling in areas where they have the potential to become global leaders.

Targeted funding mechanisms also play a crucial role in promoting top-tier research by providing financial support to key areas such as graduate schools, clusters of excellence, and institutional strategies. These mechanisms help foster an environment where research excellence can thrive, as institutions have the financial

backing to invest in cutting-edge projects, recruit top talent, and create interdisciplinary research hubs. For example, Germany's Universities Excellence Initiative is a model of how sustained investment in specific areas can result in measurable improvements over time. This initiative has provided substantial funding to universities with promising research potential, allowing them to enhance their infrastructure, attract world-class faculty, and support innovative research projects. As a result, many German universities have seen significant advancements in their global rankings and international standing. The initiative demonstrates how targeted funding, when aligned with strategic institutional goals, can lead to long-term improvements in research quality, visibility, and global influence.

Comprehensive national projects, like those implemented in Mainland China, have also shown how **large-scale, coordinated efforts can support holistic university development**. These projects not only focus on improving research output but also address broader institutional needs, such as enhancing campus infrastructure, developing world-class disciplines, and improving governance structures. China's efforts, including initiatives like "Double First-Class" and "Project 985," have been instrumental in transforming many of the country's universities into globally competitive institutions. These programs emphasize the development of key disciplines, often through the establishment of research centers of excellence, as well as improving the overall governance and management of universities. As a result, Chinese universities have made substantial gains in global rankings and research productivity. This holistic approach ensures that advancements are not limited to isolated improvements in research output but extend to the overall functioning and reputation of the universities, positioning them as leaders in the global academic landscape.

Many research-intensive countries have organized the public financing of scientific research in a centralized manner. For instance, countries like the United States have established agencies, including the National Institutes of Health (NIH) and the National Science Foundation (NSF), that provide substantial funding for research. Similarly, the European Union has programs like Horizon Europe, which funds research and innovation across member states. While grant funding is one of the primary ways in which governments support research, countries like Canada and the U.K. offer tax credits and incentives to businesses that invest in research and development, encouraging private sector involvement in scientific research.

4.3 Performance-based research systems

Going one step further, some countries are using performance-based research funding systems (PBRFs), which are mechanisms by governments to allocate research funding to universities and research institutions based on the quality and impact of their research outputs. The main goal of these systems is to enhance research excellence, encourage accountability, and ensure that public funds are used effectively to support high-quality research. While there is no fixed structure for a PBRF, there are some commonalities in the way these are implemented around the world.

All PBRFs are centered around the evaluation of research outputs. As well as scientific publications, these can also include patents, and creative works. The quality of these outputs is often measured by peer review, citation impact, or the prestige of the publication venues. Some PBRFs also include assessments of the broader societal, economic, or cultural impact of research. This can involve evaluating how research influences policy, industry, or public understanding. The quality of the research environment, including infrastructure, funding, support for early-career researchers, and collaborative efforts, may also be considered. Research funding is subsequently allocated based on the results of the evaluations so that institutions that perform better in the assessment receive a larger share of funding, incentivizing them to focus

on research quality and impact. Some notable examples of PBRFs are summarised in Table 19.

Table 19: Summary of notable PBRFs

PBRF	Country	Description
Research Excellence Framework (REF)	United Kingdom	The REF assesses the quality of research in UK higher education institutions, with funding allocated based on research outputs, impact, and environment.
Excellence in Research for Australia (ERA)	Australia	ERA evaluates the research quality of Australian universities, informing funding decisions and strategic planning.
Performance-Based Research Fund (PBRF)	New Zealand	PBRF assesses individual researcher performance and allocates funding to institutions based on research quality and capacity.
Research Assessment Exercise (RAE)	Hong Kong (China)	Similar to the REF, the RAE evaluates the research performance of Hong Kong universities, guiding funding allocation.

4.3.1 Lessons learned

One of the main benefits associated with PBRFs is the promotion of research excellence. By tying funding to research performance, PBRFs encourage institutions to prioritize high-quality and impactful research. Furthermore, institutions are held accountable for the public funds they receive, with a focus on demonstrating value and impact. PBRFs also help governments direct funding towards areas of national importance and emerging research fields. A relevant example from Saudi Arabia that aligns with the principles of PBRFs is the KAUST Research Centers Funding Model. KAUST uses a performance-driven approach to allocate research funding, where the institution ties a portion of its funding to measurable research outcomes, such as publications in high-impact journals, patents, and collaborations with industry. This model encourages faculty and researchers to prioritize high-quality, impactful research, while also ensuring that public and institutional funds are used effectively to achieve tangible results.

However, the emphasis on certain metrics (e.g., publication in high-impact journals) can lead institutions to **prioritize quantity over quality or neglect teaching and other academic responsibilities**. Furthermore, the process of collecting, assessing, and reporting data for PBRFs can be resource-intensive and time-consuming for institutions. It also creates a risk of inequality, as institutions with established research strengths may continue to receive more funding, potentially widening the gap between them and less-established institutions.

A balance must be struck in terms of linking funding to performance in a way that avoids fixation on quantity at the expense of quality. It is essential to have the university research aligned with national priorities, ensuring that institutions contribute to the broader goals of economic, social, and technological development. However, this alignment should not come at the expense of academic freedom.

Universities must still have the flexibility to pursue their own research agendas, allowing individual faculty members and departments to explore innovative or emerging fields of study that may not yet be prioritized at the national level. One effective way to achieve this balance is by granting universities greater autonomy in key areas such as promotion and salary decisions, empowering them to recognize and reward research excellence in a way that aligns with their unique strengths and strategic goals. At the same time, creating incentives for universities to maintain a strong research profile is critical. This could involve a system of mixed individual and institutional research grants. For instance, universities could receive institutional grants partially based on their past research performance, which would motivate them to consistently invest in high-quality research while providing room for individual researchers to pursue novel ideas. Additionally, such a grant system would encourage universities to maintain a healthy balance between teaching and research responsibilities. Rather than prioritizing teaching to the detriment of research output, institutions would be encouraged to allocate resources and time for faculty to engage in meaningful research activities, thereby fostering a culture where both teaching and research are valued equally. This balanced approach would lead to more sustainable academic environments, where research and teaching mutually reinforce one another, contributing to both individual career advancement and the overall institutional mission.

4.4 Research environment

While productivity, excellence, and funding are core aspects of research performance, it is important to note that none of these occur in a vacuum. Rather, they should be seen as specific elements within a much broader environment in which research takes place. To stimulate long-lasting research development, this environment must also be considered.

4.4.1 Open science

Open science is a movement that aims to enhance collaboration, increase transparency, and accelerate scientific discovery by making knowledge more accessible and inclusive[7]. RDIA's open access policy[8] is designed to achieve the following objections:

- Facilitate, Optimize and enhance the efficiency of RDI players access to government-funded research infrastructure
- Promote open innovation, reducing RDI ecosystem fragmentation
- Attract top local and international researchers and scientists
- Harmonize guidelines on open access to government-funded research infrastructure across the kingdom

Open science promotes transparent research practices that are intended to address common issues around reproducibility and integrity in research (Stewart et al., 2021).

It is seen as an important means of promoting scientific advancement by increasing scientific collaborations and sharing of information for the benefit of science and society; making multilingual scientific knowledge openly available, accessible and reusable for everyone; and opening the processes of scientific knowledge creation, evaluation and communication to societal actors beyond the traditional scientific community. The principles of open science have been embraced in international

[7] See: https://www.unesco.org/en/open-science/about
[8] https://rdia.gov.sa/docs/OPEN%20ACCESS%20TO%20GOVERNMENT-FUNDED%20RESEARCH_V2.pdf

policymaking by institutions such as the European Union[9] and UNESCO[10], but also by individual universities such as University College London[11].

Table 20: Pillars of open science

Open science pillar	Description
Open access	Making research publications freely available to the public, allowing anyone to read and use them without subscription fees
Open data	Sharing research data openly so that others can verify results, reuse data for new research, and build upon existing work
Open source	Making research software and tools available for others to use, modify, and distribute
Open methodology	Sharing research methods and protocols to ensure transparency and reproducibility
Open peer-review	Making the peer review process transparent by sharing reviewers' comments and the authors' responses
Open educational resources	Providing educational materials and resources freely to support learning and research

As such, open science is an example of an approach towards driving research development that is not exclusively implemented at the national level but also initiated by individual institutions and even researchers. Research from the U.K. (Stewart et al., 2021) shows that some institutions incentivize individual researchers to adopt open and transparent research practices through:

- Hiring criteria,
- Probations and promotion decisions,
- Recognition of the importance of open research,
- And publishers mandating publication of workflows.

4.4.2 Human capital development

For the purposes of promoting research development, it is critical to ensure there is an adequate and stable local research workforce to develop and maintain long-term domestic research capacity. Scholarships and fellowships have been used to this end, including Australia's Endeavour Leadership Programme as well as the U.K.'s Chevening Scholarships. Both are examples of schemes designed to attract international talent to conduct research at the postgraduate and doctoral levels, contributing to the host country's research output. Related approaches are talent

[9] See: https://research-and-innovation.ec.europa.eu/strategy/strategy-2020-2024/our-digital-future/open-science_en
[10] See: https://www.unesco.org/en/open-science/about
[11] See: https://www.ucl.ac.uk/library/open-science-research-support/open-science/8-pillars-open-science

retention programs that refer to initiatives to attract and retain researchers through competitive salaries, funding, and research opportunities.

Singapore, for instance, aims to retain and attract top international researchers to the country by providing competitive research funding and career opportunities through the Singapore NRF Fellowships program[12]. The program offers substantial funding for research projects, including grants for equipment, research staff, and collaboration, as well as providing opportunities for leadership roles within research institutions and support for career advancement. The scheme also encourages partnerships with industry, offering additional incentives and resources for applied research. As a result of the program, Singapore has successfully retained leading researchers in key areas such as biomedical sciences, engineering, and information technology.

Mainland China has also implemented several talent development and recruitment programs, such as the Thousand Talents Plans and the Yangtze River Scholars Program. Both programs are part of Mainland China's broader strategy to become a global leader in research and innovation by fostering world-class academic talent.

The Yangtze River Scholars Programme[13] was a prestigious academic initiative launched by the Chinese Ministry of Education in 1998. Its primary goal was to attract, retain, and support top academic talent in Mainland China, particularly in higher education institutions. Specifically, it targeted outstanding scholars both within Mainland China and internationally, offering them professorships or visiting scholar positions at Chinese universities. Program participants received significant financial rewards, research funding, and access to top research facilities. Overall, the program has played a crucial role in enhancing the quality of higher education and research in Mainland China, contributing to the region's rapid advancements in various academic fields.

More recently, the Thousand Talents Plan[14] was initiated in 2008 and aims to attract leading international scholars, researchers, and entrepreneurs to Mainland China to enhance its research capacity and innovation. The program attracts top-tier researchers from abroad by offering competitive salaries, research funding, and incentives. Furthermore, it provides grants and resources for young researchers to establish and develop their research careers in Mainland China. The program has been attributed to significant increases in high-impact research publications and advancements in fields like AI, biotechnology, and quantum computing in Mainland China.

Together, these programs have successfully brought international researchers and Chinese expatriates back to Mainland China, enhancing the research and teaching capabilities of Chinese universities.

4.4.3 Lessons learned

The examples discussed in this section highlight that **research productivity, excellence, and funding should be viewed within the broader research environment.** Long-lasting research development requires considering this holistic context.

A stronger research environment can be fostered by adopting open science principles focused on transparency, collaboration, and accessibility. Open access to research articles, data, methodologies, and peer reviews promotes wider dissemination of knowledge, enabling greater collaboration and reproducibility. This approach helps address issues like research integrity and reproducibility by making research more accessible and verifiable. Open science also accelerates scientific advancements, as findings are shared quickly and inclusively, benefiting not only the academic community but also society at large. It allows researchers worldwide,

[12] See: https://www.nrf.gov.sg/grants/nrff/
[13] See: https://www.k12academics.com/Higher%20Education%20Worldwide/Higher%20Education%20in%20China/changjiang-scholars-program
[14] See: https://sccei.fsi.stanford.edu/china-briefs/evaluating-success-chinas-young-thousand-talents-stem-recruitment-program

including those from low-resource settings, to engage with high-quality research, contributing to more equitable knowledge-sharing and societal progress.

Finally, building and maintaining **a stable and skilled local research workforce** is fundamental to ensuring long-term research capacity and sustainability. A well-trained, competent workforce forms the backbone of any successful research ecosystem, enabling consistent innovation, knowledge generation, and scientific advancements. To achieve this, it is essential to invest in comprehensive scholarships and fellowship programs that attract young, talented individuals into research fields early in their academic careers. These programs not only provide the financial support needed for advanced education but also offer mentorship opportunities and access to cutting-edge resources that can inspire students to pursue research as a long-term career path. A relevant example is the King Abdullah Scholarship Program (KASP), which has been instrumental in nurturing local talent by funding higher education opportunities both within the country and abroad. This program allows students to study at leading international universities, gaining advanced skills and global research exposure before returning to contribute to Saudi Arabia's growing research ecosystem. Moreover, the recent emphasis on Vision 2030 has seen the establishment of initiatives like KAUST, which not only attracts global researchers but also aims to develop a highly skilled local research workforce by providing state-of-the-art facilities and world-class education in fields such as sustainable energy, water desalination, and artificial intelligence.

Moreover, talent retention programs are critical to preventing brain drain, where highly skilled researchers leave their home country in search of better opportunities abroad. Governments and academic institutions must develop targeted initiatives to retain local talent by offering competitive salaries, opportunities for career advancement, and access to world-class research facilities. This could include creating partnerships with leading international institutions to provide local researchers with global exposure while keeping them rooted in their home institutions. Furthermore, providing clear career pathways and ensuring that research is seen as a viable, respected profession are crucial for retaining talent within the local research ecosystem. A strong, skilled workforce will be the driving force behind sustained research output and will enable countries to address both national and global challenges more effectively.

4.5 Key opportunities

This section outlines key opportunities derived from the improvement areas identified in the research performance analysis performed in the section Research Evaluation within National Priority Areas and from the above identified analysis of initiatives, policies and strategies addressing research development.

4.5.1 Overall

- Establishing dedicated national research institutes focused on the national priority areas. Such institutes could have the necessary research infrastructure—such as state-of-the-art laboratories and innovation hubs—providing the necessary resources for researchers to conduct cutting-edge studies locally. This will ensure the building of local expertise and focus on the national priorities. RDIA has launched the Reactivation and Rebuilding of Existing Labs Initiative that targets the enhancement of existing research infrastructure. Such efforts are essential to develop state-of-the-art laboratories in the national priority areas. Through such initiatives, RDIA recently allocated 135M SAR for 36 research lab infrastructure advancement. Moreover, RDIA facilitated collaboration of different stake holders in the

innovation ecosystem to create innovation hubs through initiatives, such as the National Semiconductor Hub and the Innovation Districts Alliance.

- This study highlights the importance of a centralized funding body, a function now under RDIA's remit. Distributing resources according to national focus areas would help align research activities with the nation's strategic goals. RDIA has already launched several funding initiatives centered on national priority areas. For example, the Saudi Basic Science Initiative aims to enhance basic and fundamental scientific research in the Kingdom; the Saudi Applied Research and Technology Initiative focuses on technology development and the commercialization of research output; and the Reactivation and Rebuilding of Existing Labs Initiative seeks to improve existing research facilities in the Kingdom, which will ultimately boost both the volume and quality of research output.
- Establishing mentorship programs that pair seasoned researchers with early-career academics can also foster a supportive environment for producing high-quality local publications and building local expertise. An example of such efforts already being put in place, is the Young Scholars Grant within the Saudi Basic Science Initiative, that is dedicated to fostering and empowering the next generation of national research.
- Creating national research awards or recognition programs for outstanding contributions in national priority areas can incentivize researchers to focus on topics of national importance and raise awareness in the research community about the importance of those topics.

4.5.2 Health & Wellness

- While Saudi Arabia has experienced an increase in the number of research publications, the relatively lower citation impact signals a need to enhance the global relevance of the research. The focus should be placed on fostering impactful research without compromising output. This can be achieved by incentivizing high-quality, interdisciplinary collaborations that target globally significant issues and prioritize innovation.

5 Women in academic research

Internationally, gender equality is regarded as a fundamental human right and a necessary foundation for a peaceful, prosperous, and sustainable world. Gender inequality is persistent in many sectors and areas of activity, including research and innovation. Thus, in this section, we have an overview of gender equality in research and academia globally. We then analyze global approaches, initiatives, policies and models that would accelerate progress toward proportional representation within Saudi Arabian academic research. From those models it is possible derive a set of actions that could be implemented in Saudi Arabia in this context.

5.1 Gender equality in research

In general terms, gender equality refers to a state in which individuals have equal access to resources and opportunities regardless of their gender. This includes a wide range of aspects including economic participation and decision-making, as well as the equal valuation of different behaviors, aspirations, and needs. In environments where gender equality is achieved, all genders have the freedom to pursue their careers, lifestyle choices, and abilities without discrimination. Internationally, gender equality is regarded as a fundamental human right and a necessary foundation for a peaceful, prosperous, and sustainable world (United Nations Department of Economic and Social Affairs, 2023).

However, to achieve gender equality, many forms of inequality still need to be addressed. This includes the gender wage gap, gender-based violence, and unequal representation in political and leadership positions. A proportional representation of women that ranges between 40% and 60% is generally regarded as gender balance. Gender parity, on the other hand, is a specific state in which the ratio of men to women is approximately 50:50.

In this context, a distinction is often drawn between horizontal and vertical segregation in terms of representation (European Commission & Directorate-General for Research and Innovation, 2021b). Horizontal segregation relates to the concentration of men and women in different sectors and occupations. It can occur within education and employment in the form of over- or under-representation of one gender in a particular subject, profession, or industry. Vertical segregation, on the other hand, refers to the concentration of either men or women in 'top' posts, such as decision-making positions or other positions of responsibility. Such roles are often associated with 'desirable' features, including greater pay, prestige and social security.

Gender inequality is persistent in many sectors and areas of activity, including research and innovation. An example of vertical segregation in research, for instance, is the over-representation of men amongst heads of universities. Persistent gender-based differences have also been observed in the demographics, productivity rates, and general career advancement of the global scientific workforce (Shen, 2013). For example, as of 2015 UNESCO reported that only 28% of the global scientific workforce were women (Huyer, 2015). While more recent research findings indicate that significant gains have been made in this regard with women representing around one-third of active researchers as of 2022, there are still disciplines where female participation is significantly lower, such as STEM (Elsevier, 2024). As of 2020, for instance, women only accounted for 28% of engineering graduates and 22% of people working in the field of AI (World Economic Forum, 2021).

Despite there being more female than male undergraduate students in many countries, there is a disproportionately small number of female professors at universities, gender inequalities in hiring practices are perpetuated, and major discrepancies in terms of wages, ability to secure funding, career satisfaction, and patenting activity and success (Larivière et al., 2013). In terms of publication activity,

an analysis covering 2008-2020 has shown that, on average, women publish around 20% fewer papers than men (Valian, 2023).

While detailed statistics on gender equality in research are limited and often not collected on a structural basis, a 2024 study of gender equality in research and innovation found produced the following results that still point to a considerable gender gap (Elsevier, 2024):

- Amongst grant awardees, the average share of women as of 2022 was 37%.
- Across all career stages, fewer papers are being published by women compared to men and this gap has remained relatively unchanged for the last two decades.
- Publications by men are, on average, cited more than those cited published by women.
- As of 2022, approximately 75% of patent applications are filed by men alone or by teams consisting exclusively of men and only 3% of patent applications are filed by teams consisting of women only.

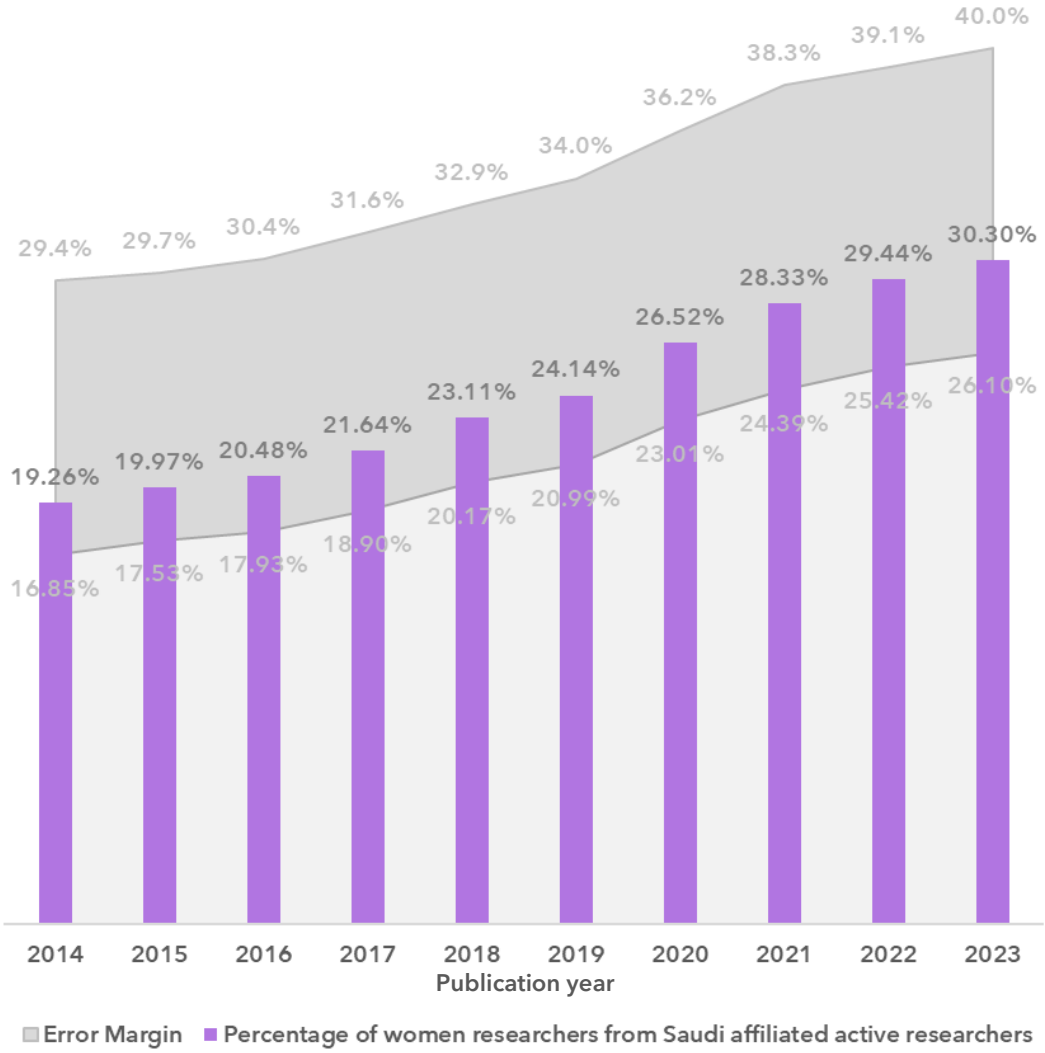

Figure 91: Percentage of women researchers with an affiliation to a Saudi organization identified from the total active researchers identified from overall research output

5.1.1 Women percentage in research and inventions in Saudi Arabia

In this section we analyse the percentage of women in research in Saudi Arabia and benchmark it with other countries from the G20 countries. The analysis is based on identifying gender from the names of active researchers identified.

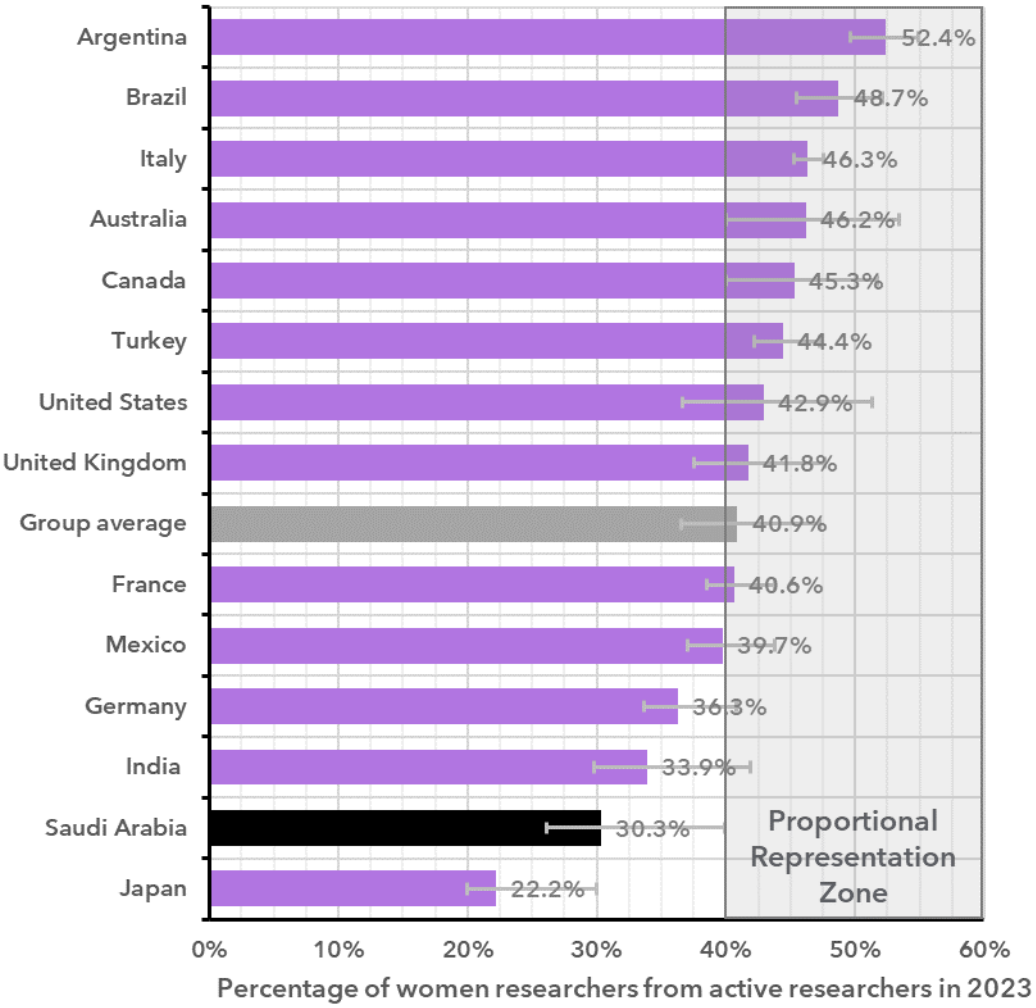

Figure 92: Percentage of women researchers with an affiliation to an organization in the respective G20 country identified from the total active researchers identified from overall research output in 2023

Active researchers are identified by considering unique researchers appearing on papers with an affiliation to an organization in a certain country in a certain period. For more information on the methodology used to identify unique active researchers please see the section Number of active researchers.

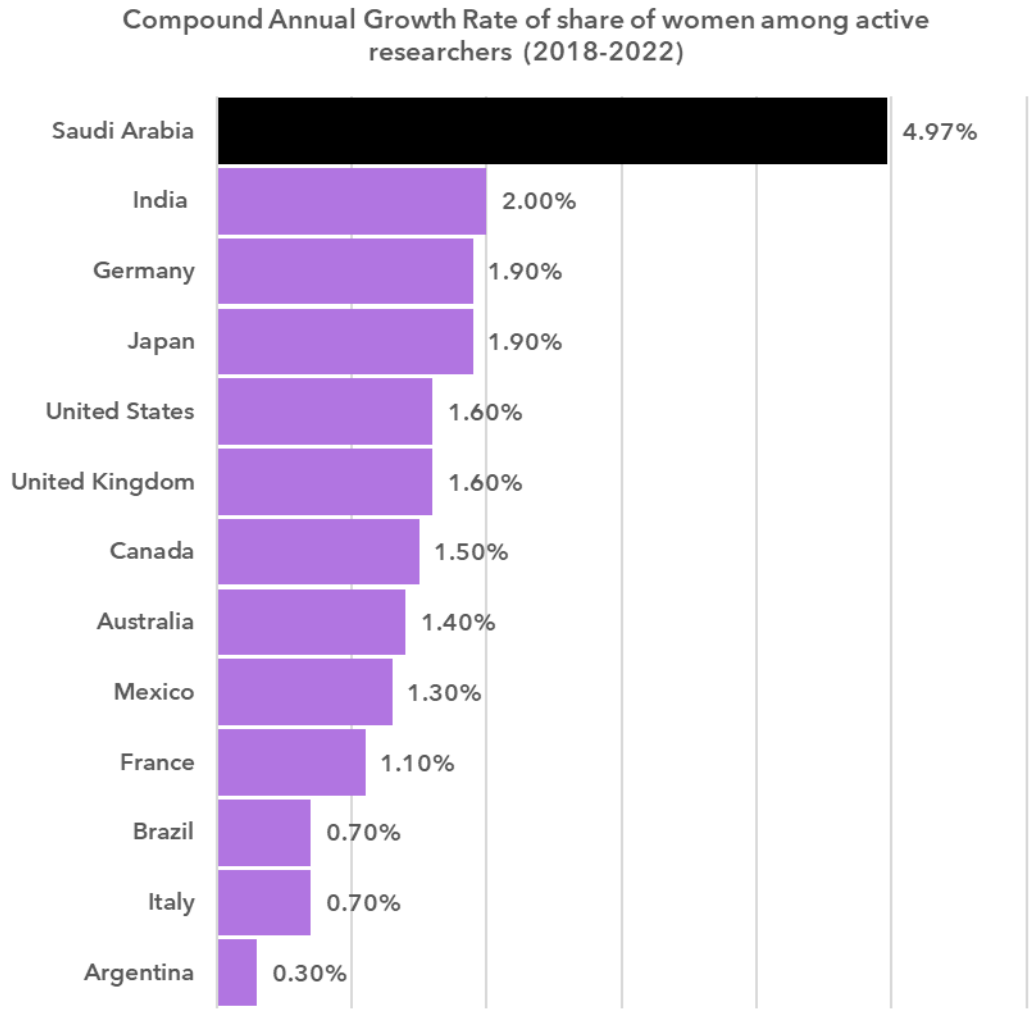

Figure 93: The compound annual growth rate (CAGR) of the percentage of women from active researchers in the period 2018-2022. The data for Saudi Arabia is from the current analysis. The data for other countries is from Elsevier's Gender Equality in Research & Innovation Report[15]. The validity of comparing values from different analysis is discussed below[16].

It is important to note that this does not reflect Full Time Equivalent (FTE) researchers, but rather unique researchers appearing on papers with an affiliation to an organization in a certain country. The gender of an active researcher is inferred by using Namsor[17] from the name associated with the researcher profile. Namsor can help determine if a name is more likely to be male or female. For more information on the methodology used, limitations and statistical analysis please see the section Percentage of Women in Research. Due to statistical inference limitations, some countries were excluded from the G20, for which it was not meaningful to infer a percentage of women.

We also show the percentage of women in patent data. For this we utilize WIPO IP Statistics Data Center[18] and report two metrics: the share of Patent Cooperation Treaty (PCT) patent applications with one woman inventor and the share of women

[15] https://www.elsevier.com/insights/gender-and-diversity-in-research
[16] The analysis here as well as in the mentioned report use the names of active researchers as well as the tool Namsor to infer a gender for an identified name. Also, both analyses use similar thresholds on the datasets. Although, the CAGR is based on different datasets, as the methodology is similar, comparing this metric would provide an estimated benchmark to the CAGR achieved by Saudi Arabia in the same period.
[17] https://namsor.app/
[18] https://www3.wipo.int/ipstats/pmh-search/pct

inventors among listed PCT inventors. These metrics are benchmarked with the global baseline and with GCC countries for which data is available.

5.1.2 Percentage of women identified from research output

The percentage of women researchers in Saudi Arabia increased continuously in the last 10 years from 19.3% in 2014 to 30.3% in 2023 as shown in Figure 91. This indicates an increase in the percentage of women researchers with an average growth rate of around 5% in the period 2014-2023 and reflects the efforts made in Saudi Arabia to support the participation of women in research. This also shows that the growth in "women" active researchers was higher than the "men" active researchers in this period.

When comparing this percentage to other G20 countries in 2023, Saudi Arabia has a percentage only higher than that of Japan as shown in Figure 92. When comparing the compound annual growth rate (CAGR) of the share of active women researchers in Saudi Arabia in the period 2018-2022 to that of considered G20 countries, we observe that it was more than double than that of the highest value achieved among these countries as shown in Figure 93.

This further confirms the efforts made in Saudi Arabia to increase the participation of women in research. Continuing this growth in the following years would lead not only to increasing the total number of active researchers but also reaching the proportional representation zone (40%-60%). Knowing that the Saudi Arabia compound annual growth rate for the 2018-2023 is 4.67%, indicating a consisting growth in this metric in 2023.

In the period 2014-2023 the percentage of women researchers from active researchers affiliated to a Saudi organization was highest in the area Health and Wellness, which was also slightly higher than the one identified from overall research output, followed by the percentage in the area Economies of the Future, Sustainability and Essential Needs and Energy and Industrials as shown in Figure 94. Though, in the areas with the lowest percentages we observe also the highest average growth in the last 10 years. Maintaining similar growth rates in the coming years, in the areas of low percentages but high growth rates, will result in higher percentages in those areas, which will, in turn, impact the overall percentage.

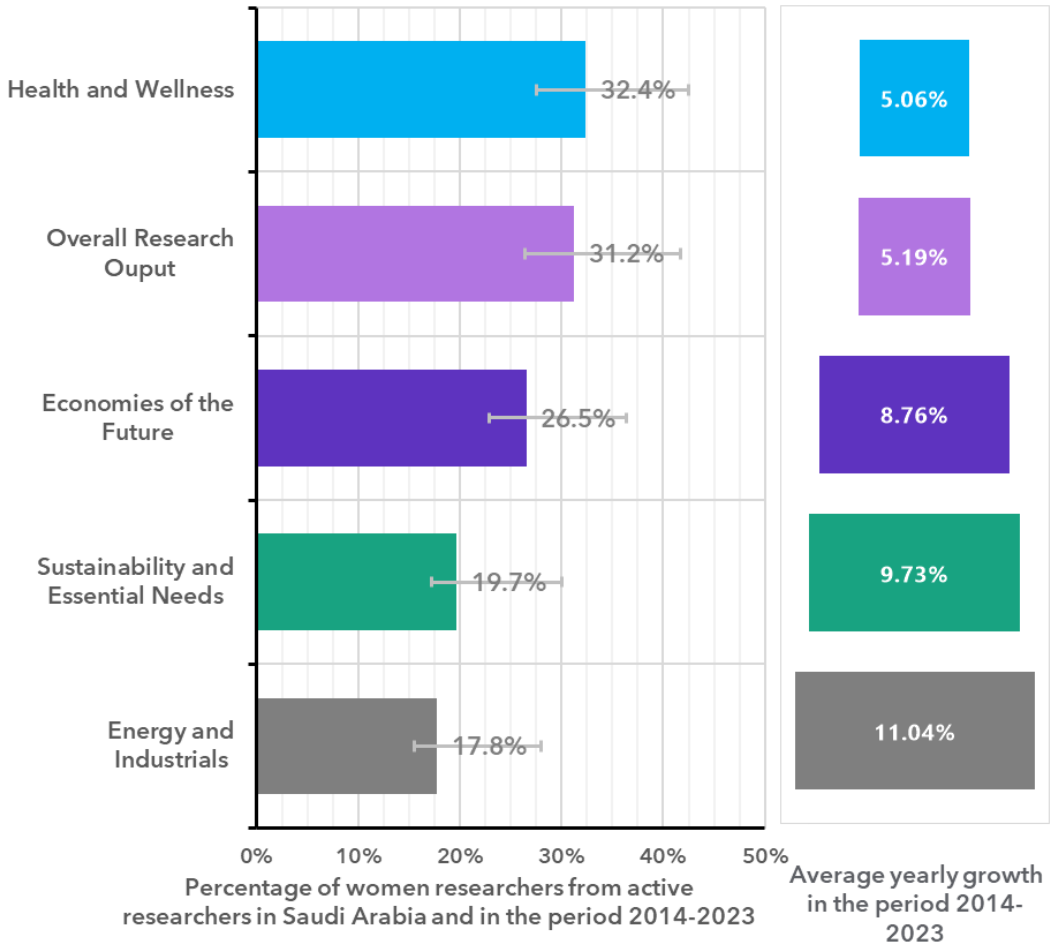

Figure 94: Percentage of women researchers with an affiliation to a Saudi organization identified from the total active researchers identified from overall research output and in each national priority area in the period 2014-2023

5.1.3 Percentage of women identified from invention output

The percentage of PCT[19] applications with one woman inventor increased from 10.1% in 2014 to 23% in 2023 with fluctuations from one year to another but with an overall positive trend as shown in Figure 95.

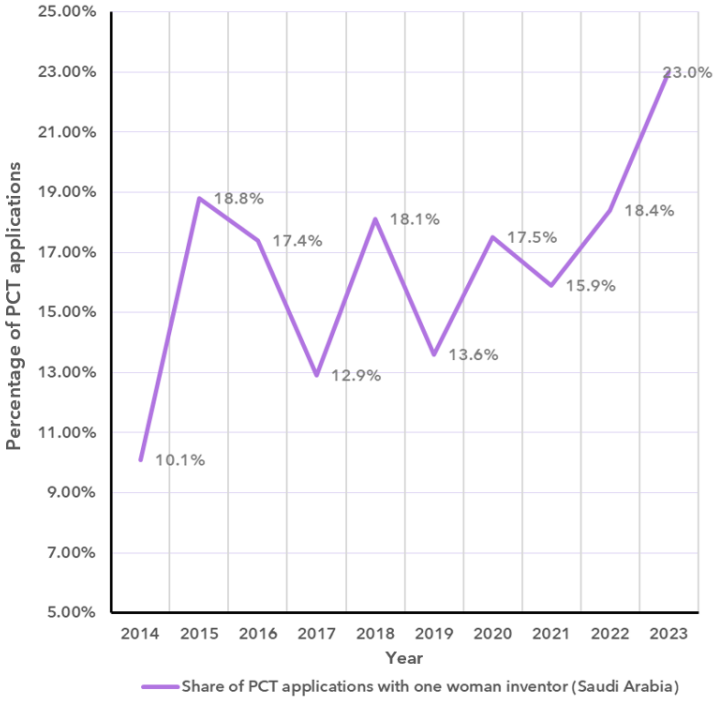

Figure 95: Share of PCT applications with one woman inventor in Saudi Arabia

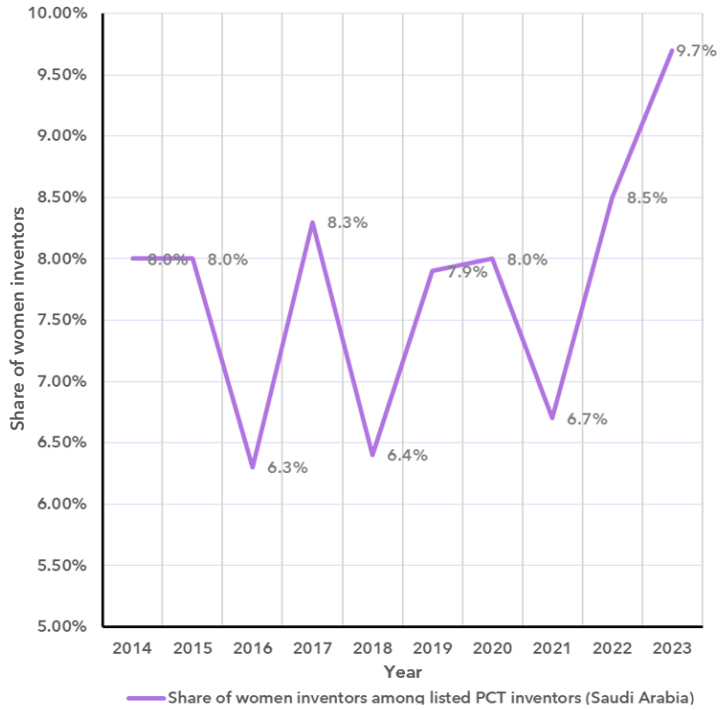

Figure 96: Share of women inventors among listed PCT inventors in Saudi Arabia

[19] A PCT application is an international patent application filed through the Patent Cooperation Treaty (PCT).

Also, the share of women inventors among listed PCT inventors in Saudi Arabia fluctuated in the period 2014-2024 but slightly grew from 8% in 2014 to 9.7% in 2024 as shown in Figure 96. This reflects the efforts in Saudi Arabia to increase the participation of women in inventions.

Though, in both metrics the 2023 percentage in Saudi Arabia was lower than the global benchmark, than that of United Arab Emirates and Qatar but higher than that of Oman, as shown in Figure 97 and Figure 98.

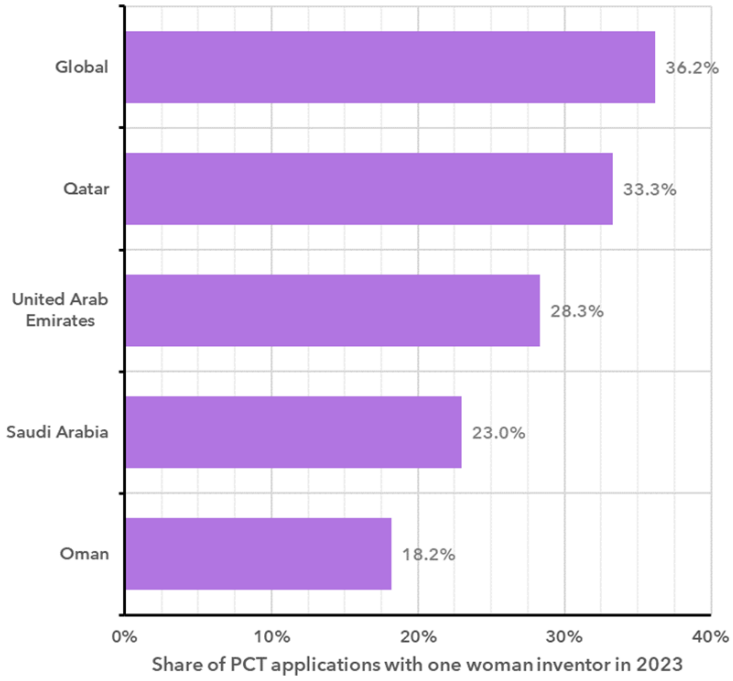

Figure 97: Share of PCT applications with one woman inventor in 2023

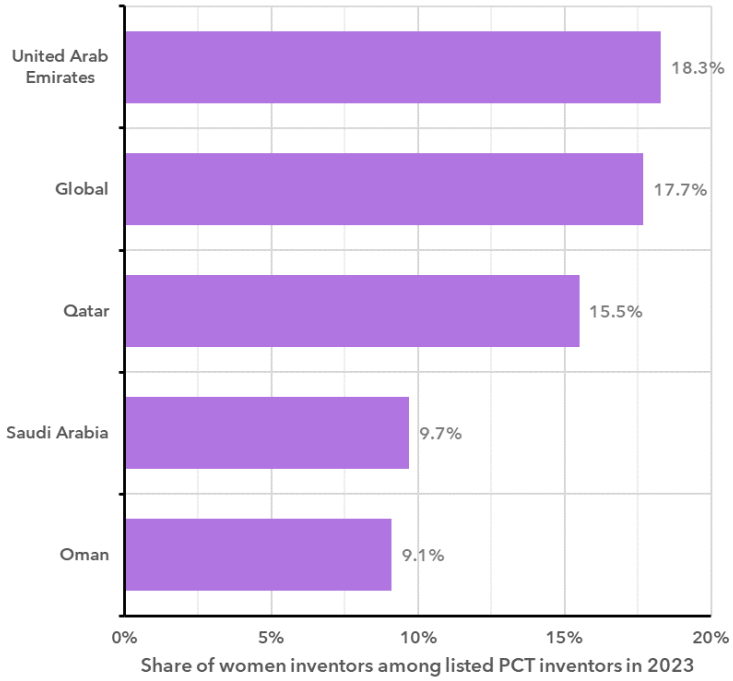

Figure 98: Share of women inventors among listed PCT inventors in 2023

5.2 Impact of gender equality on research quality

The gender gap in research and innovation is problematic for a wide range of reasons, including the adverse effects it has been found to have on the quality of research.

First and foremost, diversity in research is seen as crucial since it adds to the collective intelligence of a research group and enhances creativity (Elsevier, 2017). The more diverse a team of researchers, the greater the variety of perspectives which can lead to more innovative thinking and solutions (European Commission, 2022). On a related note, gender inequality tends to result in a narrower scope of research topics due to the absence of diverse perspectives. The implication of this is that important areas of research can get overlooked, especially subjects that may be more relevant to or be better understood by women (Belingheri et al., 2021).

Secondly, the gender gap that exists in research also affects research productivity and publication patterns. Research has shown that women currently publish fewer papers, and are less likely to co-author internationally or across sectors (Elsevier, 2017). Other studies have shown that increasing the participation of female researchers can lead to improved publication and citation rates (Bührer et al., 2020).

A third area of impact is related to workforce dynamics. **Gender inequality has been shown to affect dynamics in the scientific workforce such as compensation, role, education, decision-making, and career progression**. Over time, these factors can compound to hinder the overall progress and quality of research activities (Belingheri et al., 2021).

Fourthly, the aforementioned effects combine and manifest in the long term as a negative impact on the overall career advancement of female researchers. **Ultimately, a lack of gender balance means that women in research are placed at a disadvantage which holds back their individual careers by limiting their opportunities for collaboration, mentorship, and leadership** (Belingheri et al., 2021). This ultimately means female researchers are limited in the extent to which they can attain economic and societal advancement.

In sum, a lack of gender equality in research limits the potential of the research enterprise by reducing the diversity of ideas and contributions that are essential for high-quality, innovative, and impactful research. Economically, this means the gender gap in research is also limiting the economic, business, and innovation benefits that flow from research while also holding back the careers of female researchers and limiting their opportunities for advancement.

5.3 Global efforts and initiatives to improve gender equality in research

The promotion of gender equality in research is an ongoing global effort. The ambitions to achieve better representation of women in science has been articulated by many high-profile stakeholders. For instance, the United Nations is actively promoting gender equality through the Sustainable Development Goals (SDGs). Specifically, SDG 5 represents the UN's ambition to achieve gender equality and empowerment of all women and girls, including in research and academia. This requires comprehensive policy reforms as well as political leadership to dismantle systemic barriers. This helps ensure that women are able to achieve full and effective participation in the workforce and have equal opportunities for leadership (United Nations Department of Economic and Social Affairs, 2023). Through this SDG, individual countries are encouraged to adopt policies and measures to promote gender equality in various sectors, including research and education.

In the context of gender equality in research, the Global Research Council has called for specific policy changes to promote gender equality in the scientific workforce including training to correct unconscious gender biases and the exploration of new

career pathways by which women are able to succeed in research and rise to leadership positions (Global Research Council, 2016).

To achieve these ambitions, various policies and initiatives have been put in place at international, national, and local levels to address disparities and ensure more inclusive research environments. At the UN level, UNESCO implemented the STEM Gender Advancement (SAGA) program, which provides countries with tools to assess and monitor gender equality in STEM fields. SAGA focuses on identifying and addressing barriers to gender equality in STEM education and research, supporting evidence-based policymaking, and fostering gender-inclusive cultures in scientific fields (UNESCO Institute for Statistics, 2016). Furthermore, UNESCO also runs the Women in Science program together with L'Oréal which recognizes outstanding female researchers and supports young women in their scientific careers with dedicated awards[20]. The program also emphasizes capacity-building as well as mentoring to support female scientists in advancing their careers.

5.3.1 European Union

The European Union is currently implementing some of its equality commitments through the Gender Equality Strategy (GES) 2020-2025. The GES outlines measures to support gender equality in research and innovation, including improving the gender balance in decision-making roles and integrating gender considerations into its research and innovation policies in alignment with the broader goals of the European Research Area (ERA). The strategy includes a monitoring element to track progress through specific indicators and encourages member states to adopt national strategies for gender equality (European Commission & Directorate-General for Communication, 2020). Regarding research specifically, Horizon Europe also reaffirms the European Commission's commitment to strengthening gender representation in research and innovation.

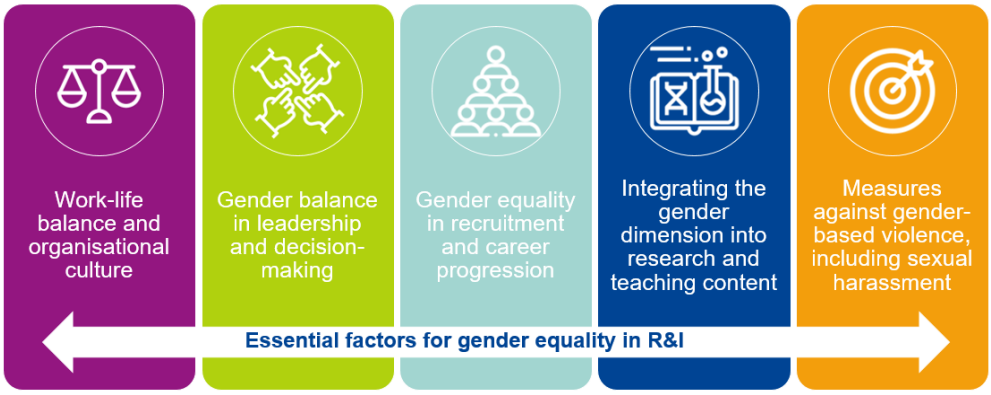

Figure 99: Overview of a Gender Equality Plan as mandated by Horizon Europe[21]

As of 2022, Horizon Europe requires all public bodies, research organizations, and higher education institutions to have a Gender Equality Plan (GEP) in order to be eligible for funding. Each GEP must cover specific aspects such as the gender balance in leadership, career progression, and integrating the gender dimension into research and teaching content (European Commission & Directorate-General for Research and Innovation, 2021a). Furthermore, gender differences must also be taken into consideration in the design, implementation, and outcomes of funded research projects. A similar approach was taken by the GENDER-NET Plus initiative, which aimed to promote gender equality in Horizon 2020, Horizon Europe's

[20] L'Oréal-UNESCO For Women in Science Programme: https://www.unesco.org/en/prizes/women-science
[21] European Institute for Gender Equality - Gender Equality in Academia and Research - GEAR tool: https://eige.europa.eu/gender-mainstreaming/toolkits/gear/what-gender-equality-plan-gep?language_content_entity=en

predecessor, as well as the European Research Area more broadly. GENDER-NET Plus ran until 2023 and was a translational funding initiative supporting gender equality through gender-focused research and innovation projects[22]. It encouraged the integration of gender analysis in research design and the funding of innovative projects addressing gender equality challenges.

5.3.2 Europe

At the national level, there are many examples of countries that are implementing policies in support of gender equality in the research space. UK Research and Innovation (UKRI), for instance, has a gender equality plan in place for the period 2022-2026 that includes a range of commitments and actions across five thematic areas recommended by the European Commission.

This plan is an example of a GEP developed to be eligible for research and innovation funding through the Horizon Europe program. The plan is designed to ensure that gender equality is embedded in all aspects of research funding, policies, and practices. It also emphasizes the accountability of senior leaders, collecting and analyzing gender-disaggregated data, providing training and resources for awareness raising, as well as specific measures to ensure gender balance in funding panels, decision-making bodies, and applicants (UK Research & Innovation, 2022). Furthermore, policies that enable flexible working arrangements are supported in recognition of individuals with caregiving responsibilities. Institutions are also required to develop their own gender equality plans that address recruitment, retention, career progression, and work-life balance.

In 2008, Germany implemented the Women Professors Program ("Professorinnenprogramm"), an initiative by the German government to promote gender equality in academia[23]. The program provides funding to universities and research institutions that are able to demonstrate effective gender equality strategies, particularly with regard to increasing the number of female professors. The ultimate aim is to contribute to the creation of a more inclusive academic environment across Germany by enhancing the visibility of women in academia and supporting their career progression (Bührer et al., 2020).

5.3.3 North America

In the U.S., the National Science Foundation (NSF) has implemented the ADVANCE program, which aims to increase the representation and advancement of women in academic science and engineering careers, thereby contributing to the development of a more diverse science and engineering workforce[24]ADVANCE provides grants to institutions to support systemic changes needed to promote gender equality in academic, scientific, and engineering careers. The program focuses on increasing the representation and advancement of women of all backgrounds in academic STEM careers and funds leadership development initiatives and research on gender equity practices.

In Canada, the Institute of Health Research (CIHR) has adopted the Sex and Gender-Based Analysis Plus (SGBA+) approach, which is used to help CIHR formulate responsive and inclusive health research policies, programs, and services by considering factors that contribute to differences in accessing health-related resources and health outcomes. This approach mandates researchers applying for funding to consider gender as part of their research design, analysis, and reporting in order to ensure that the outcomes of the research are relevant and applicable to both

[22] GENDER-NET Plus: https://gender-net-plus.eu/what-is-gender-net-plus/
[23] Women Professors Programme: https://www.bmbf.de/bmbf/de/forschung/gleichstellung-und-vielfalt-im-wissenschaftssystem/frauen-im-wissenschaftssystem/frauen-im-wissenschaftssystem_node.html
[24] NSF ADVANCE Programme: https://www.nsf.gov/crssprgm/advance/

men and women. CIHR also uses targets for gender equality in its leadership and decision-making positions within its funded projects and institutions.

5.3.4 MENA

With regard to the MENA region, the Arab Science and Technology Foundation supports the Arab Women in Science and Technology (AWST) network[25]. This aims to empower Arab women in science and technology fields by providing support, mentorship, and networking opportunities. Women are encouraged to pursue careers in research and innovation and to increase their visibility in these fields. The Qatar Foundation has several initiatives aimed at promoting women in research, encourages young women to participate in scientific research and innovation. The Foundation offers scholarships, research grants, and leadership training for women in science. It also provides platforms for women researchers to showcase their work and engage with the global scientific community.

The UAE Gender Balance Council[26] is an initiative by the UAE government to promote gender equality across all sectors, including research and academia. The council aims to position the UAE among the top 25 countries for gender equality by implementing policies and initiatives that support women in various fields. The council has launched several programs to support female researchers, including funding opportunities, leadership training, and partnerships with international organizations to promote best practices in gender equality.

Finally, as part of Saudi Arabia's Vision 2030, there is a strong focus on increasing women's participation in all sectors, including research and academia. Through Vision 2030, the Saudi government is working to break down barriers and create opportunities for women in STEM fields. For instance, it has launched scholarships for women to study STEM subjects, created mentorship programs, and is working to improve workplace policies to support female researchers. Notably, institutions like the King Abdullah University of Science and Technology (KAUST) have specific initiatives to support female scientists in its Biological and Environmental Science and Engineering (BESE) Division[27] as well as the Department for Computer, Electrical and Mathematical Sciences and Engineering (CEMSE)[28]. Additionally, the MIT Ibn Khaldun Fellowship for Saudi Arabian Women was strategically designed to empower Saudi women scientists and engineers to excel as leaders in their research domains and as prominent educators and administrators in the Kingdom. All of those initiatives and policies is already showing their positive impact.

The Kingdom's progressive policies and initiatives aimed at empowering women are already yielding remarkable results, as evidenced by the growing global recognition of Saudi women in science and technology. For example, several Saudi females have been honoured with the prestigious L'Oréal-UNESCO For Women in Science Awards, celebrating their exceptional contributions to research and innovation. Furthermore, the achievements of Rayyanah Barnawi, the first Saudi Muslim woman to venture into space as part of a groundbreaking mission with Axiom Space, underscore the transformative impact of these initiatives. These accomplishments reinforce the Kingdom’s commitment to fostering gender equity and excellence in all sectors.

5.3.5 Effective strategies and models

A wide variety of strategies and models exist that can be used to reduce the gender gap, and these have been implemented around the world, as discussed in the previous section. These approaches can be summarized according to the type of action they involve.

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[25] Arab Women in Science and Technology: https://www.astf.net/index.php/en/wom-conf-about-en
[26] UAE Gender Balance Council: https://www.gbc.gov.ae/
[27] BESE – Empowering Women in Science: https://www.kaust.edu.sa/html/bese/women-in-science/
[28] CEMSE women in science: https://cemse.kaust.edu.sa/women-in-science

From the perspective of public sector institutions, a critical strategy is regulation. This approach involves the **implementation of specific policies that are designed to directly address gender disparities from a top-down perspective.** Examples of effective policy interventions include mandatory gender quotas, gender-sensitive budgeting, and anti-discrimination laws (Alcalde-Rubio et al., 2020). Research funders can effectively mandate such policies by integrating these types of requirements into their award criteria.

Educational initiatives typically try to take early action to increase the representation of women in the scientific workforce. Such initiatives generally **stimulate early investment in education as well as outreach programs with the objective of encouraging girls and young women to pursue careers in research and STEM fields** (Kong et al., 2020).

A third category of strategies is concerned with workplace practices specifically. This category aims to **foster more inclusive work environments that support gender diversity**. These strategies are applicable to workplaces in general but are also relevant for research as well. Examples of effective workplace practices that can help to reduce the gender gap are the adoption of more flexible working hours and arrangements, adequate policies for parental leave, and anti-harassment policies (Kong et al., 2020).

Mentorship and networking strategies have also been found to be effective means of supporting the careers of female researchers. Through the establishment of mentorship programs and professional networks dedicated to women in research and innovation, targeted support and guidance can be provided while also creating better opportunities for career advancement. Academic conferences, for instance, provide researchers with excellent opportunities to disseminate research, network, and form collaborative relationships. However, these conferences need to take action to reduce participation barriers for female scientists and researchers (Sardelis et al., 2017).

Data collection is seen as an effective means of understanding gender gaps. Specifically, **the collection and analysis of gender-disaggregated data will shed more light on the representation of women in education, research, and innovation**. In turn, this will generate a much better understanding of the prevalence of gender inequality in specific fields and sectors, enable the monitoring of progress over time, and the creation of more targeted policies and initiatives (United Nations Entity for Gender Equality and the Empowerment of Women, 2018).

In a similar vein, awareness and training strategies are important for the reduction of gender gaps in research. **By raising awareness of gender biases and providing training to researchers and decision-makers at research institutions, unconscious biases related to gender can more effectively be recognized and mitigated** (Alcalde-Rubio et al., 2020).

Finally, **recognition and award strategies are popular for promoting gender equality in research and innovation**. Creating recognition and award schemes that highlight the achievements of women in science helps to increase overall visibility and can inspire others (Rivera-Lozada et al., 2024).

5.4 Key opportunities

This section provides an overview of actions that could be implemented for the improvement of gender equality in research and innovation, based on the findings of this study.

5.4.1 Practical actions for short-term implementation

Regarding the allocation of research funding, exerting a certain amount of leverage on beneficiaries and stakeholders by setting assessment criteria and closely monitoring funded projects in a gender-sensitive and inclusive manner. Gender-

sensitive research funding procedures are applicable across the entire funding cycle and are summarized in Table 21.

Table 21: Summary of actions to promote gender equality in the research funding process

Funding cycle phase	Suggested considerations and actions
Planning	• Collect statistical information on a regular basis covering female representation amongst applicants and grantees, on evaluation panels, and evaluators by discipline. • Define program targets and funding conditions (eligibility, assessment criteria, assessment procedures, etc.) based on this statistical information in line with organizational goals regarding gender equality.
Funding calls	• Include statements promoting gender equality on organizational commitments to encourage more women to apply. • Gender-sensitive language and images should be used as much as possible in promotional activities. • Review distribution and communication channels for funding calls to ensure a diverse pool of potential applicants is reached. • Select diverse evaluation panels that are balanced in terms of gender.
Application	• Increase the share of female applicants by explicitly addressing potential women applicants through ambassadors, workshops, gender networks, etc. • Require proposals to demonstrate how gender considerations are integrated into the research (or why they are not relevant to the proposed research). • Care obligations of female researchers can be made visible in applications and compensation for this can be considered, such as extended application periods, compensation for third-party care, supplementary allowances for team member replacement in case of maternity leave, etc.
Assessment	• Implement clear evaluation guidelines and precise assessment criteria to minimize gender bias, • Set gender-sensitive eligibility criteria (e.g., considering slower career progression for female researchers due to care obligations). • Include alternative assessment policies and practices, such as narrative CVs, to consider a broader range of research outputs attributed to applicants and non-traditional career paths.
Decision-making	• A gender quota can be used to ensure that a certain proportion of women receive research funding. • Some funding bodies use a tie-breaking approach, where preference is given to female applicants when they have equal scores to male applicants.
Monitoring	• A clear monitoring strategy enables a research funding body to be informed about the progress on gender equality at the program or grant level • Gender-specific indicators can be used to determine whether gender objectives are being met or whether further adaptations are needed. • This also provides accountability to the stakeholders involved.

Evaluation	• Once all final data along all steps of the funding cycle is available, the funding body can check whether all objectives were met and where adaptations for a next call are needed. • Analyse all granted and non-granted applications with respect to gender, discipline (where relevant) and other categories to assess the gender distribution. • Evaluation should also cover qualitative aspects, such as a check of biased language used in panel discussions or evaluation reports, as well as in the call text or guidelines for reviewers and panel members.

Source: adapted from the European Institute of Gender Equality: Gender Equality in Academia and Research (GEAR) tool

Internally, research funding bodies can ensure the importance of gender equality in research and organizational goals by actively checking that such goals are properly understood and implemented. For instance, gender capacity-building activities can help enable staff members to implement gender equality measures for applicants or reviews, or to address stakeholders in a gender-sensitive manner.

5.5 Long-term efforts to promote gender equality in research

To guide the changes in research funding processes as well as internal efforts, there is an opportunity to formulate and implement a gender equality plan (GEP)[29]. The GEP is a formal document setting out all gender-relevant goals and activities in a systematic manner. Ideally, GEPs are drawn up by national institutions such as the RDIA as well as individual universities and other research-performing organizations. In this sense, the requirement of GEPs for participation in the Horizon Europe funding program provides a compelling example of how this can be encouraged from a top-down perspective. To develop a GEP, gender-specific objectives and measures need to be designed, discussed, and negotiated within the organization, for which the following steps are usually implemented:

1. **Understand the organization context: Analyze the types of research supported, the history of the organization, and the scope of the funding, and consider the perspectives of the organization's** internal and external stakeholders. For organizations with little experience with implementing gender equality measures, it is generally recommended to start by reviewing all activities and processes related to grant allocations and reflect on where gender equality could play a role.
2. **Assess the status quo**: Assess the organization's strengths and weaknesses with regard to gender equality based on the information collected. Based on this data, start by producing descriptive statistics. This will help to identify the areas for improvement for which objectives and targeted measures need to be developed. At this stage it is also useful to consider any applicable national legislation or policies, allowing the status quo assessment to be focused on the most relevant intervention areas.
3. **Establish a gender equality plan**: The scope of the GEP depends on the nature of the research funder and can range from defining research priorities and funding programs to defining eligibility criteria, application procedures, and evaluation and grant-awarding procedures. It can also include objectives and measures that aim to promote gender equality for employees, ranging from work–life balance to work culture or career progression and leadership. Due to the variety of actions and areas that could potentially be covered by a GEP, it is useful to focus on the intervention areas with the highest priority, as

[29] See: https://eige.europa.eu/gender-mainstreaming/toolkits/gear/what-gender-equality-plan-gep

identified in the previous step. While there is no set template or structure for a GEP, it should provide the following for intervention area:

a. Objectives,
b. Measures and indicators with targets,
c. Timelines,
d. And responsibilities.

The European Institute for Gender Equality maintains a searchable repository[30] of GEPs that can be used to provide indicative examples.

4. **Implement the GEP**: To implement the GEP developed in the previous step, it is important to set up a dedicated task force responsible for enacting the specified measures. In parallel with the implementation efforts, it may also be useful to engage in continuous awareness-raising and capacity-building efforts to maximize the GEP's chances for success. Furthermore, progress must be tracked and discussed on a regular basis so that achievements and areas of improvement are identified early, and improvements or adjustments can be made where needed.
5. **Monitor and evaluate progress**: GEPs usually address a wide range of issues and, therefore, encompass a broad range of measures. Effective monitoring and evaluation can help measure progress, support implementation, ensure accountability, and improve the organizational understanding of ongoing changes. The status quo assessment should be used as a baseline against which to measure progress. The core aspect of the monitoring and evaluation strategy should be to identify appropriate indicators and to select suitable data collection methods. Indicators should be both quantitative and qualitative and can include a range of gender aspects summarized in Table 22.

[30] See: https://eige.europa.eu/gender-mainstreaming/toolkits/gear/action-toolbox

Table 22: Overview of potential indicators to monitor the implementation of gender equality plans in research organizations.

Indicators for gender in decision-making for internal stakeholders	Indicators for gender in decision-making for external stakeholders	Indicators for the integration of the gender dimension into R&I
• shares of women and men members of decision-making bodies. • shares of women and men members of decision-making bodies who have participated in specific gender training and capacity building. • number of gender training and capacity-building courses for members of decision-making bodies. • self-assessment of increase in gender competence (e.g., through feedback surveys after training courses). • share of women among newly appointed members of decision-making bodies.	• share of women in evaluation panels in relation to men. • shares of women and men evaluators who have participated in specific gender training and capacity-building courses. • number of gender training and capacity-building courses for evaluation panel members. • share of members of evaluation panels with gender competence (e.g., men and women who have participated in gender training). • share of women among newly appointed evaluation panel members.	• description of calls in relation to the integration of gender (calls with a focus on gender, calls that include integrated gender analysis as an aspect in research, calls that do not explicitly address the sex/gender dimension). • description of (lack of) gender expertise in evaluation panels. • gender composition of research teams (share of women in research teams). • number of funded projects with a gender focus in relation to all funded projects (share of gender projects). • numbers of women and men participants (applicants, reviewers) in awareness-raising activities or training on gender in R & I.

Source: adapted from the European Institute of Gender Equality: Gender Equality in Academia and Research (GEAR) tool

In addition to these, qualitative indicators are also valuable to understand whether the desired outcomes are being reached as well as understand the dynamics of the ongoing change. In this context, useful indicators include:

- **Mainstreaming of gender knowledge:** the extent to which relevance is given to knowledge creation on gender equality within the organization, the institutionalization of gender, the dissemination of gender equality knowledge across disciplines, and so on.
- **Awareness among different categories of staff and external stakeholders**: Level of attention given to gender equality by different categories of stakeholders through communication initiatives, codes of conduct, and activities centered on gender-related aspects.
- **Uptake of gender equality objectives set in the GEP**: Observing the participation in and acceptance of implemented measures and the (human and financial) resources allocated to support these measures.
- **Transformation towards greater gender sensitivity**: Level of attention given to women's ideas and perspectives in decision-making mechanisms that are traditionally dominated by men.

- **Diffusion of a gender equality culture**: Observed changes in terms of working conditions, verbal and non-verbal interactions, decision mechanisms, management of work-life balance, awareness of sexual harassment, etc.

6. **Beyond the GEP**: Depending on the outcomes of the evaluation of the GEP, conclusions may be drawn regarding the progress made toward gender equality within the organization and its stakeholders. Similarly, new areas may emerge that require intervention, which can be addressed by a new GEP that draws on the lessons learned from the first iteration. At this point, it may also be relevant to benchmark the progress made against other comparable organizations and to continue engaging with internal and external stakeholders to understand ongoing needs in the research community with respect to gender equality.

As discussed in this chapter, examples of initiatives such as European GEP, ADVANCE program and AWST promote the participation of women in research and innovation, consistent progress through local initiatives can also be observed in Saudi Arabia. To further enhance the participation of women in research, the integration of gender consideration within the processes and mechanisms used to allocate funding to research and innovation can be a powerful tool to drive change. It can essentially require universities and other research organizations to take gender equality into account when applying for funding as well as managing their respective research processes. Mandating GEPs would go one step further by requiring individual institutions to reflect on the status of gender equality within their own organizations and act where this is needed.

6 Definitions, metrics and data sources

6.1 General definitions

Academic institution

An establishment dedicated to education and research, generally conferring academic degrees across various levels of learning. While academia can more widely be used as a term as primary through tertiary education, we limit and define for the purposes of this study the tertiary sector only. However, note, we further expand the definition of academia in this study to government research institutions more generally.

Academic-Corporate Partnership

Refers to a collaborative arrangement between educational institutions and business entities, aiming to leverage their respective strengths for mutual benefit, often in the realms of research, technology development, and knowledge exchange. The relationship typically involves shared resources, strategic alignment, and a commitment to achieving common objectives that advance both academic and corporate interests. Defined and identified in this study as a scientific publication or a patent family that contains bibliographic information as authors or inventors from organizations that are both an academic institution and a corporate entity.

Applied Research

Refers to the process of systematic investigation that aims to solve practical problems by applying scientific knowledge. It typically involves collaboration with industry to develop tangible solutions, such as new products, technologies, or processes, that directly address specific challenges in various fields.

Basic Research

Often also called pure or fundamental research, this refers to the process of systematic investigation aimed at gaining a deeper understanding and knowledge of the underlying principles of phenomena and observable facts, without immediate practical application in mind.

Commercialization

Commercialization refers to the process of managing, typically via a business or corporate entity, activities in return for economic or monetary gain. It involves introducing a new product or service to the market and is often associated with the production, distribution, marketing, and sales necessary to achieve commercial success. Frequently used in the context of scaling up business operations to reach a broader market. In this study, it is specific to understanding the level of commercialization activity and directionality of research areas.

Corporation

A corporate entity is a legally recognized organization designed to conduct business. Typically, a corporation is a body formed and authorized in law to act as legal person, as distinct from the natural persons owning or operating within the entity. Corporate entities can enter into contracts, own assets, and are subject to taxation, while providing limited liability protection to their owners

G20

The Group of Twenty is an international forum that brings together the world's major economies. Its members include 19 countries and the European Union, collectively representing most of the global economy. The G20 aims to address issues of global economic importance, ranging from international financial stability to climate change mitigation and sustainable development. Established in 1999, the G20 has evolved to be a central platform for international economic cooperation. The members of the G20 collectively represent most of the world's largest economies, including Saudi Arabia, and accounting for around 80% of gross world product, 75% of global trade, and two-thirds of the world population. The G20 is therefore used a basket of comparable nations for the evaluation of research and innovation benchmarked performance.

OECD

The Organisation for Economic Co-operation and Development (OECD) is an intergovernmental organization with 38 member countries, founded in 1961 to stimulate economic progress and world trade.

GCC

The Cooperation Council for the Arab States of the Gulf, also known as the Gulf Cooperation Council (GCC) is a regional, intergovernmental, political, and economic union comprising Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, and the United Arab Emirates.

GII

The Global Innovation Index is an annual ranking of countries by their capacity for, and success in, innovation, published by the World Intellectual Property Organization. In the benchmark we use the term GII top 25 marking the top 25 countries in the latest edition of the ranking published in 2024.

Innovation

Refers the process of progressing new ideas or inventions into products, services or other economic activity that is valued and in demand by businesses or consumers. As a general principle, innovation can encompass the conversion of creativity, technical knowledge and information into new and useful products and services. In this study, we focus the definition to technical innovation and the process of developing and applying new technologies or improving existing ones to create advancements in various fields. It involves the use of technical knowledge and expertise to address challenges, enhance efficiency, and create value through novel solutions.

Invention

A novel or unique method, device, or process developed from research and experimentation, typically patented and designed to solve a specific problem or improve existing solutions. Within this study, due to the database structure of the Derwent World Patents Index, we use "invention" as synonymous with "patent family" (see definition) - an individual idea, meeting the criteria of an invention, as patented at various patent offices around the world. This definition includes patent applications that have not yet granted. This definition removes the need to deduplicate multiple patent documents surrounding the single invention/idea, and in turn transforms the collection of multiple patent documents into meta data of invention strength

Nominal Gross Domestic Product (GDP)

Nominal Gross Domestic Product (GDP) is a macroeconomic metric that measures the total market value of all finished goods and services produced within a country's borders in a specific time period, using current prices without adjusting for inflation. Presented here in US dollars.

6.2 Research related definitions

Citation

An academic citation is a formal reference to a published or unpublished source that is used to support the author's arguments or findings in a scholarly work. It acknowledges the original creator of an idea or piece of information and provides readers with the details necessary to locate the source material themselves. Citations are essential in academic writing to avoid plagiarism, uphold intellectual honesty, and facilitate the verification of facts or ideas presented.

Patent citation is a similar process and refers to any significant document or research paper that a patent applicant, examiner, or third party cites as relevant to the content of a patent application. It serves as a formal acknowledgment of prior art and related work in the field, providing a trail of the intellectual property landscape pertinent to the invention.

In both cases, citations are significant sources of impact meta data, as the aggregation and analysis of papers, patents, topics, organizations and economies via citation measures provides a method of assessing the preponderance of downstream reference research and innovation the work has on others, thereby reflecting the importance and impact of the cited work itself.

Papers/publications/documents

A written document that presents the results of original research or an innovative study in a systematic and standardized format. A core activity of the scientific method, the publication of research via a formal paper is intended to communicate new research and knowledge discovery to the scientific community and to contribute to global and collective knowledge. Such papers are peer-reviewed and published in academic journals, ensuring the integrity and validity of the research presented. Clarivate abstracts publications including research journal articles, editorials, meeting abstracts and book reviews. The terms "paper", "document", "Web of Science Document" and "publication" are often used interchangeably to refer to printed and electronic outputs of many types. In the analyses presented here, the terms used exclusively to refer to substantive journal articles, reviews and proceedings papers

Researcher Affiliation

Researchers affiliated organization. A single researchers could provide several affiliations in one publication. The publication is then associated with all organizations and, correspondingly, all geographical locations in which these organizations are located.

Citation Topics

Citation Topics are named document clusters based on cited and citing relationships between documents**.** They are algorithmically derived citation clusters (using an algorithm developed by CWTS, Leiden). This is a three-level hierarchical document-level classification system. The three levels of the hierarchy and their content according to the 2024 clustering are:

- Macro-topics (10)
- Meso-topics (326)
- Micro-topics (2449)

Macro- and meso-topics are manually labelled based on their contents. Micro-topics are algorithmically labelled with their most significant keyword. As Citation Topics are based on citation relationships and not the content or subject matter of their constituent documents, topics are labelled by inference, and any name may not be descriptive for every document in the topic. More information and a description of the 2024 schema can be found on Clarivate website.

Web of Science Research Areas

The Web of Science schema comprises approximately 250 subject areas in science, social sciences, and arts & humanities. Many broad areas such as physics and materials science are represented by smaller sub-fields. Selecting subject areas from this list enables you to make comparisons in targeted areas such as Applied Chemistry or Geriatrics & Gerontology. Journals are assigned to the categories and thus documents from those journals inherit the assigned category. Articles from multidisciplinary journals may be reclassified into specific subject areas.

Sustainable Development Goals Schema

The 2030 United Nations Agenda for Sustainable Development contains 17 core Sustainable Development Goals, which are calls for action by all countries.

The Sustainable Development Goals schema allows to explore and analyse according 17 SDGs. Partnerships for the goals: Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development, the 17th SDG, is now included in the schema.

The schema is based on Category-to-category mapping where Sustainable Development Goals are mapped to

sets of related Micro Citation Topics. The first mapping to Micro Citation Topic was in January 2022. In April 2024, Citation Topics clustering has been updated, together with the mapping to the SDGs. The current mapping can be found here.

6.3 Saudi Arabia specific definitions

Research, development and innovation (RDI)

The Research, Development and Innovation (RDI) sector in Saudi Arabia refers to the collective activities and initiatives aimed at fostering scientific research, technological development, and innovation across various fields. This sector is pivotal to the Kingdom's Vision 2030, driving economic diversification and sustainable development. The RDI sector encompasses a network of institutions, policies, and programs that support and finance scientific research, coordinate activities of research centres, and propose legislation to nurture an environment conducive to innovation and technological advancement.

National Priority Areas

Refers to the strategic objectives set by the Kingdom to guide its development and innovation efforts. These priorities include Health and Wellness, Sustainable Environment and Supply of Essential Needs, Energy and Industrial Leadership, and Economies of the Future. They are designed to enhance the nation's global competitiveness and align with the goals of Saudi Vision 2030.

Vision 2030

Saudi Vision 2030 is a strategic framework aimed at diversifying Saudi Arabia's economy, transforming the nation into a global investment powerhouse. Launched in 2016, Vision 2030 seeks to foster economic, social, and cultural development by capitalizing on the country's strategic location and enhancing the quality of life for its citizens. It emphasizes three core pillars: a vibrant society, a thriving economy, and an ambitious nation, with a focus on public sector efficiency, private sector growth, research and innovation, and international collaboration.

6.4 Description of data sources

Web of Science™

The data used in this study came from the Clarivate Web of Science databases, which give access not only to journals but also to conference proceedings, books, patents, websites, and chemical structures, compounds and reactions.

Web of Science has a unified structure that integrates all data and search terms together and therefore provides a level of comparability not found in other databases. It is widely acknowledged to be the world's leading source of citation and bibliometric data. The Web of Science Core Collection is the premier resource on that platform and includes over 22k peer-reviewed, high quality scholarly journals published worldwide (including Open Access journals), over 308k conferences, over 151k editorially selected books and 92M records going back to 1900.

Coverage is both current and retrospective in the sciences, social sciences, arts and humanities. Clarivate has extensive experience with databases on research inputs, activity and outputs and has developed innovative analytical approaches for benchmarking and interpreting international, national and institutional research impact.

InCites™

Additionally, InCites Benchmarking & Analytics was used in this project to generate relevant metrics and indicators.

InCites is a customized, citation-based research evaluation tool enabling analysis of productivity and benchmarking of output against peers worldwide, with underlying data drawn from the Web of Science Core Collection™.

InCites provides disambiguated data for all publications in the Web of Science Core Collection.

6.5 Metrics

Web of Science Documents

This is an indicator to refer to substantive journal articles, reviews and proceedings papers and excludes editorials, meeting abstracts or other types of publication. It is based on the Web of Science Core Collection™ dating till Sunday, December 31, 2023.

Category Normalized Citation Impact

The Category Normalized Citation Impact (CNCI) of a document is calculated by dividing the actual count of citing items by the expected citation rate for documents with the same document type, year of publication and subject area. When a document is assigned to more than one subject area an average of the ratios of the actual to expected citations is used. The CNCI of a set of documents, for example the collected works of an individual, institution or country/region, is the average of the CNCI values for all the documents in the set. CNCI is a valuable and unbiased indicator of impact irrespective of age, subject focus, or document type. Therefore, it allows comparisons between entities of different sizes and different subject mixes.

- A CNCI value of 1 represents performance at par with world average.
- Values above 1 are considered above average.
- Values below 1 are considered below average.
- A CNCI value of 2 is considered twice world average.

CNCI is an ideal indicator for benchmarking at all organizational levels (author, institution, region etc). When dealing with small sets of publications, for example, the publications of one individual, the CNCI values may be inflated by a single highly cited paper. More information can be found on InCites website.

Documents in Top 1% and 10%

Number and percentage of publication in the top 1% and 10% based on citations by category, year, and document type. The % Documents in Top 1% indicator is the top one percent most cited documents (as defined in the description of Average Percentile) in a given subject category, year and publication type divided by the total number of documents in a given set of documents, displayed as a percentage. A higher value is considered to be higher performance. A value of "1" for a set of documents represents that one percent of the publications in that set are in the top one percent of the world regardless of subject, year and document type and would therefore be considered to be performing at the same level as global average. The % Documents in Top 1% indicator is considered to be an indicator of research excellence as only the most highly cited papers would make the top one percent in their respective field, year, and document type. The % Documents in Top 10% is very similar to the % Documents in Top 1% simply with a threshold of 10 percent instead of one percent. Therefore, typical performance will be around a value of 10 and values of higher than 10 would be considered above average performance.

Growth and Average growth

In this study we visualize the evolution of the number of Web of Science documents for a certain entity and period. In order to quantify the change

of the number of documents from one year to another, we use the growth. The growth is then the number of documents in the most recent year (Ny2) subtracted from the number of documents in an earlier year (Ny1) and divided by it and represented as a percentage:

G= (Ny2- Ny1)/ Ny1

The average growth over a certain period of time is the arithmetic average of the growth from one year to another in that period. Sometimes a considered entity does not have documents in a certain year causing division problems for the considered year. In such cases the growth for that year is excluded from the arithmetic average.

Funding Acknowledgment

The Funding Agencies Explorer in InCites, which includes more than 1000 unified funding organizations found in and curated from Web of Science funding acknowledgments, was utilized to identify documents with funding acknowledgment and the corresponding funding agencies.

International Collaboration

Papers that contain one or more international co-authors.

Number of active researchers

The number of active researchers is calculated by considering the number of unique researchers appearing on papers with an affiliation to an organization in a certain location within a certain period. To calculate the number of unique researchers we utilize the researcher ID on Web of Science platform. The ID to each research name is assigned through an algorithm or manually by the researcher. Errors in the assignment could emerge, especially in situations in which different researchers use same names or the same person is not using their name on publications consistently. To approximate the error in the dataset used for Saudi Arabia, a sample set was reviewed and compared with the number of IDs. From this an approximate error of around ±15% in the number of researchers was derived. It is important also to note that researchers could be affiliated to several organizations in different countries and could use different affiliations on different publications and could change affiliations in time.

Percentage of Women in Research

To calculate the percentage of women we utilized the names of the unique active researchers identified from a certain dataset. The dataset used is restricted to profiles for which a first name is provided. We considered only datasets that have at least 85% of the profiles with a first name, in order for the dataset to be representable. Thus, countries from the G20 for which the dataset has lower than 85% of the profiles with names were excluded.

The gender of an active researcher is inferred by using Namsor from the name associated with the researcher profile. Namsor can help determine if a name is more likely to be male or female. The tool provides a calibrated probability for the most likely gender associated with a certain name. In accordance with Namsor documentation we have included only profiles for which a most likely gender is associated with a calibrated probability of 0.85. Also here to ensure that we have a representable analysis we excluded countries for which less than 85% of the names have a calibrated probability lower than 0.85.

With both dataset thresholds, the threshold on the profiles with names and the threshold on the calibrated probability we excluded from the analysis the G20 countries: Mainland China, South Africa, Russia and Indonesia.

To calculate the error margin on the percentage we considered the number of names from the dataset for which the calibrated probability was lower than 0.85. The upper bound of the error margin is considering that all these names are female, while the lower bound is considering that all these names are male.

Other limitations associated with the analysis include that there could be two profiles associated with a single researcher and that not all profiles

have a first name (some provide only initials). Nevertheless, the analysis provides an indication of the percentage of women among active researchers. Since the same methodology is applied on all considered countries, the analysis provides also meaningful benchmarks.

Strengths, Weakness, Opportunities and Threats Analysis (SWOT)

A Strength, Weakness, Opportunity and Threat (SWOT) analysis is based on two main metrics: productivity relative to the world and impact measured by the category normalized citation impact. The productivity relative to the world is measured by the number of a countries papers in specific research topic divided by the number of global documents in the same research topic and period. This is then normalized by the share of the country overall research from the global research in the same period. Thus, a value in this indicator above 1 indicates that the country has a share from the world research in this research topic higher than the share of the country from the global research in the same period. Similarly, a CNCI above 1 indicates a research impact footprint in the research topic higher than that of the world average. Accordingly, we can classify the research topics into four regions:

- Strength: Productivity relative to the global productivity is above 1 and the CNCI above 1
- Weakness: Productivity relative to the global productivity is above 1 and CNCI less than one
- Opportunity: Productivity relative to the global productivity is less than 1 but CNCI above 1
- Threat: both the productivity relative to the global productivity and CNCI are less than 1

6.6 Dataset description

As this study, and the wider program of research performed for RDIA, intends to analyze the National Priorities under the wider Vision 2030 policy, a dataset has been created that allows a detailed review of both the research activities occurring within the Kingdom as well as comparisons to that activity globally.

To facilitate this program of study, a technical analysis was undertaken to identify key research topics under each National Priority. Further, these research topics then go on to define the datasets of the National Priority Areas themselves.

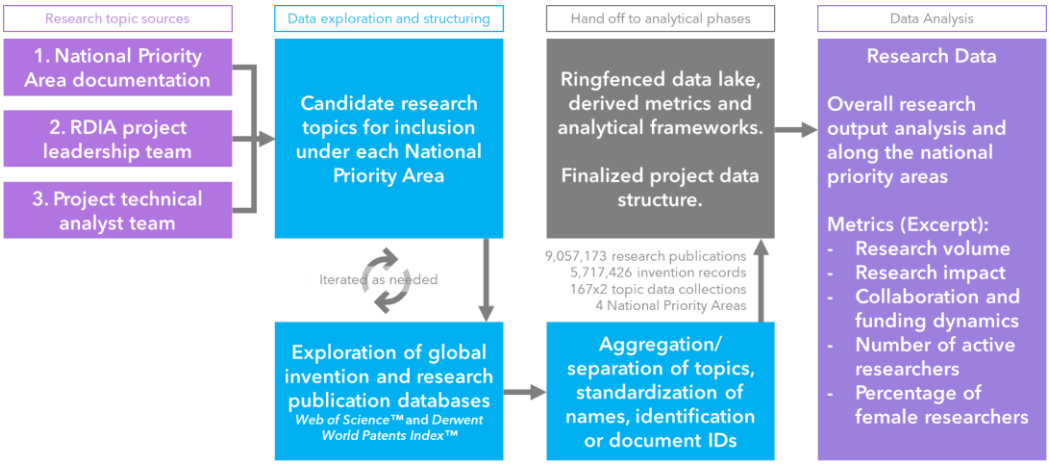

Figure 100 - study data curation process flow diagram

The creation of these content sets is based on three primary sources of information:

1. The published documentation by RDIA and other agencies in Saudi Arabia concerning the national priorities themselves.
2. The study's technology analyst team, comprising STEM professionals with many years' experience performing innovation and technology research intelligence projects.
3. The RDIA leadership, project management team, including key RDIA Missions.

In total, 167 research topics were identified and collated across both research publications (gathered from the Web of Science) and patented inventions (sourced from the Derwent World Patents Index), using traditional keyword and technology classification search techniques.

Topics were reviewed by the project technology analyst team for review of completeness, introduction of error or need for further definition and extraction. This is performed via an iterated review and amendment process, using the scientific and engineering expertise of the project's technical analyst team.

Once these data extraction strategies were finalized, the records associated with each research topic category were aggregated, name normalized and ring-fenced into a project specific data lake ready for analytical work up.

The finalized data structure for this study is summarized as:

- Over 9 million research publications.
- Over 5.5 million patented inventions.
- This data is then structured into 167 research topic categories, across both research publications and inventions.
- The 167 research topics themselves then define the 4 National Priority Areas.

The number of research topic categories varied slightly across the four National Priority Areas (Figure 101).

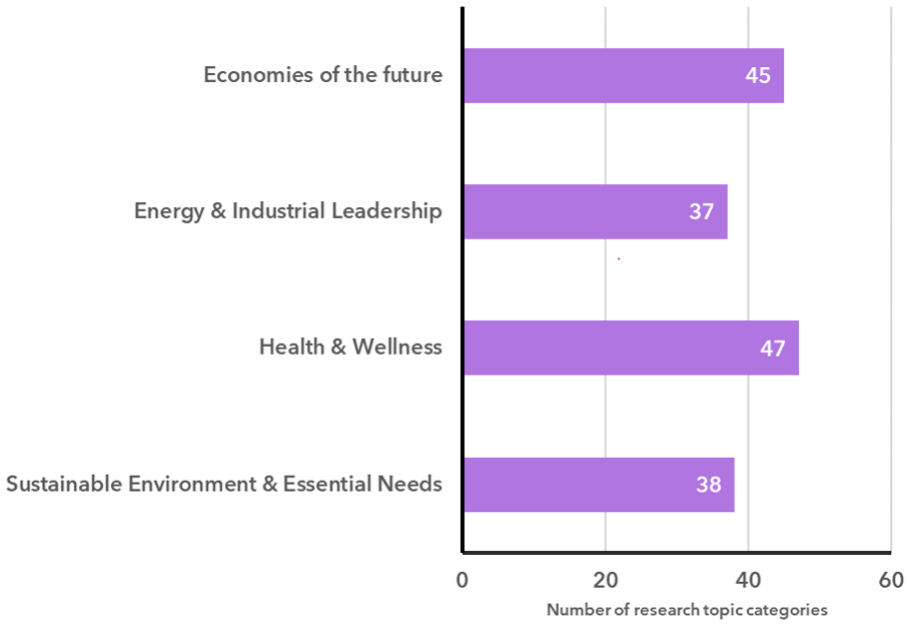

Figure 101 - number of research topic categories under each of the four National Priority Areas

Collection of publication records for each of the 167 topics and each of the national priority areas

- To identify research publications in the 167 topics, search queries were conducted in Web of Science Core Collection™ database indexed till 30th of June 2024, using the Web of Science™ platform.
- In order to have a consistent dataset with the innovation activities dataset, the final cleansed search queries used to identify patents were used as a basis to create the search queries for research publications.
- The searches were transformed in a process where they were refined in an iterative manner, in order to collect research publications related to the underlying topic. Keywords, phrases and research areas classifications (Citation Topics, Web of Science Research Areas and SDG research areas classification) were combined in appropriate ways to collect research publications related to each of the 167 topics.
- The overall methodology aimed at finding publications specific to the topic but at the same time without excluding publications related to the underlying topic.
- In order to restrict the search to original research output, the papers were filtered to contain only journal articles, reviews and proceedings papers published in the period 2014-2023.
- The research publications dataset for a national priority area was created from merging the individual dataset of each underlying topic. Publications present in more than one topic within the area are then counted once.
- The 167 datasets (one per topic) additional to the 4 datasets (one per national priority area) we then processed using InCites Benchmarking & Analytics to generate relevant metrics and indicators values. The citation data included in the generated metrics dates to the last update on InCites performed on 26th of July 2024 including citation data till 30th of June 2024.

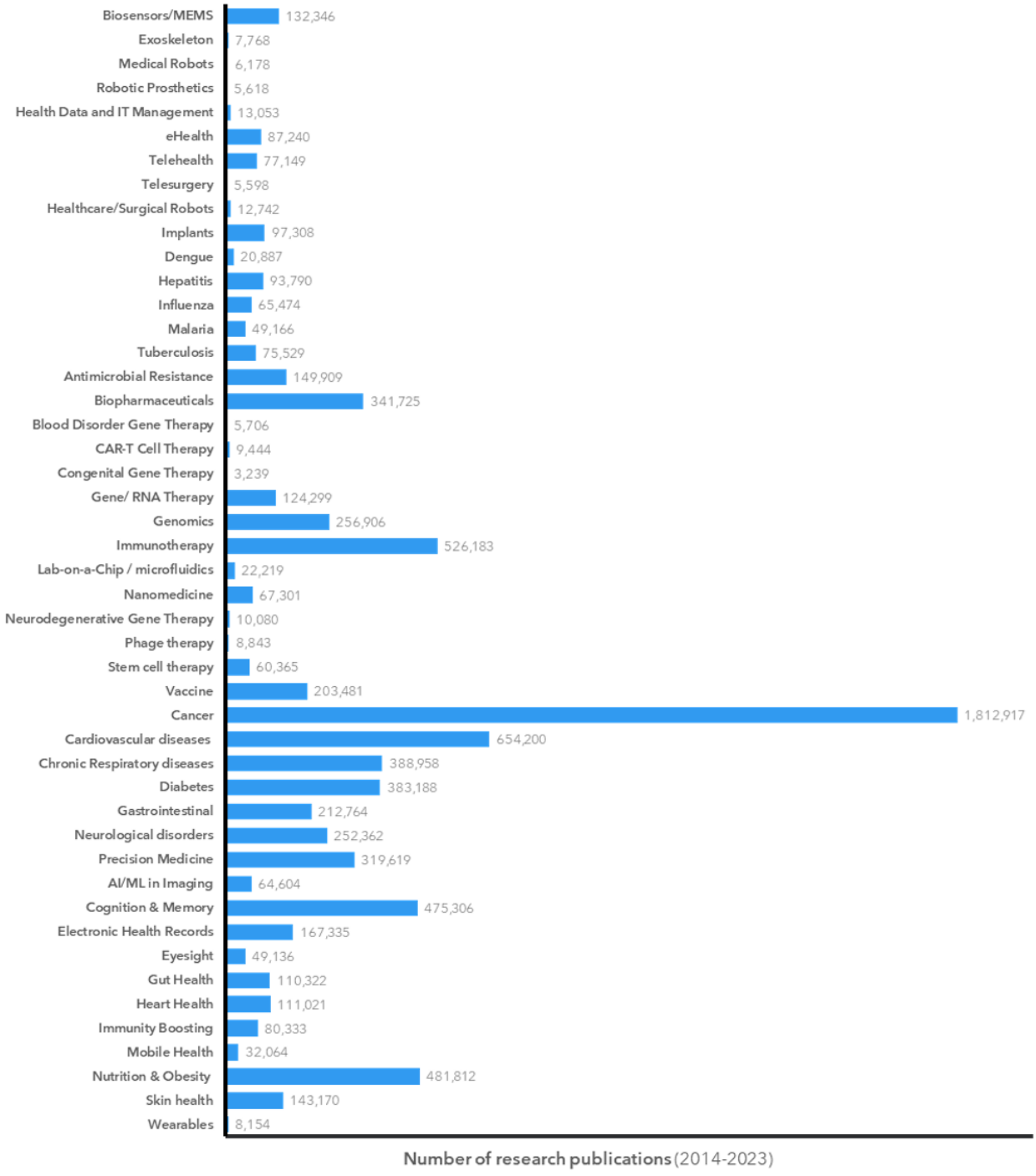

Figure 102: Number of world publications in each Health and Wellness research topic in the period 2014-2023

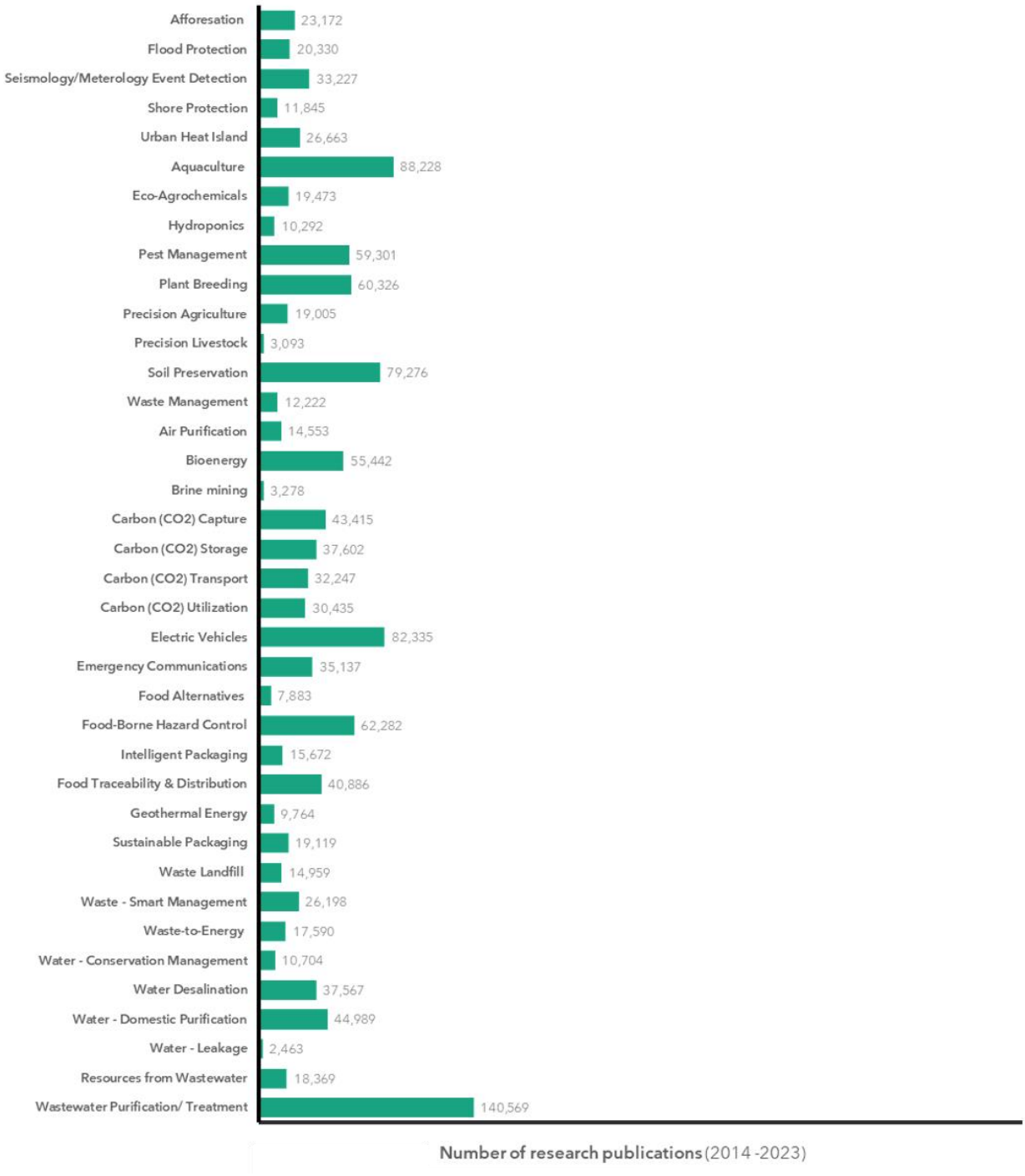

Figure 103: Number of world publications in each Sustainability and Essential Needs research topic in the period 2014-2023

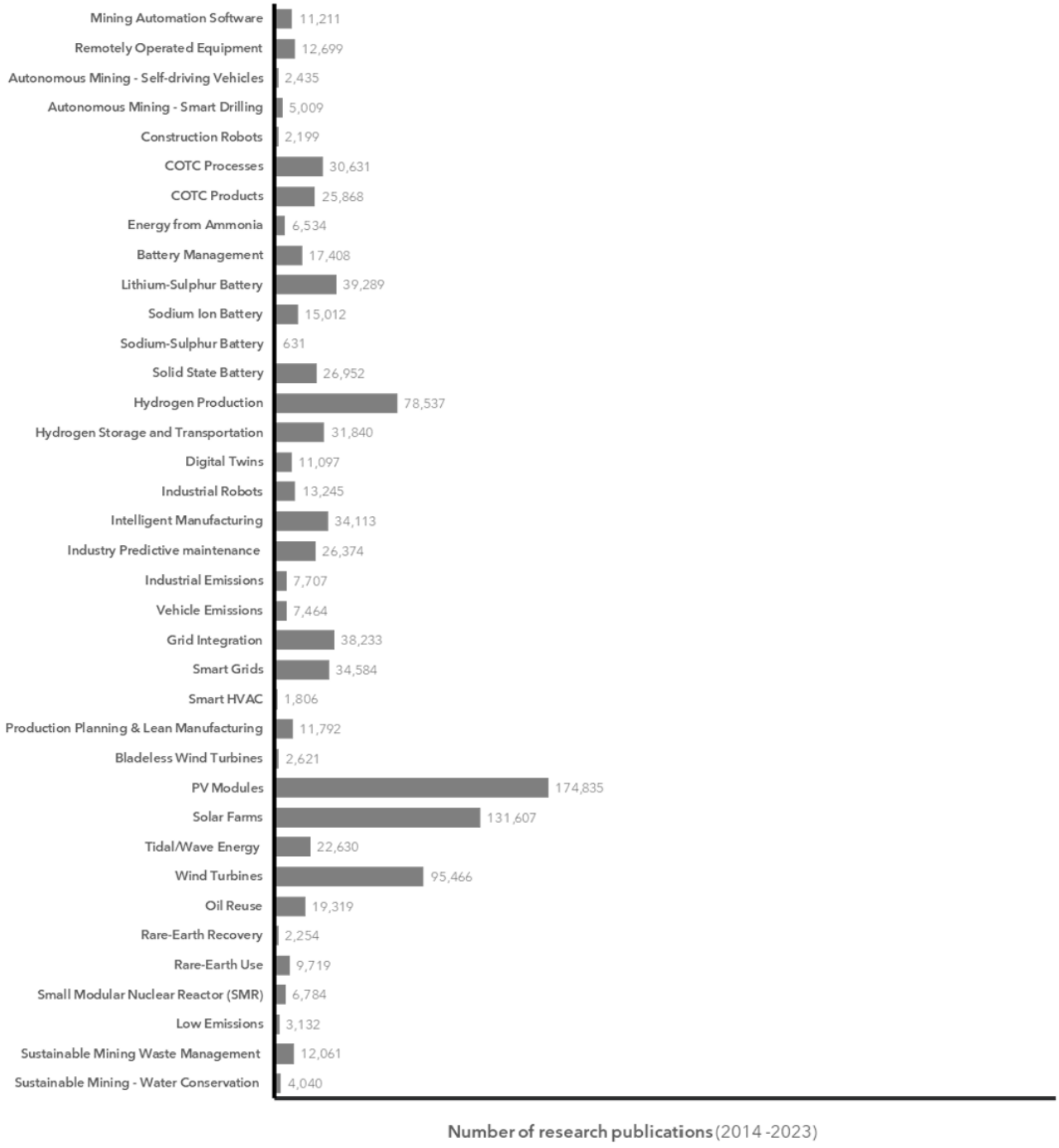

Figure 104: Number of world publications in each Energy and Industrials research topic in the period 2014-2023

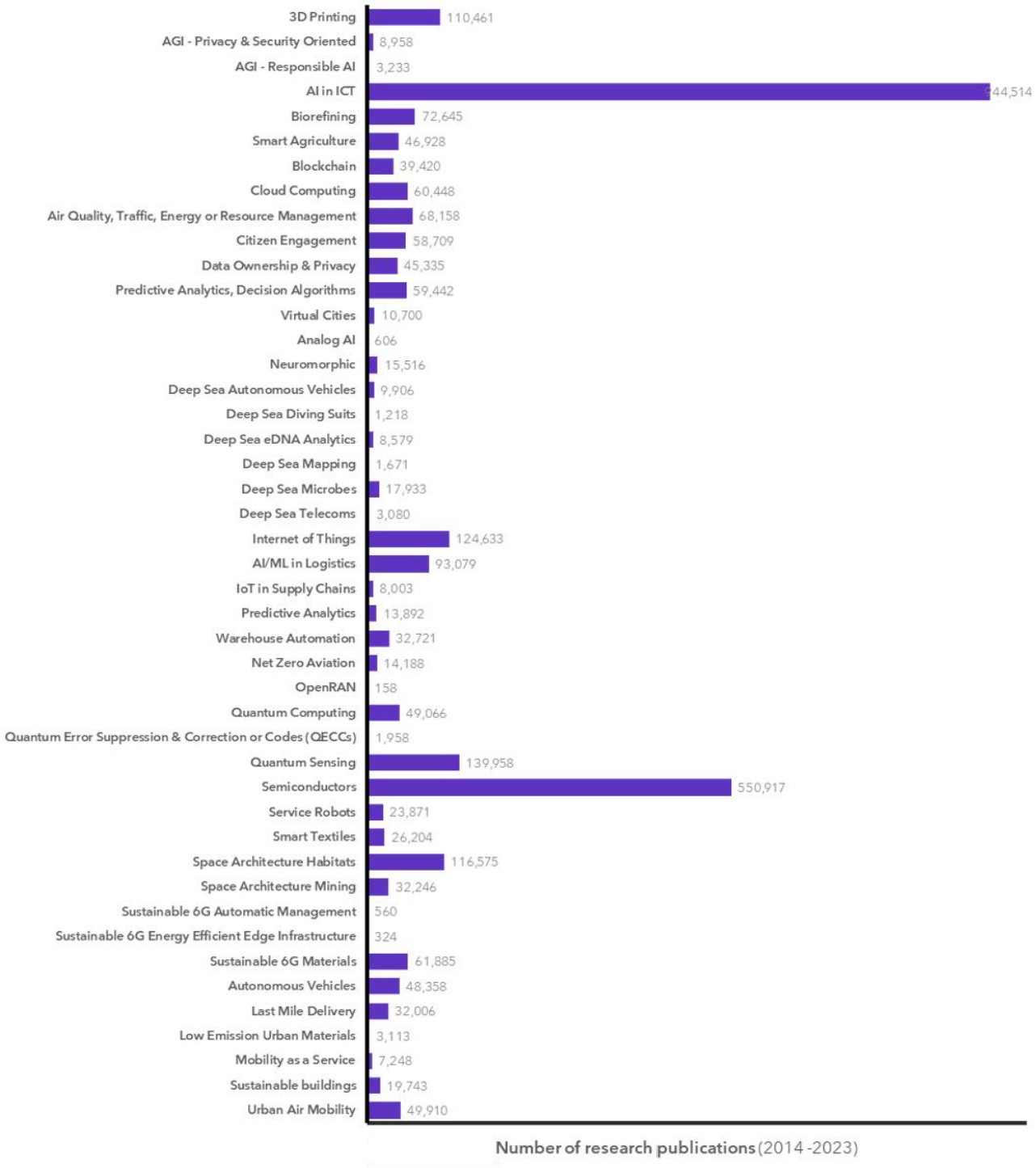

Figure 105: Number of world publications in each Economies of the Future research topic in the period 2014-2023

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