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Economies of the Future RDI National Priority in Saudi Arabia: Analytical Study

Full Study

Innovation Ecosystem in Focus

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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:

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

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 is dedicated to steering and executing the Kingdom's RDI strategies across the four national priorities. It has led the organization of capacity-building activities, equipping Saudi leaders and practitioners with the vital skills needed for digital innovation. RDIA has also crafted specialized strategies to identify numerous relevant research topics: Economies of the Future, Health and Wellness, Sustainability and Essential Needs, and Energy and Industrials. The authority's initiatives nurture local talent and foster global collaborations to develop an RDI infrastructure that benefits public and private sector innovation across the dynamic Economies of the Future sector.

Strategic partnerships between universities, established and emerging companies, and international collaborators ensure effective alignment with global trends, accelerating the deployment of solutions in connectivity, mobility, sustainability, and automation technologies. The Economies of the Future priority includes foundational and emerging technologies that are shaping new industries and revenue streams. The selected deep-dive research topics within Economies of the Future are defined as follows:

1. Air Quality, Traffic, Energy, or Resource Management: Using advanced technologies, such as AI, to optimize energy usage, improve public transport efficiency, and monitor air quality in real time.
2. Virtual Cities: Digital replicas of real cities designed for simulations and immersive interaction via virtual reality.
3. Citizen Engagement: Technologies that enable individuals in cognitive cities to shape their environment based on real-time needs and preferences.
4. Data Ownership & Privacy: Methods and systems ensuring transparent data capture and processing, particularly for personally identifiable information.
5. Predictive Analytics & Decision Algorithms: AI-driven tools that adapt dynamically to changing urban conditions and resident needs.
6. Sustainable 6G Materials: Materials with properties optimized for next generation 6G technologies, including temperature regulation.
7. Sustainable 6G Automatic Management: AI-driven systems for efficiently managing 6G networks.
8. Sustainable 6G Energy Efficient Edge Infrastructure: Energy-efficient data processing at the edge of networks, reducing power consumption.
9. Autonomous Vehicles: Self-navigating vehicles capable of operating without human intervention.
10. Semiconductors: Essential components in computing and AI technologies, enabling advancements in performance and efficiency.

11. OpenRAN: Open Radio Access Network technology that enhances interoperability between telecom vendors and interfaces.
12. Urban Air Mobility: Innovations in city-based transportation, including vertical take-off and landing vehicles.
13. Space Architecture Habitats: Technologies tailored for creating habitats in extreme environments, including outer space.
14. Space Architecture Mining: Technologies designed for extracting resources in space environments.
15. AI in ICT: Artificial intelligence applications in information and communication technology, spanning language processing, data analysis, and automation.
16. Quantum Computing: Advanced computational models leveraging quantum mechanics to solve complex problems.

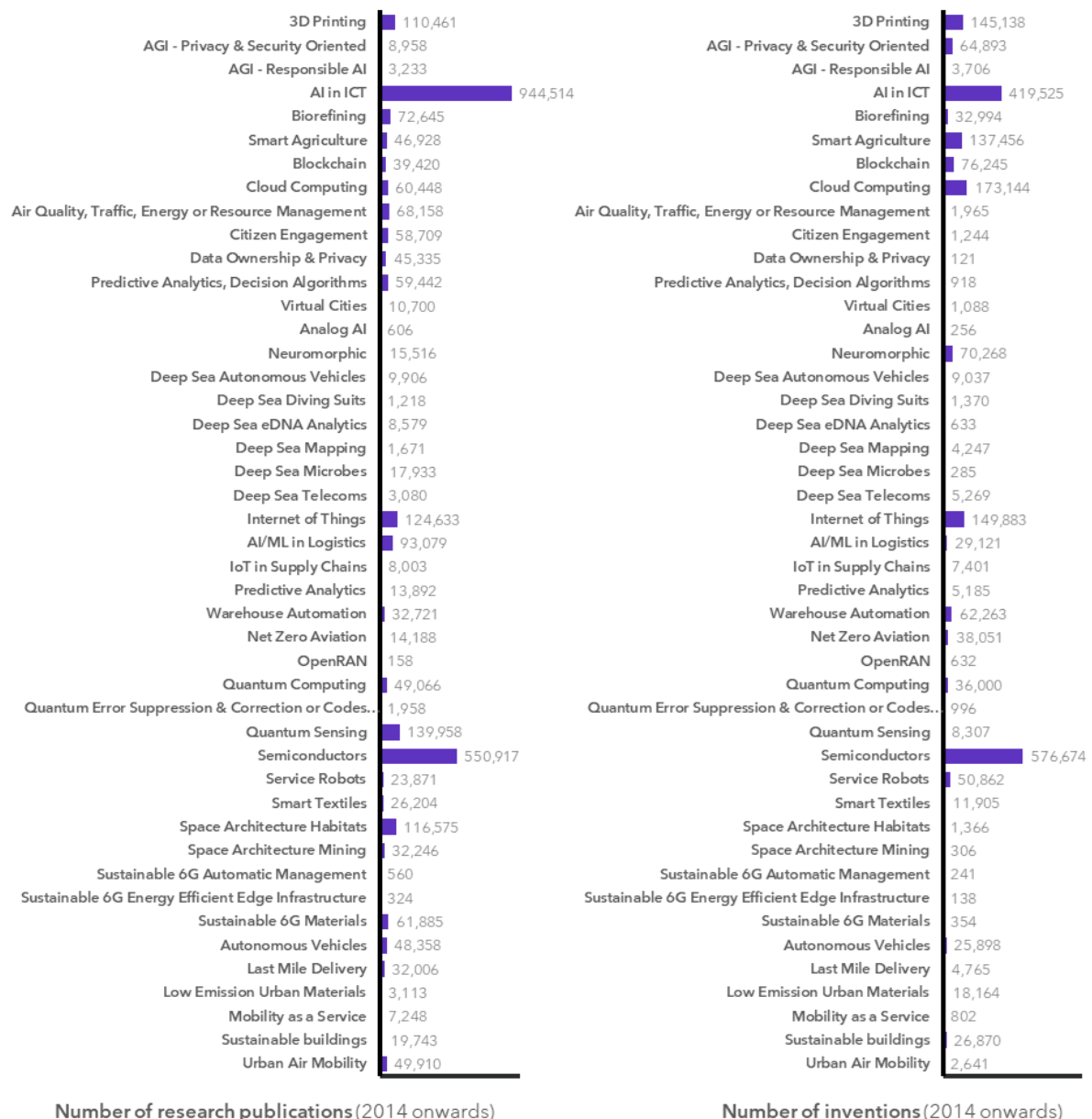


Figure 1: Number of research publications and inventions within Economies of the Future 2014-2023

The complete list of research topics that define the national priority area of Economies of the Future within this study, with global volumes across research publications and inventions, is shown in Figure 1.

This study builds on a broader initiative to establish a comprehensive baseline dataset for Saudi Arabia's research ecosystem. Seven discrete studies were commissioned to assess the Kingdom's current state and capabilities, with this study forming a key part of that effort. The content sets in this study are based on two primary sources:

1. Published documentation from RDIA and other Saudi agencies regarding the National Priorities.
2. Independent analysis by a specialized technology research team, comprising STEM professionals with extensive experience in innovation and technology intelligence.

This study draws upon the analysis undertaken in the *Enhancing Cooperation and Partnership between Academia and Companies in Research Capacity and Technology Readiness in Saudi Arabia's Program of Work*:

1. Assessment of Academic-Corporate Partnerships in Saudi Arabia
2. Insights into Saudi Arabia's Research and Innovation Ecosystem
3. Accelerating Technology Transfer from the Lab to the Market in Saudi Arabia

This multi-part study aimed to create a comprehensive overview of the significant aspects of the research ecosystem in Saudi Arabia. This study is intended to provide a baseline dataset of the capabilities of the Saudi research ecosystem. Seven (7) discrete studies were commissioned to establish this baseline, of which this study is one part. The reader is encouraged to read this study in full and explore the other studies to understand how the research ecosystem has developed over the past decade. The deep national priority studies available under this comprehensive review are:

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

To ensure a rigorous evidence base, 167 research topics were identified and analyzed. These topics were sourced from research publications (gathered from the Web of Science) and patented inventions (sourced from the Derwent World Patents Index), using established keyword and technology classification methodologies.

The project's technology analysts conducted a multi-stage review process to validate completeness, refine topic definitions, and ensure data accuracy. Leveraging scientific and engineering expertise, the team structured the data through an iterative cycle of validation and amendment. Once finalized, the records associated with each research topic were aggregated, standardized, and integrated into a project-specific data lake, forming the analytical foundation of this study. The process is illustrated in Figure 2.

The finalized data structure includes:

- Over 9 million research publications
- Over 5.5 million patented inventions
- 167 research topic categories spanning both research publications and patented technologies
- These 167 topics define the four National Priorities

By integrating the Economies of the Future priority into Saudi Arabia's broader RDI strategy, this study contributes to the Kingdom's long-term vision of achieving global leadership in intelligent innovation, fostering economic diversification, and positioning Saudi Arabia at the forefront of technological advancements.

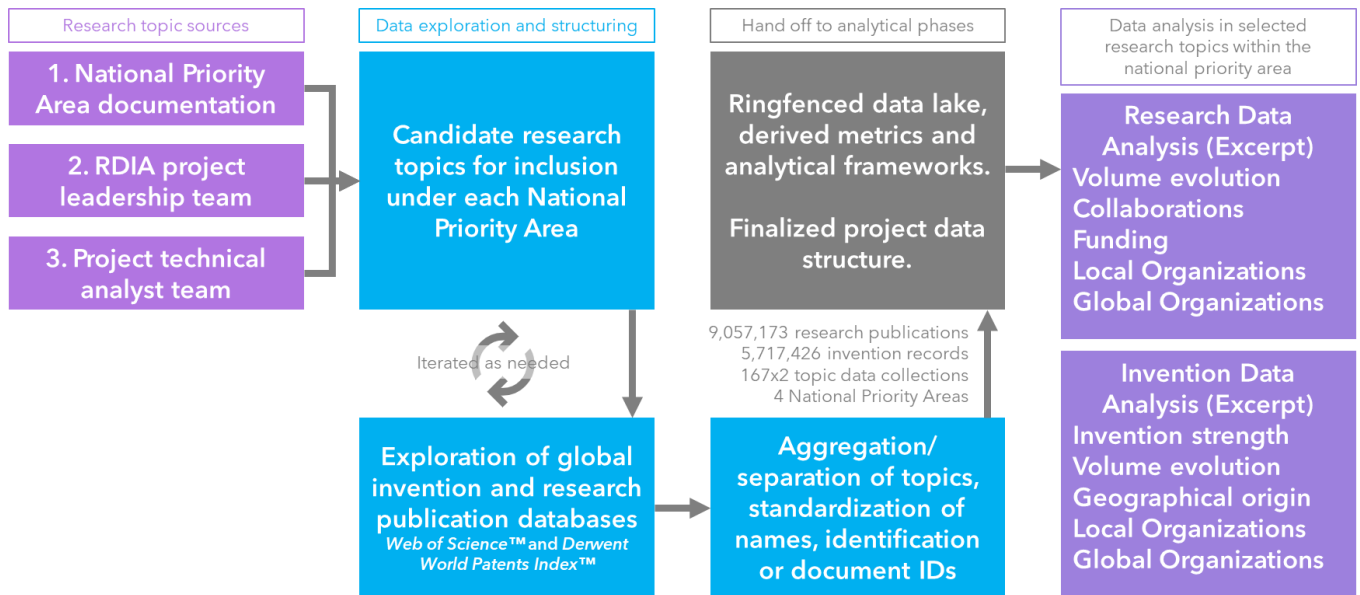


Figure 2: study data curation process

The key RDIA Missions related to the Economies of the Future are found below, and this study will focus on Missions 4.3, 4.4, 4.5 and 4.10:

- Mission 4.1 Establish habitats on Mars by 2050
- Mission 4.2 Establish a permanent outpost on the Moon by 2040
- Mission 4.3 Going beyond Smart Cities, establish 5 Cognitive Cities in Saudi Arabia by 2040
- Mission 4.4 Create a safe AI that learns and realizes autonomous work in favor of humans by 2050
- Mission 4.5 Develop programmable fault-tolerant quantum computer by 2040
- Mission 4.6 Demonstrate x10,000 computing performance improvement by 2040
- Mission 4.7 Achieve net-zero aviation by 2050
- Mission 4.8 Achieve 50% automation of in-kingdom logistics shipments by 2040
- Mission 4.9 Develop general purpose robots that assist humans in daily tasks by understanding and adapting to their dynamic environment by 2040
- Mission 4.10 Future of connectivity: building sustainable 6G technologies by 2035
- Mission 4.11 Build a self-sustainable deep-sea base to drive exploration and underwater activities by 2030

2 Executive summary



2.1 Overview

The Economies of the Future priority area of RDIA represents an opportunity to transform Saudi Arabia's innovation ecosystem and deploy applied research globally through research topics such as, but not limited to, Cognitive Cities, Deep Sea, Space Architecture, Sustainable 6G and Urban Architecture.

6G, Cognitive Cities, Space Architecture and OpenRAN research topics have the potential to transform connectivity and communications across a diverse set of industries. Saudi Arabia has academic-corporate partnerships (ACP) within 6G materials and research papers or inventions originating from the Kingdom; however, it has minimal research or inventions in the other research topics. Notably, King Saud University, King Abdulaziz University, KAUST, KFUPM, Prince Sattam Bin Abdulaziz University and Umm Al Qura University rank among the top five publishing entities in Saudi Arabia for these emerging research topics.

Economies of the Future has the largest range of Technology Readiness Level (TRL) out of the four national priority areas, with Deep Sea - eDNA Analytics TRL 1 all the way to Semiconductors TRL 9 (For more information on TRL, please see the section 6.2 Metrics). There is additionally a wide variety of global invention filing volumes across technologies strongly linked to the TRL. The complexity is combined when considering AI in ICT's potential impact on a wide variety of research topics within Economies of the Future. This extends into many other research topics such as, but not limited to, Electric Vehicles, Industry 4.0, and Digital Health Research topics.

Economies of the Future has a very diverse set of research topics. Academic Corporate Partnerships across numerous groups of global corporations are required to accelerate research and invention yield from local academic research. This includes existing corporations such as Saudi Aramco and future private corporation creation through vehicles such as joint ventures, spinouts, and incubators.

2.2 Key Opportunities within Economies of the Future

- **Prioritize higher performing and higher commercial potential research topics:** Key research topics within Economies of the Future have significant commercial potential. For example, AI in ICT and Semiconductor research topics are predicted to generate a combined \$0.86Bn to the Saudi Arabian economy, if 3,334 inventions are protected, generating the expected yield of very high-strength inventions, and are subsequently successfully commercialized. Semiconductor research levels heavily outweigh inventions in Saudi Arabian academia, focusing on technology transfer.
- **Accelerate private organization creation through industry-leading partnerships:** AI in ICT is a fast-moving field facing patentability difficulties of algorithms, software, and potential open-source models in AI. Partnering with international leading corporations may deliver a significant boost to Saudi Arabia AI innovation eco-system. The combination of AI in ICT, Quantum Computing and Semiconductor research topics is evident from the industry leadership of international corporations such as, but not limited to, Nvidia, TSMC, Intel and Samsung.
- **Double-down on areas of existing difference and leadership:** There is **significant opportunity and white space** in the technology landscape for Saudi Arabia to lead the way with the further development of Cognitive City innovation which can be deployed into giga-projects such as Neom.
- **Leverage leading global academia through academic partnerships:** The strength of leading Academic Institutions should be considered for further Academic - Academic partnerships with Mainland China in research topics

such as Cognitive Cities; Health and Wellness research topics exhibit similar key opportunities for research acceleration.

Ultimately the research topics within Economies of the Future could change the face of every industry and deliver on national missions such as Establish habitats on Mars by 2050, Achieve net-zero aviation by 2050, and Future of Connectivity: building sustainable 6G technologies by 2035. A diversified and precise academic-corporate partnership strategy will further enhance Saudi Arabia's strong research base and deliver the desired economic and societal returns.

The insight within this study provides a multi-dimensional evaluation of research topics within Economies of the Future priority area to provide key actions and options to consider, and benchmarks against global leadership. Subsequently the tailored insight, metrics and findings can enhance both the foundational research within academia, and commercially applied innovation to achieve the national missions and aspirations of Saudi Arabia.

3 Overview of research publication and patent performance in Economies of the Future



This section provides an overview of Saudi Arabia's research publication and patent performance within the Economies of the Future National Priority. This study is part of a wider program of analysis across research output, the research ecosystem and technology commercialization, and therefore the analysis presented here includes extracted data from several studies across these wider studies, now focused within this national priority area.

3.1 Overview of performance in research

In this section we evaluate the research performance of Saudi Arabia in the national priority area Economies of the Future in the period 2014-2023. The aim here is to examine the evolution as well as the status in terms of research volume and impact. For this, we start by examining the evolution of the number of papers in the priority area over this period and benchmark it with the global baseline and other countries/regions. Afterwards, we examine the citation impact. For this we will use 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 understand the research dynamics in the national priority area 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 us to identify key organizations funding Saudi Arabia research in the national priority area.

We also investigate the research performance of Saudi Arabia in this national priority areas with a specific focus on research performed within an industry collaboration. A paper with industry collaboration is a paper that contains two or more Organizations with at least one organization listing its organization type as corporate or global corporate (see Metrics). This gives us insights into the academic-corporate partnership status currently in Saudi Arabia within this national priority area. Though it is important here to differentiate that a paper published as an output of research performed through a collaboration between academic affiliated researchers and corporate does not necessarily underpin a long-term or a strategic partnership. Nevertheless, investigating papers with an industry collaboration gives insights about the academic-corporate activity. To provide an overview of the academic-corporate activity in Saudi Arabia we investigate several domains: the evolution of the percentage and number of papers with industry collaboration, funding of papers with industry collaboration, corporates collaborating with Saudi affiliated researchers and top Saudi academic institutions in terms of number of papers with industry collaboration.

Finally, we analyze the research out and impact of the priority area on a more granular level by performing a SWOT analysis of the categories constituting the national priority area. This allows to have an overview of research performance in the research topics constituting this area, before investigating in more detail chosen priority research topics in following sections. This allows classifying the underlying categories into strength, weakness, opportunity, and threat areas. Accordingly, all the above analysis will create a relatively detailed overview of Saudi Arabia research performance in the priority area.

Main Findings

- Saudi Arabia's research output increased very rapidly in the national priority area Economies of the Future, with an average annual growth rate (28%) higher than that of the comparable countries/regions considered.

- The citation impact of Saudi Arabia publications in this area is 57% higher than the global average and higher than that of most considered countries/regions
- Although the number of Saudi Arabia papers with an industry collaboration in the area Economies of the Future increased between 2014 and 2023, the percentage from all publications in the area decreased massively. One possible explanation for such dynamics is that the implemented efforts of increasing the research output did not focus on increasing in parallel the academic-corporate collaborations.
- Only 16% of Saudi Arabia papers with industry collaborations are performed with a local corporate. This has the advantage of gaining international visibility and expertise from international corporates. On the other hand, having more local corporations that collaborate with Saudi affiliated researchers would further enhance local knowledge transfer and building local expertise.
- The top 3 Saudi academic institutions in terms of number of papers with an industry collaboration in the area Economies of the Future and in the period 2014-2023 are King Abdullah University of Science & Technology followed by King Abdulaziz University and King Saud University
- When investigation Saudi Arabia's 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, 16 opportunity research topics listed and three weaknesses. One should focus on increasing the research output in the opportunity areas and improve the research quality as well as research output in the identified weakness areas.

3.1.1 Research volume analysis

The number of Saudi Arabian 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 3. 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%.

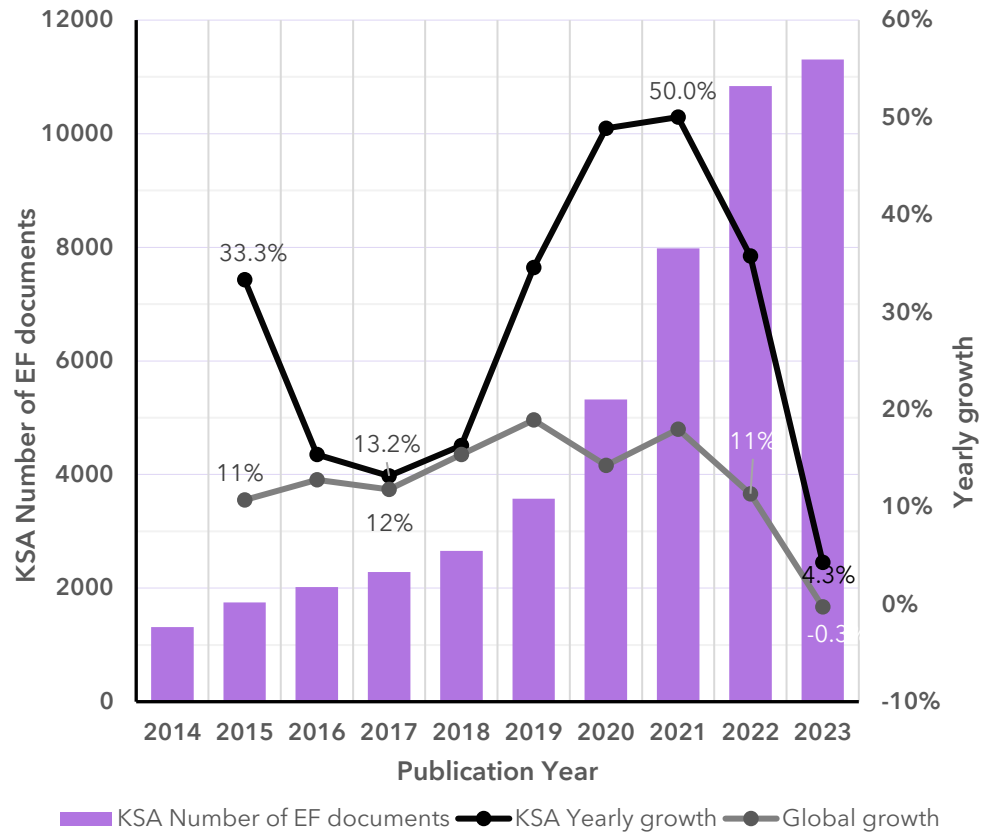


Figure 3: Saudi Arabia number of papers and growth in the national priority area Economies of the Future

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 4. It is worth mentioning that this is growth rate not only higher than countries with more almost saturated research output such as Japan, Germany, and the USA but also higher than that of countries/regions with growing research output such as Mainland China and the GCC excluding Saudi Arabia. All the above indicates, the focus nationally on increasing the research activity in this national priority area

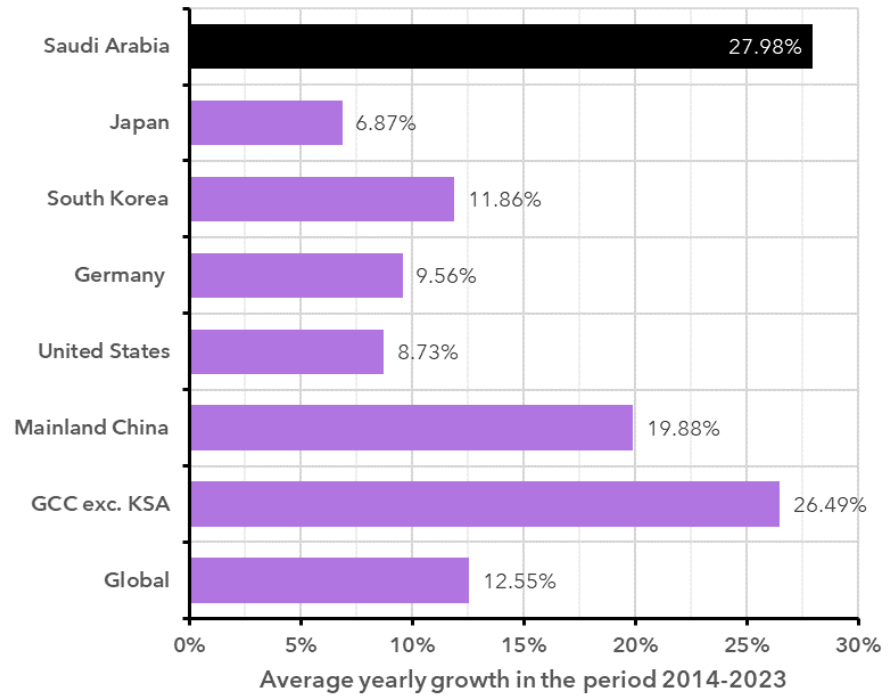


Figure 4: Average yearly growth of number of papers in the area Economies of the Future in the period 2014-2023

3.1.2 Citation impact analysis

The category normalized citation impact (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 5.

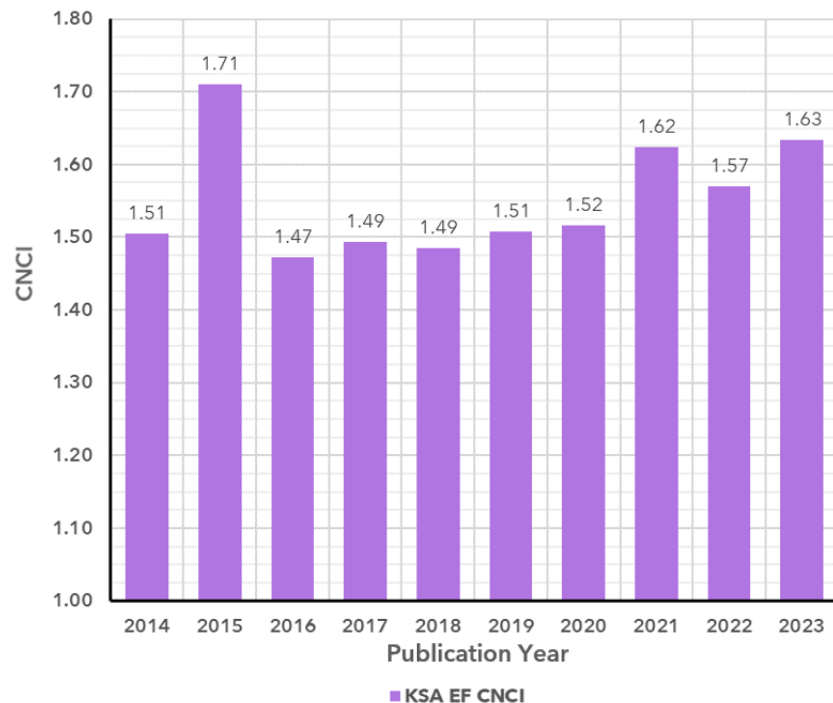


Figure 5: Saudi Arabia yearly category normalized citation impact in the area Economies of the Future

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 that the one achieved by USA and GCC excluding KSA as shown in Figure 6.

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.

Usually, we notice citation impact decrease in periods with high volume growth, because in such periods the knowledge and expertise are being accumulated by the expanded researcher's base.

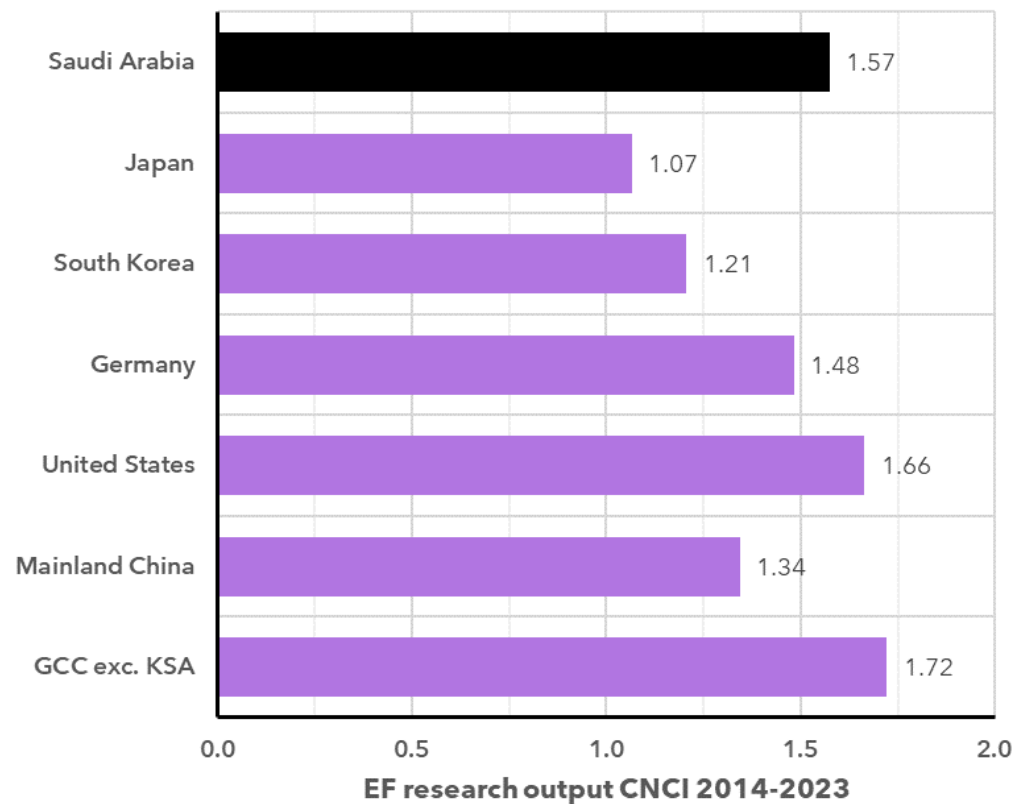


Figure 6: Economies of the Future research output CNCI in the period 2014-2023

3.1.3 Funding dynamics analysis

The top 3 funding organizations mentioned in the funding text of Saudi Arabia publications 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 publications respectively as shown in Figure 7.

Saudi Arabia Research in the area Economies of the Future that was funded by 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. We observe that there are three funding organizations based in Saudi Arabia that are among the top 20.

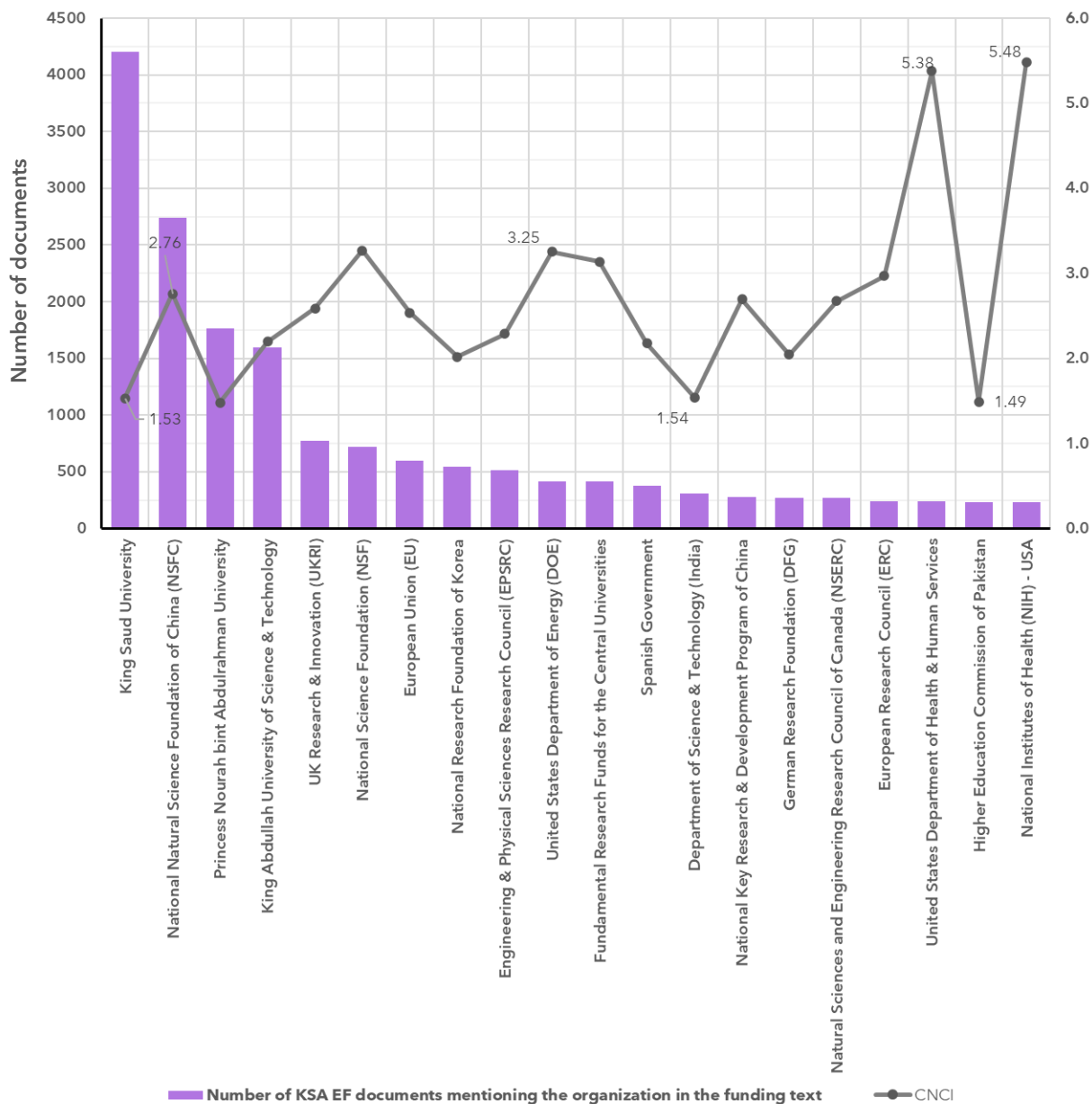


Figure 7: Top 20 funding organizations mentioned in the funding text of Saudi Arabia Economies of the Future papers in the period 2014-2023

3.1.4 Collaboration dynamics analysis

Egypt, followed by Pakistan and India, had the highest number of publications 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 publications respectively as shown in Figure 8. In terms of citation impact measured by the category normalized citation impact, papers in collaboration with Taiwan followed by Spain and Italy 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 the global average performance of ~1.

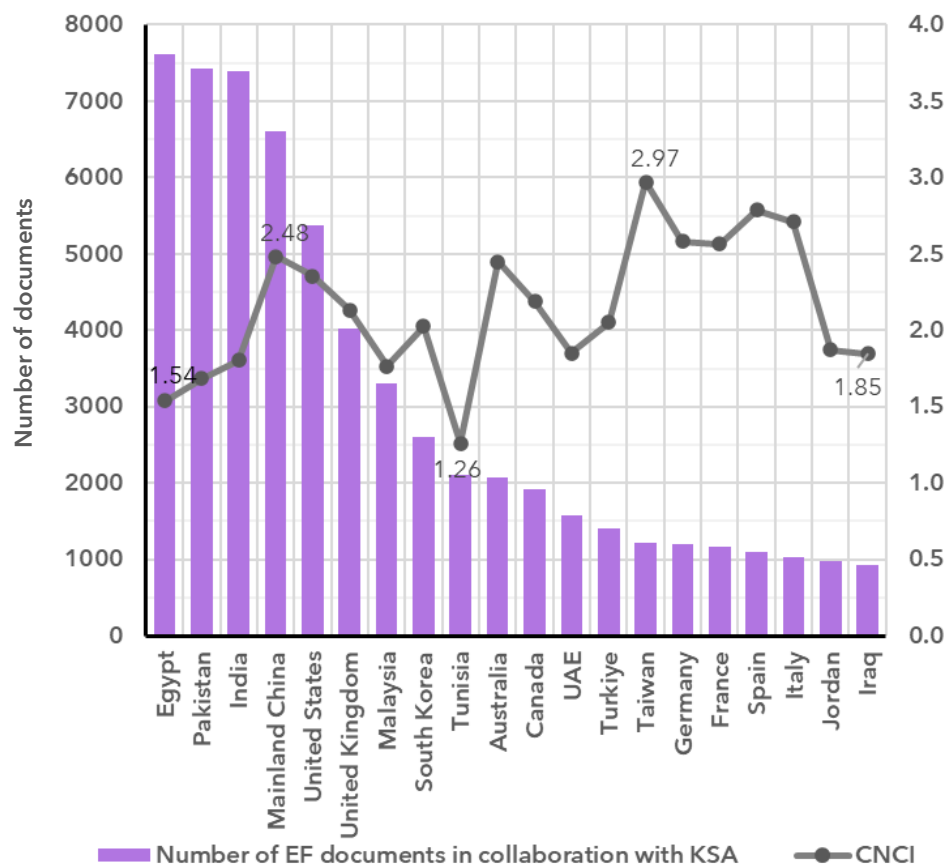


Figure 8: Top 20 collaborating countries with Saudi Arabia in the area Economies of the Future in the period 2014-2023

3.1.5 Academic-corporate collaboration in Saudi Arabia identified from research publications in the area Economies of the Future.

The percentage of Saudi Arabia papers with industry collaboration in the area Economies of the Future decreased almost continuously from 2.3% in 2014 to 0.7% in 2023 as shown in Figure 9.

On the other hand, the number of Saudi Arabia papers in the area Economies of the Future with industry collaborations also increased almost continuously from 30 in 2014 to 83 in 2023.

The reason behind the decrease in the percentage of Saudi Arabia papers in the area Economies of the Future is that higher growth rate of papers in the area in comparison to the growth of papers with industry collaborations.

One possible explanation for such dynamics is that the implemented efforts of increasing the research output in Economies of the Future did not focus on increasing in parallel the academic-corporate collaborations via building on existing collaborations.

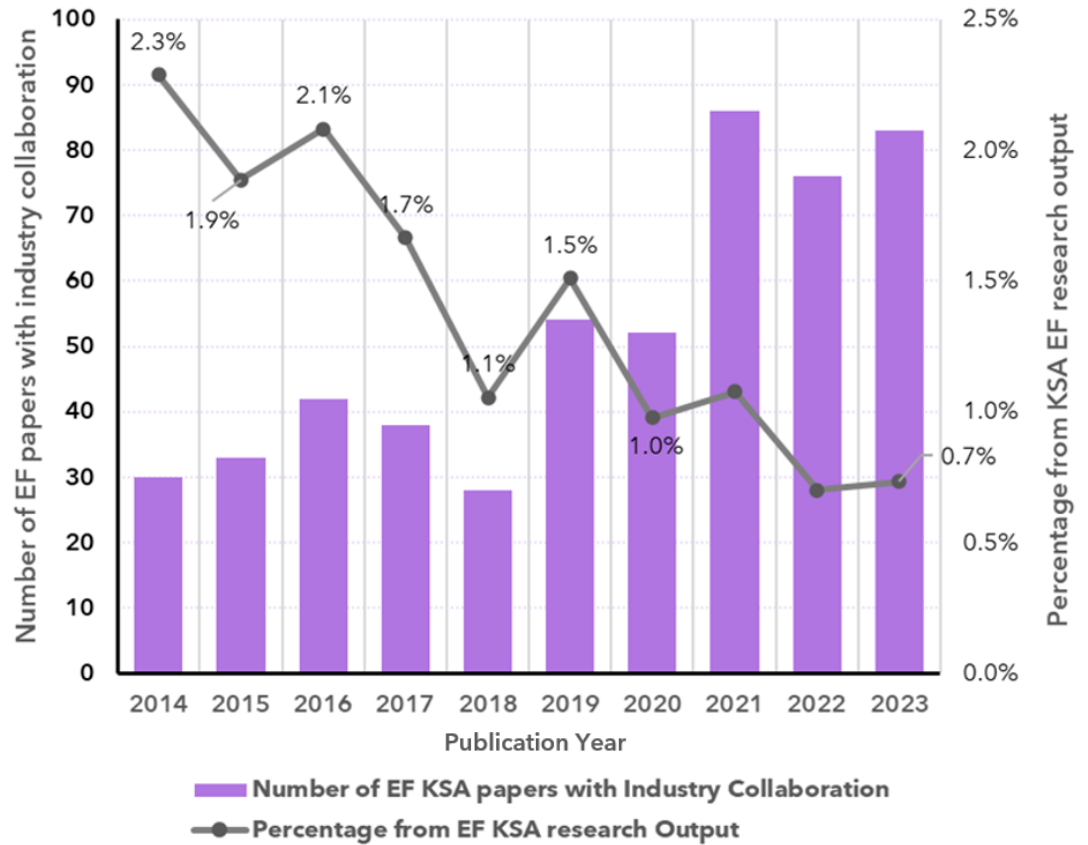


Figure 9: Number and percentage of Saudi Arabia publications that have been performed with an industry collaboration in the national priority area Economies of the Future

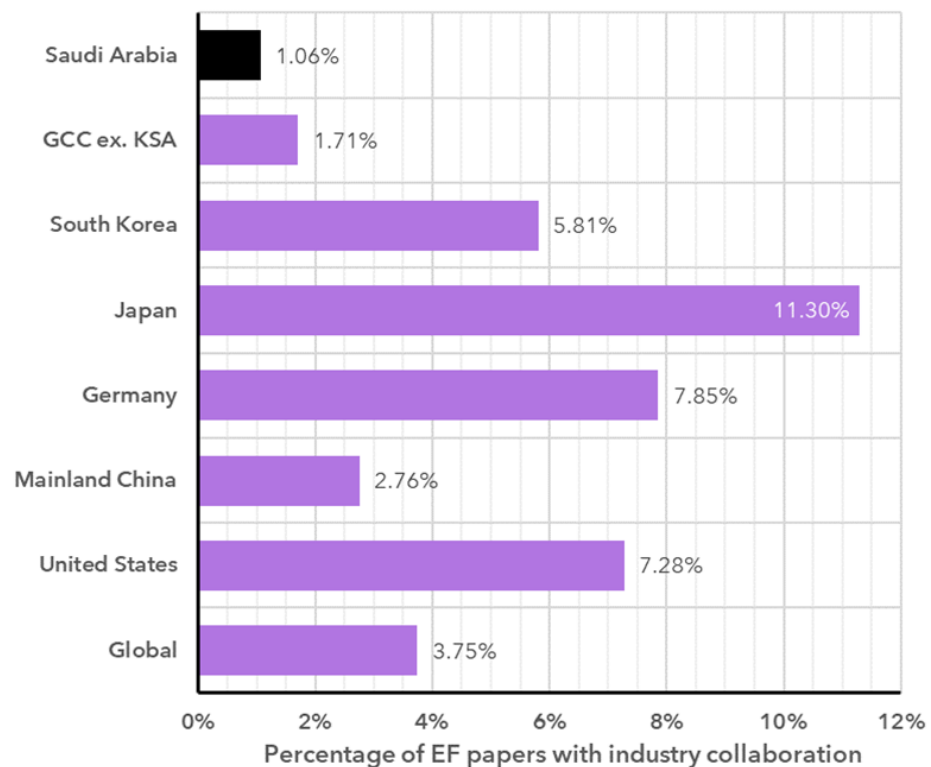


Figure 10: Percentage of papers that have been performed with an industry collaboration in the period 2014-2023 in the national priority area Economies of the Future

When benchmarking the percentage of papers with industry collaborations in the area Economies of the Future in the period 2014-2023 of Saudi Arabia with the considered benchmark countries we notice that it is lower than the global baseline

and then that of all considered countries/regions as shown in Figure 10. The highest percentage of papers with industry collaborations among the considered countries/regions is observed in Japan with ~11.3% followed by Germany with 7.85% and USA with 7.28%.

In Figure 11, the top 20 funding organizations of Saudi Arabia publications with industry collaborations in the area Economies of the Future ranked by number of funded collaborations is shown. The top 3 funding organizations are National Natural Science Foundation of China (NSFC), followed by National Science Foundation (NSF) and King Abdullah University of Science & Technology with 44, 39 and 38 publications, respectively. Among the top 20 funding organizations there is only two Saudi organizations.

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 corporates in an international context.

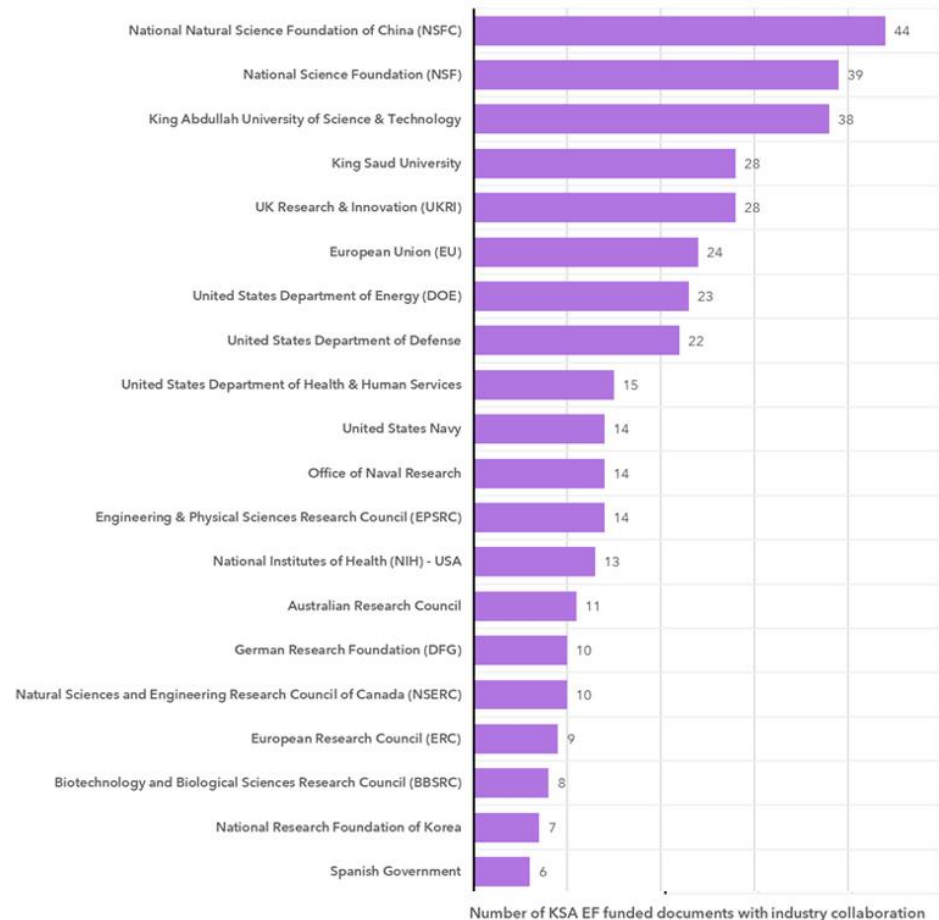


Figure 11: Saudi Arabia top 20 funding organizations of research with industry collaboration in the national priority area Economies of the Future in terms of number of publications and the period 2014-2023

In Figure 12 we investigate the top 40 corporates collaborating with Saudi Arabia affiliated researchers in terms of number of publications in the area Economies of the Future. Specifically, the share of a specific corporate from the overall Saudi Arabia publications in Economies of the Future with industry collaborations is plotted on the y-axis. A logarithmic scale is used because of the significant difference between the top 3 and the rest of the corporates. On the x-axis the CNCI of those publications is plotted. Corporates that have a share above 1% of the overall Saudi Arabia papers with industry collaborations lie above null on the y-axis. Corporates that have a CNCI above 1, lie right to the dotted line, marking a citation impact higher than the global average when considering the same document type, year of publication and subject area. Accordingly, all corporates lying in the upper quadrante are corporates that have more than 1% share of Saudi Arabia papers with industry collaborations and an impact performance higher than the global average measured by the CNCI. These corporates that lie in the upper quadrante and their output are listed in Table 1. As

these corporates are having relatively high share from Saudi Arabia overall publications with industry collaborations and their impact is higher than the global average, further developing these collaborations to partnerships could be considered. Here it is also important to consider other criteria such as alignment with national priorities, goals of the partnerships, etc. Such criteria can be derived from the analysis illustrated in the section Academic Corporate Partnership Models.

The top three corporates collaborating with Saudi affiliated researchers in the period 2014-2023 in the area Economies of the Future are Saudi Basic Industries Corporation (SABIC) followed by State Grid Corporation of China and Aramco Services Company (ASC) sharing the same number of publications followed by Polyera with ~12%, ~3.4% and ~3.2% from the overall Saudi Arabia publications with industry collaborations in Economies of the Future. Among the top three there are two national corporates. Having two local corporations among the top three is important to ensure local knowledge transfer. Though among the top 40 there are only three local corporations, and the others are international ones. 84% of Saudi Arabia Economies of the Future papers with an industry collaboration are performed with an international corporate as seen in Figure 13. Having more local corporations that collaborate with Saudi affiliated researchers would further enhance local knowledge transfer and building local expertise.

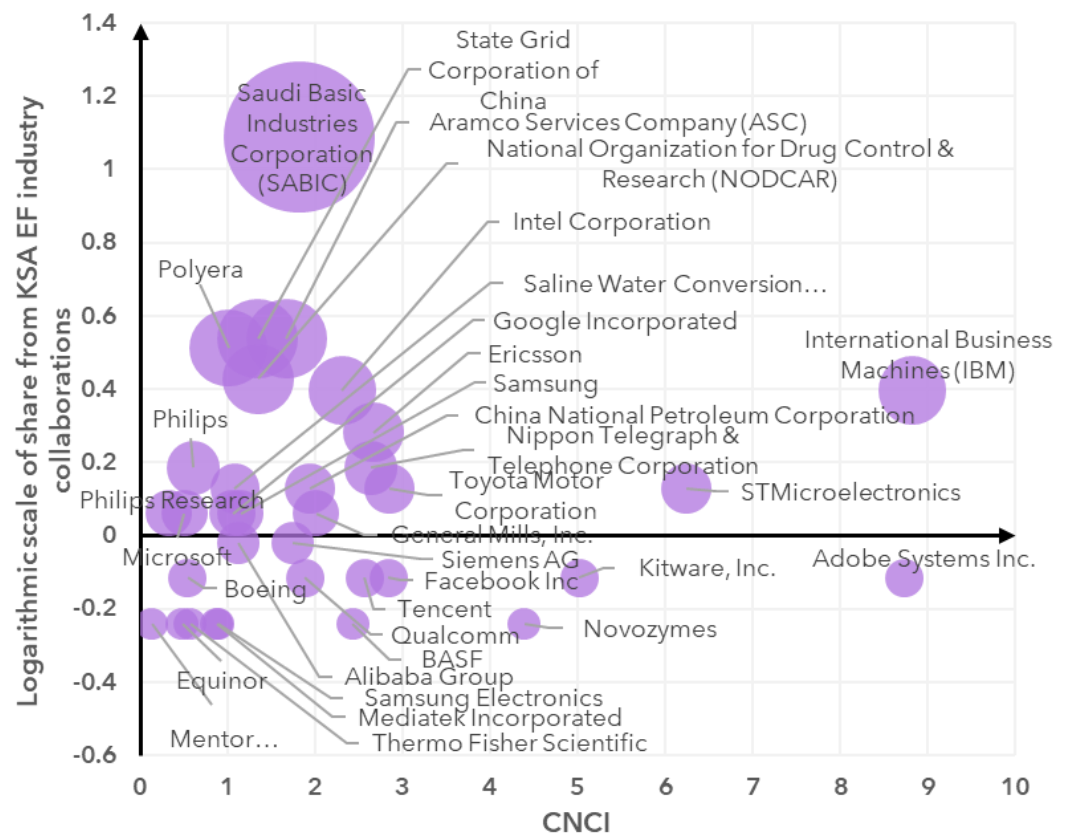


Figure 12: Top 40 corporates that have paper collaborations with Saudi affiliated researchers in terms of number of papers in the period 2014-2023 in the area Economies of the Future. The figure plots the share of papers with industry collaboration in the area Economies of the Future in logarithmic scale that an organization has versus the CNCI.

Table 1: Corporates having at least 1% share from Saudi papers with industry collaboration in the area Economies of the Future and have at least an impact on par with the global average (CNCI 1 or above)

Corporate	Number of papers	Share	CNCI
Saudi Basic Industries Corporation (SABIC)	64	12.26%	1.82
State Grid Corporation of China	18	3.45%	1.34
Aramco Services Company (ASC)	18	3.45%	1.67
Polyera	17	3.26%	1.01
Huawei Technologies	16	3.07%	13.38
National Organization for Drug Control & Research (NODCAR)	14	2.68%	1.35
International Business Machines (IBM)	13	2.49%	8.82
Intel Corporation	13	2.49%	2.31
Ericsson	10	1.92%	2.67
Taiwan Semiconductor Manufacturing Company	9	1.72%	10.71
Nippon Telegraph & Telephone Corporation	8	1.53%	2.64
STMicroelectronics	7	1.34%	6.24
China National Petroleum Corporation	7	1.34%	1.93
Saline Water Conversion Corporation (SWCC)	7	1.34%	1.08
Toyota Motor Corporation	7	1.34%	2.84
Google Incorporated	6	1.15%	1.05
General Mills, Inc.	6	1.15%	2.01
Samsung	6	1.15%	1.15

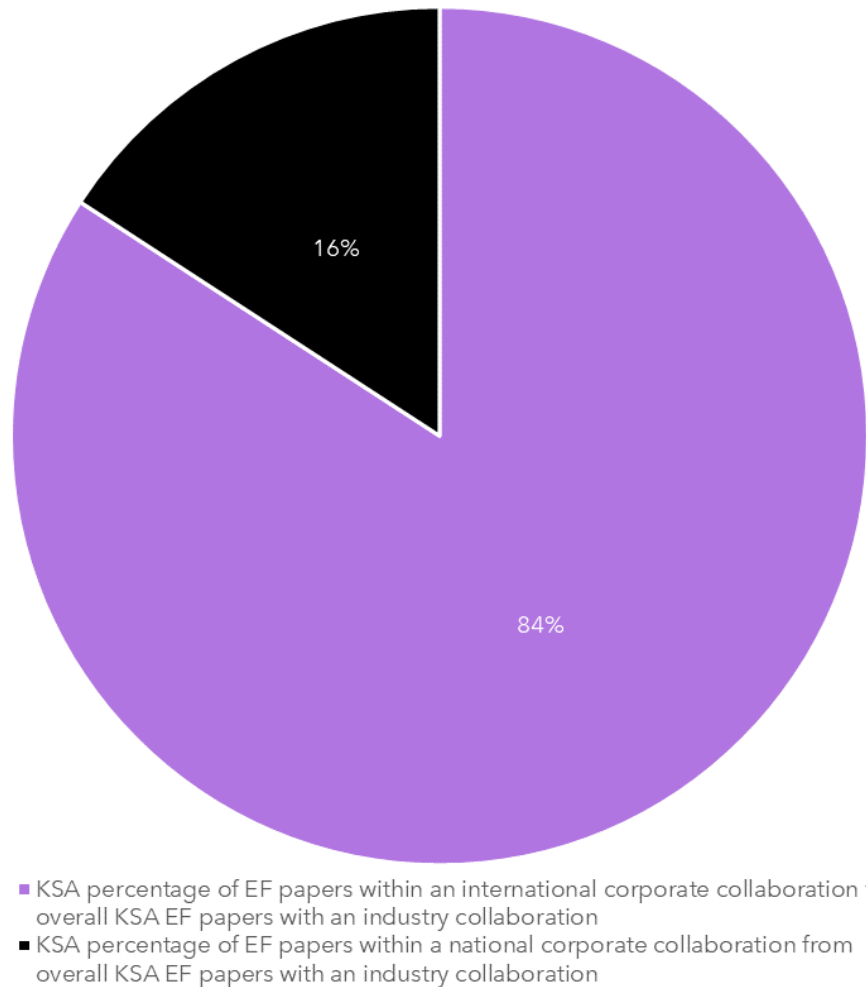


Figure 13: Percentage of Saudi Arabia Economies of the Future papers with an industry collaboration with national versus international corporates from overall papers with an industry collaboration

The top 3 Saudi academic institutions in terms of number of papers with an industry collaboration in the area Economies of the Future and in the period 2014-2023 are King Abdullah University of Science & Technology followed by King Abdulaziz University and King Saud University with 174, 82 and 75 publications as shown in Figure 14.

When looking at the of Economies of the Future papers with an industry collaboration from the overall Economies of the Future papers, King Abdullah University of Science & Technology has the highest percentage followed by King Faisal Specialist Hospital & Research Centre and King Abdulaziz City for Science & Technology with 3.79%, 3.05% and 2.82%, respectively.

It is worth noting that King Abdullah University of Science & Technology (KAUST) has the highest volume and percentage of Economies of the Future papers with industry collaboration. This indicates that KAUST is a central academic institution in Saudi Arabia for performing academic-corporate collaborations in this area.

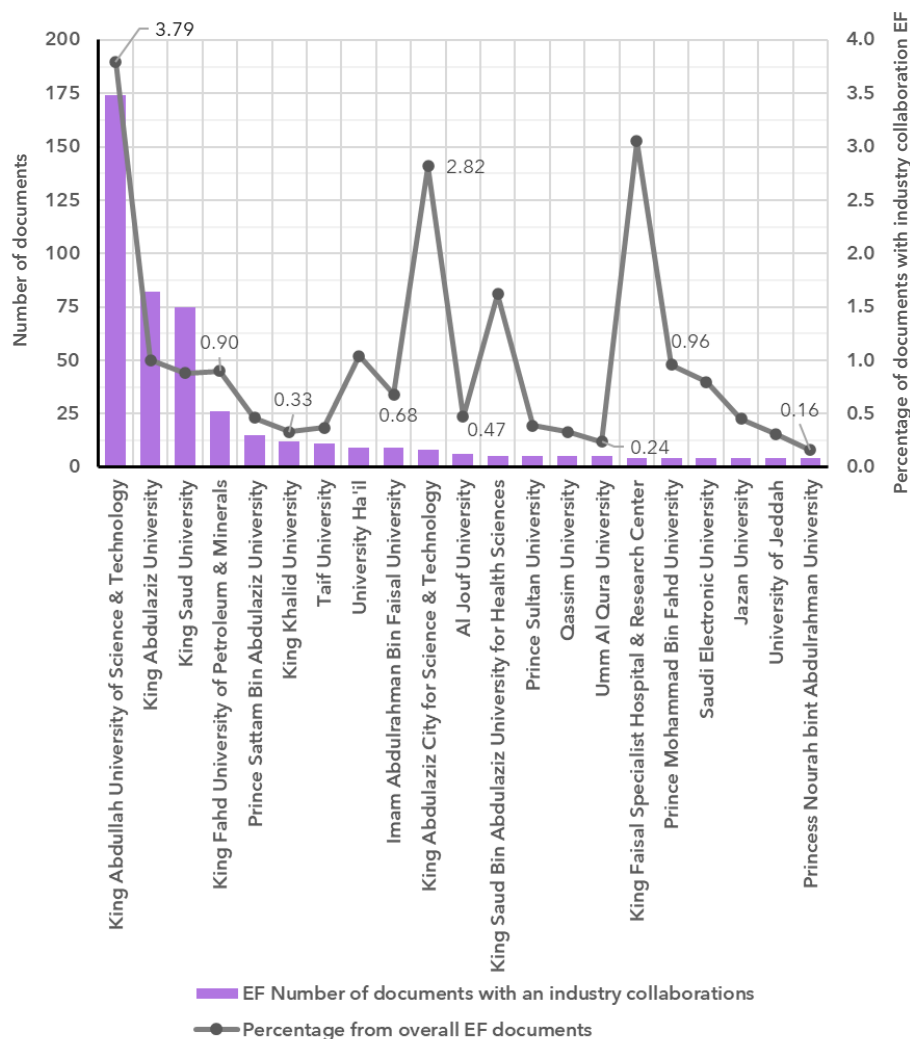


Figure 14: Number and percentage of publications with an industry collaboration in the area Economies of the Future and the period 2014-2023 of the top 20 Saudi academic institutions in terms of the number of papers with an industry collaboration

3.1.6 SWOT Analysis of Underlying Research Topics in the area Economies of the Future

In this part we have a more granular look by analysing the research performance of Saudi Arabia in the underlying categories that constitute the national priority area Economies of the Future.

To perform this a Strength, Weakness, Opportunity, and Threat (SWOT) analysis was undertaken. The analysis is based on two main metrics: productivity relative to the global productivity and impact measured by the category normalized citation impact. The productivity relative to the global productivity is measured by the number of Saudi Arabia papers in specific research topic divided by the number of global publications in the same research topic and period.

This is then normalized by the share of Saudi Arabia overall research from the global research in the same period. Thus, a value in this indicator above 1 indicates that Saudi Arabia has a share of the global research in this research topic higher than the share of Saudi Arabia from the global research in the same period.

Similarly, a CNCI above 1 indicates a citation impact footprint in the research topic higher than the global 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

- Threat: 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
- Weakness: both the productivity relative to the global productivity and CNCI are less than 1

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 2, 16 opportunity research topics listed in Table 3 and three weakness research topics listed in Table 4 as also shown in Figure 15.

As all of these research topics are of national priority, one should try to conserve the high performance in the strength research topics and 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 OpenRAN has very few publications, 158, globally in the period 2014-2023, from which none were published by Saudi affiliated researchers.

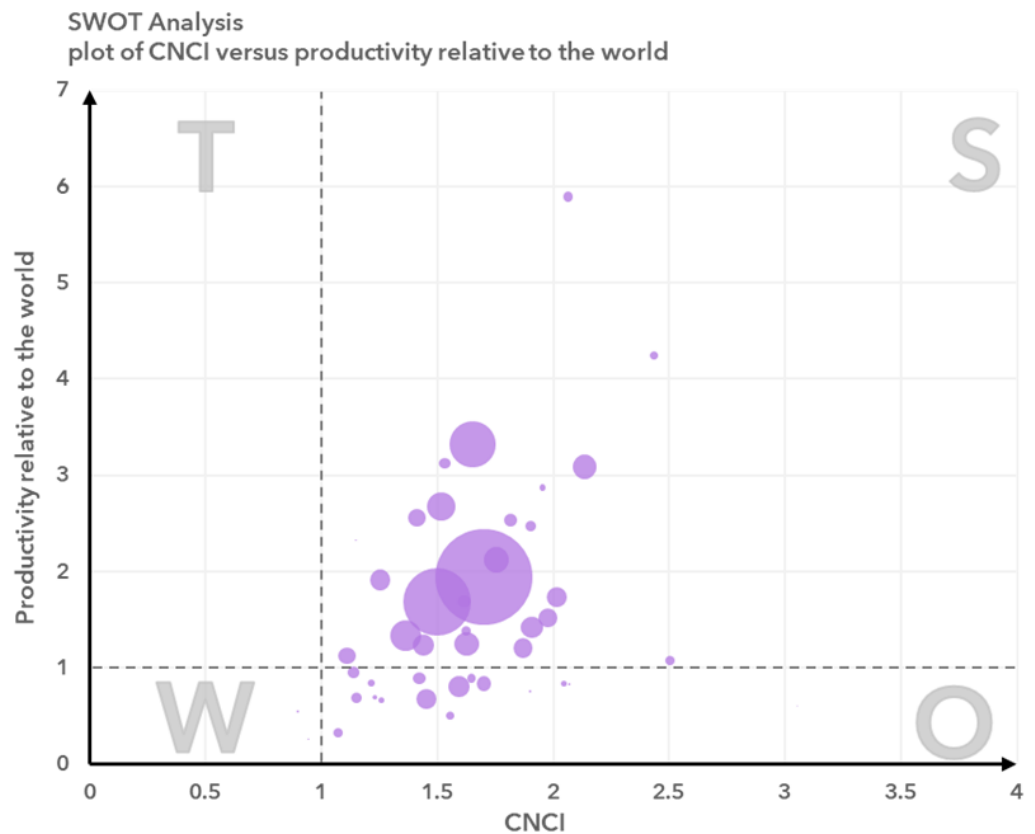


Figure 15: SWOT analysis of the national priority area Economies of the Future. The y-axis shows the productivity relative to the world (share of Saudi Arabia from the world productivity in the research topic normalized by Saudi Arabia share from world productivity when considering overall research). The x-axis shows the impact relative to the world.

Table 2: Saudi Arabia's 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 3: 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 4: 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
OpenRAN	0	0

3.2 Overview of performance in patents

In this section, we summarize, and review information collated during the study Assessment of Academic-Corporate Partnerships in Saudi Arabia of the program that are specific to the Economies of the Future National Priority.

This section related to the benchmarking of invention volumes, strength, and Academic-Corporate Partnerships in Saudi Arabia against globally relevant benchmarks.

3.2.1 Percentage of academic-corporate invention activity

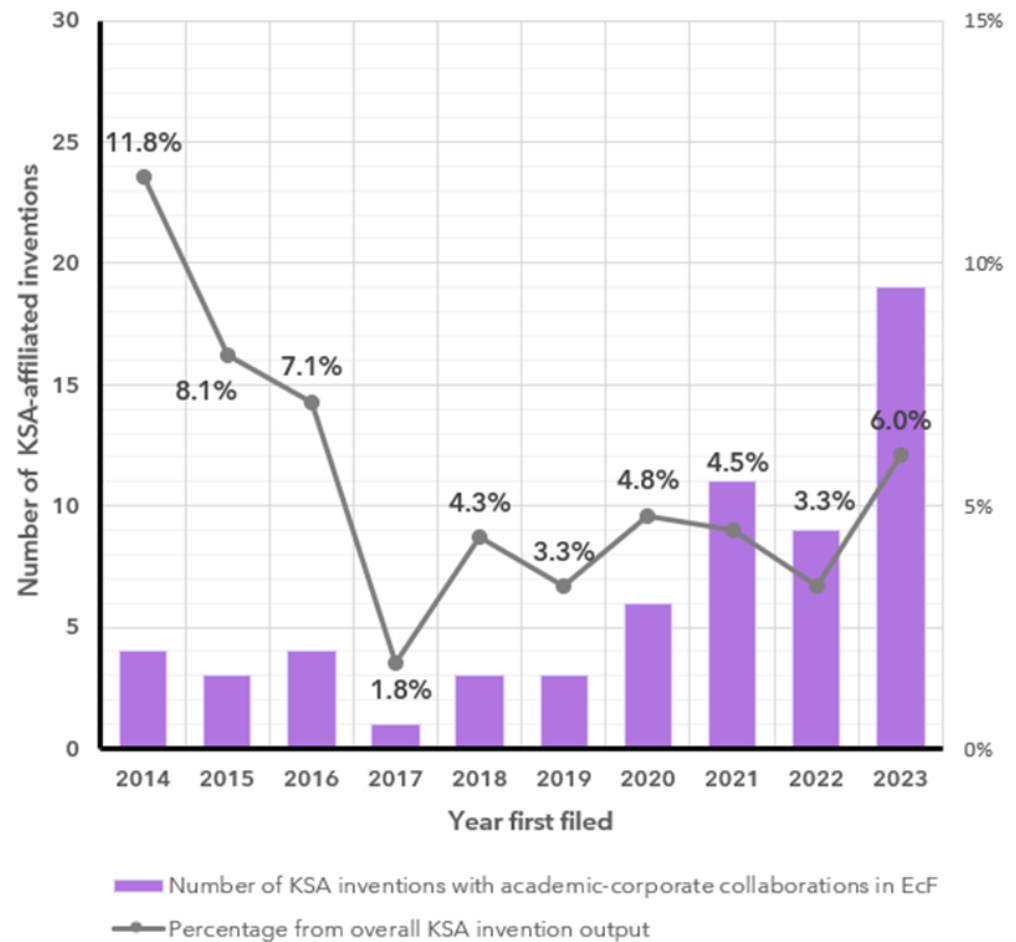


Figure 16: Timeline and trend of Saudi Arabia-affiliated inventions with industry collaboration in Economies of the Future, 2014-2023

Economies of the Future has experienced one of the highest growth rates in Saudi Arabia among the priority areas, with Saudi Arabia-affiliated inventions increasing nearly 10 times between 2014 and 2023 in Figure 16. Despite this rapid growth, the proportion of academic-corporate partnerships that constitute overall invention output has declined over time from 11.8% in 2014 to just 6.0% in 2023. The lowest point in collaboration occurred in 2017, where only 1.8% of inventions involved partnerships, reflecting a significant drop in engagement during this period. With invention output growing at a much faster rate than partnerships, this would seem to suggest that innovation capacity might be expanding with a corresponding increase in partnerships. As Economies of the Future matures, strengthening partnerships could be a critical driver of activity.

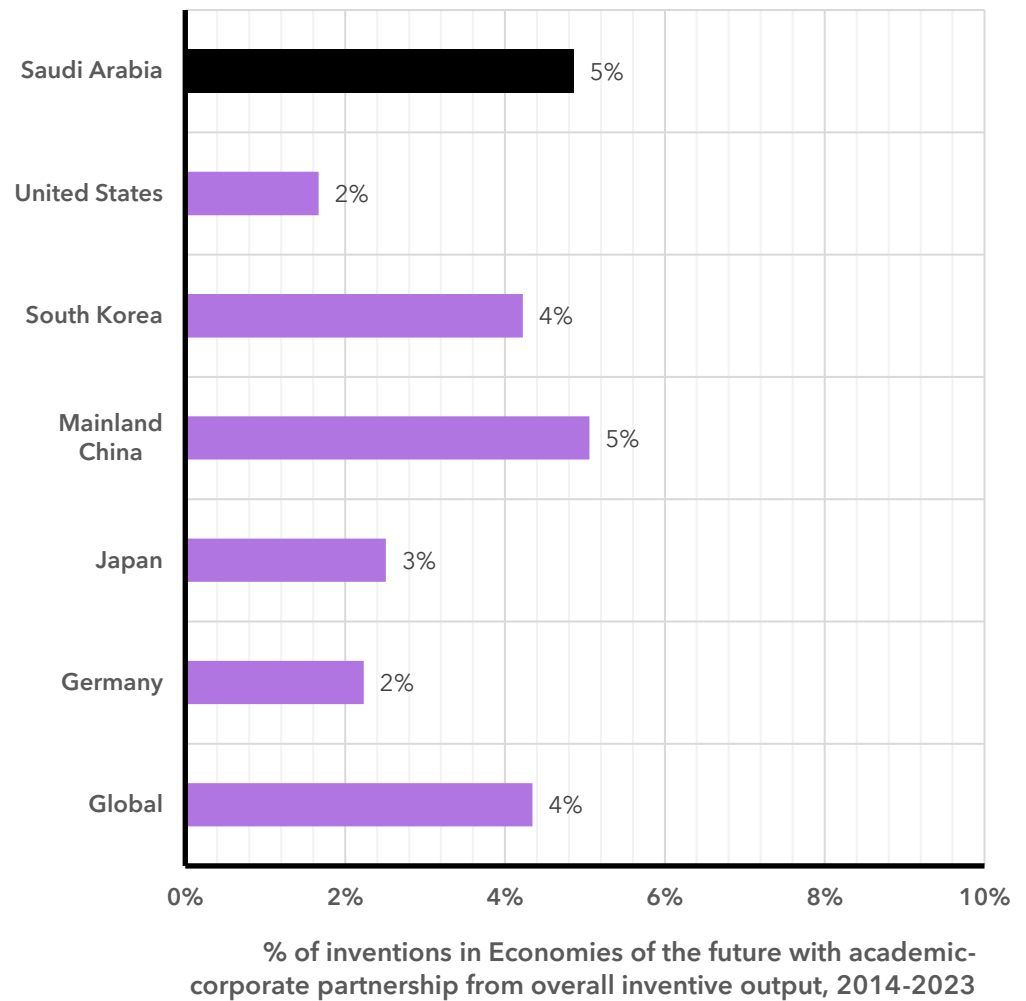


Figure 17: Academic and industry collaboration in inventions in Economies of the Future by major countries, compared to global baseline, 2014-2023

In Figure 17, ~5% of Saudi Arabia’s invention activity (2013-2024) is attributed to academic-corporate partnerships, aligning closely with Mainland China, and exceeding the global average of ~4%.

This indicates that, despite Saudi Arabia’s smaller patent output, its engagement in partnerships is relatively high. In contrast, Germany, and the United States each show only ~2% of partnership activity, even with substantial patent volumes, including ~258,000 patents in the US.

This suggests that while Saudi Arabia operates on a smaller scale, its engagement in partnerships is more effective in driving innovation. South Korea, with ~4% of its patents deriving from partnerships, remains in line with global trends.

In Figure 18 the strength of academic-corporate partnerships in Economies of the Future, Saudi Arabia and the United States score similarly in invention strength, despite Saudi Arabia’s lower patent volume. Mainland China, with over 1 million inventions, scores lower, yet still ranks ahead of Japan and South Korea in terms of quality indicators. Saudi Arabia’s strong invention strength in this priority area demonstrates the high-quality results of its academic-corporate partnerships, even with a smaller overall patent output. This indicates that Saudi Arabia has the potential to scale its partnerships more effectively and leverage its invention strength to drive future growth in emerging technologies.

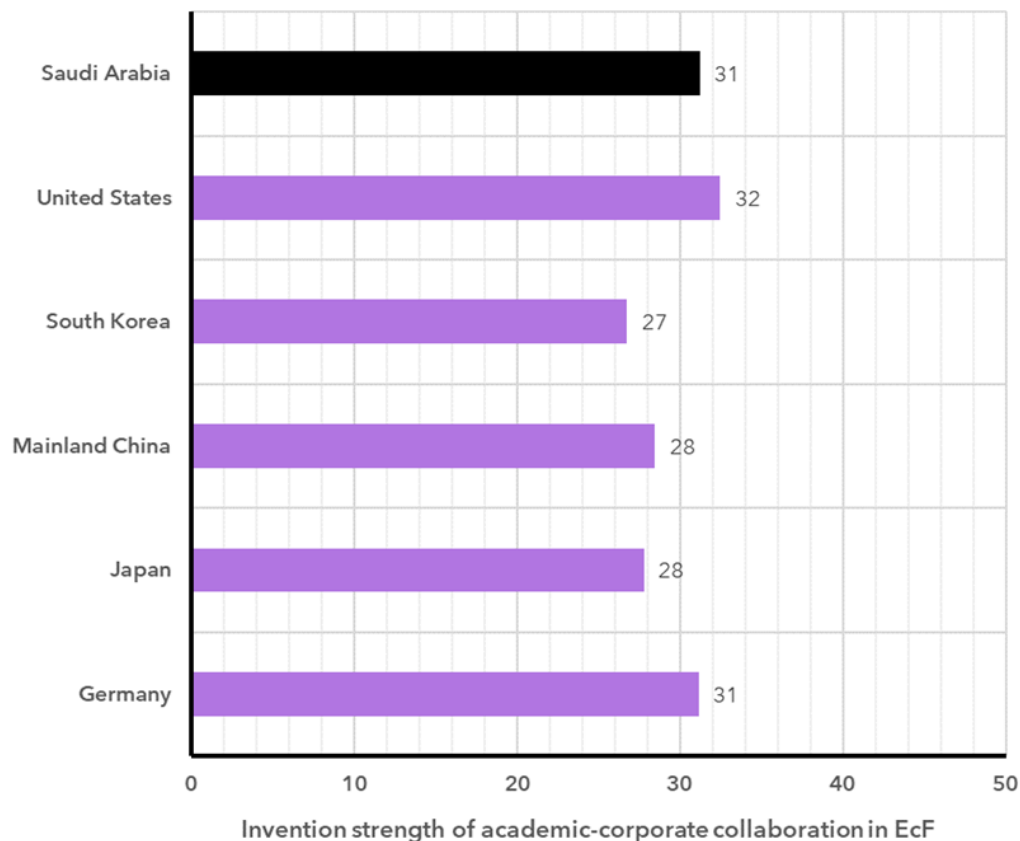


Figure 18: Strength of academic and industry collaboration inventions in Economies of the Future by major countries, 2014-2023

Economies of the Future have seen one of the highest growth rates among priority areas, with invention output increasing nearly tenfold from 2014 to 2023. However, academic-corporate partnerships have not kept pace, declining from 11.8% in 2014 to 6% in 2023.

Despite lower patent volumes compared to global leaders like the US and Mainland China, the strength of partnership in Economies of the Future remains competitive. Saudi Arabia's ~5% patent-led collaboration in Economies of the Future exceeds the global average (~4%) and aligns closely with Mainland China. Countries like the US and Germany, with higher patent outputs, show lower partnership rates (~2%). Moving forward, strengthening academic-corporate partnerships will be key to sustaining rapid growth. As the sector matures, expanding these collaborations will help Saudi Arabia capitalize on emerging technologies and enhance its global competitiveness in the innovation landscape.

3.2.2 Invention impact analysis

In Figure 19, Saudi Arabia stands out in terms of competitive invention strength, surpassing Mainland China, South Korea, and Japan, despite a smaller volume of patent activity. This indicates that Saudi Arabia is translating academic-corporate partnerships into applied research. South Korea and Mainland China, although producing larger volumes of patents, lag in invention strength. In contrast, the United States and Germany exhibit strong invention strength and relatively newer technologies, underscoring their leadership in forward-looking technologies within Economies of the Future. While Saudi Arabia may have fewer inventions in Economies of the Future compared to major economies, the quality and impact of its academic-corporate collaborations are positioning well for growth.

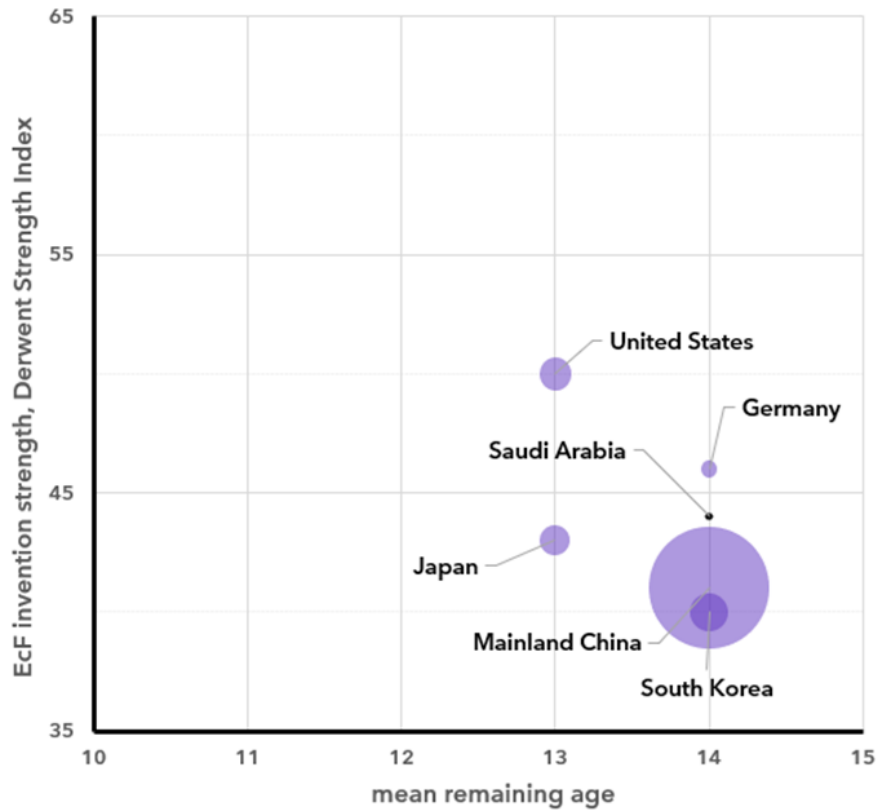


Figure 19: Invention strength dynamics of academic and industry collaboration in Economies of the Future by major countries and Saudi Arabia, 2014-2023

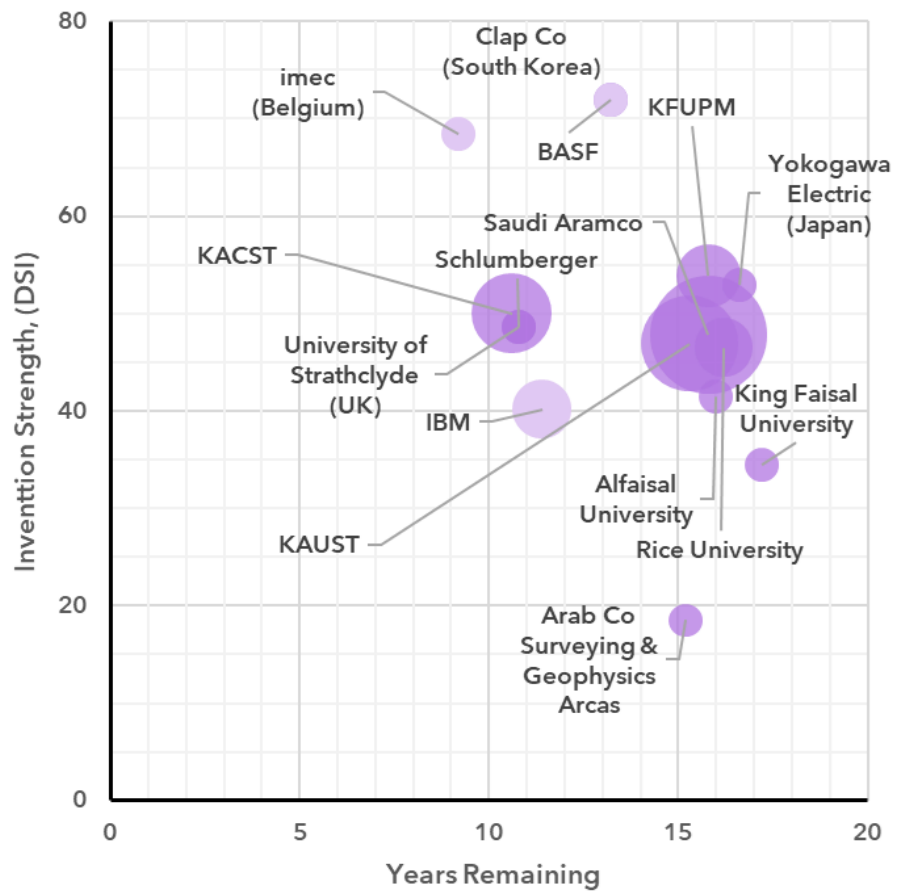


Figure 20: Invention strength dynamic of top collaborating entities in Saudi Arabia in Economies of the Future, 2014-2023

In Figure 20 international corporations like BASF (Germany) and Clap Co (South Korea) are noted as key collaborators in academic-corporate partnerships both with

the highest strength scores at 71.9. This signals Saudi Arabia's increasing collaboration with global leaders in specialized technologies. Imec (Belgium), known for its focus on nanotechnology, adds further weight to Saudi Arabia's strategy to integrate advanced semiconductor technologies into its future-focused industries. The inclusion of academic institutions such as Rice University (USA) and University of Strathclyde (UK) indicate that partnership, and utilisation of research talent, is occurring outside the Kingdom. Overall, within Economies of the Future Saudi Aramco is a key collaborator with a solid invention strength (DSI 47.8) and the highest instance of partnership.

3.3 Overview from Technology maturity, readiness, and commercialization

In this section, we summarize, and review information collated during the Study - Accelerating Technology Transfer from the Lab to the Market in Saudi Arabia of the program that are specific to the Economies of the Future National Priority. For more information about the program and studies conducted, please refer to the Introduction.

This analysis within the program necessarily focuses on the invention levels globally, and in Saudi Arabia, due to the strong link between research and commercial activity inherent to the patent process, as well as the role of patent protection in the ownership and usage of technology in commercial contracts and processes.

Inherent to the analysis in Figure 21 is a review of several key measures:

1. The evaluation of the overall technical maturity of research (on a scale of basic theory through to full market commercialization) within a specific research topic.
2. Evaluation of Saudi Arabian research commercialization activity within the National Priority, particularly in comparison to global levels. This also includes assessment of the current depth and strength of invention levels currently occurring within the Saudi Research & Innovation ecosystem.
3. The future commercial potential of individual research topics within the National Priority Area

Using these criteria, we can describe the dynamics of research within Economies of the Future, how it meets commercial application, where Saudi Arabia contributes today, and how future research funding policy in the National Priority can be tailored to these dynamics.

At a global level, Economies of the Future research topics trend more immature than the other National Priorities. For example, it is the only priority area with research topics classified at the lowest Technology Readiness Level (TRL) levels 1-2. It also has the greatest spread of technology maturity, alongside only Health & Wellness having a research topic at TRL 9 - most mature.

In this case, the semiconductor technology sector reflects the underlying and mature foundational nature of chips and devices to modern society. The National Priority can, therefore, be described as highly diverse in the profile of research need it exhibits - from the early foundational concept through to major multi-billion-dollar industries.

Several topics that have developed rapidly over the past 10-15 years are now reflected as relatively mature among the 167 categories assessed during the maturity assessment, including 3D printing, cloud computing and biorefining, indicating widespread commercial use and applicability of these approaches.

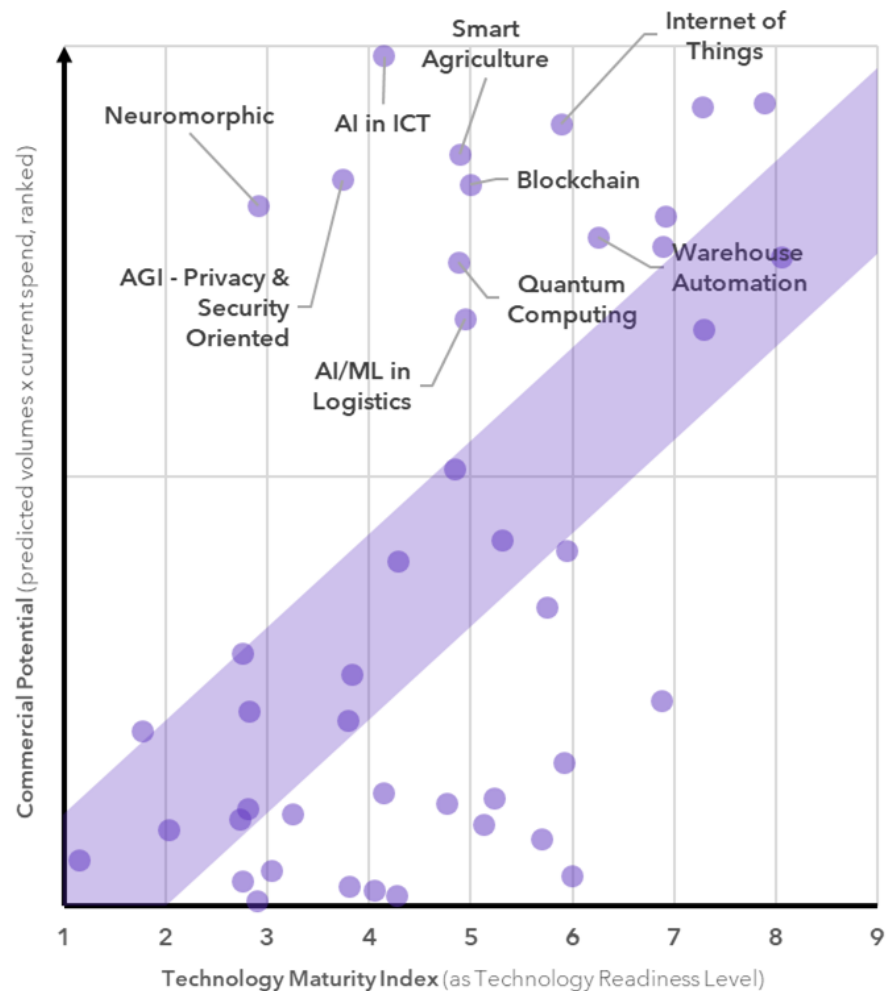


Figure 22: scatterplot of Technology Maturity Index for each research topic (represented on a technology readiness scale) and commercial potential (a ranked axis based on the future predicted invention volumes in each topic, multiplied by the current relative level of investment in Intellectual property protection)

Also shown in the analysis of Figure 22, and a profile that is exhibited in all four National Priorities, is a strong relationship between future commercial potential of the research topics and their evaluated TRL maturity. This is to a degree inherent in the modelling of technology maturity itself, and therefore an expected result.

However, in the Economies of the Future space, while at a summary level, this trend is measured, in distribution, there is a suggested split in the outcome. Several research topics break out from the trend in a way that implies a significant need for further applied research that can take them to higher technology maturity. These topics show in global data analysis high future demand for solutions, but in remain lower than expected in TRL level.

These include several computing architectures and platforms: AI topics generally, quantum computing, blockchain and the Internet of Things. This analysis creates an interesting dichotomy, in that the factors that map to potential (high predicted volumes in invention output globally) disagree with other factors that map to maturity (high enforcement, high dominance by major corporates, low levels of academic patent filing).

The inference is that their significant potential for further, earlier research intervention. Therefore, within this National Priority, a focus on earlier TRL research topics is likely fruitful for economic returns.

Moving to Saudi Arabian applied research within the Economies of the Future sector, a review of predicted commercial potential versus the depth of Saudi invention levels shows a very strong correlation: the Saudi research and innovation ecosystem tends to focus on research topics that are also more likely to be in demand in future years.

The very highest commercial potential fields in Economies of the Future surround major technical themes generally: AI in ICT applications and semiconductors. Noteworthy is that these two fields sit at almost opposite ends of the TRL spectrum (TRL 9, semiconductors; TRL 4 for AI). Also notable is that lowest commercial potential fields show low or mostly zero invention depth for Saudi Arabia - these topics are not active areas of applied research that produces patent filing.

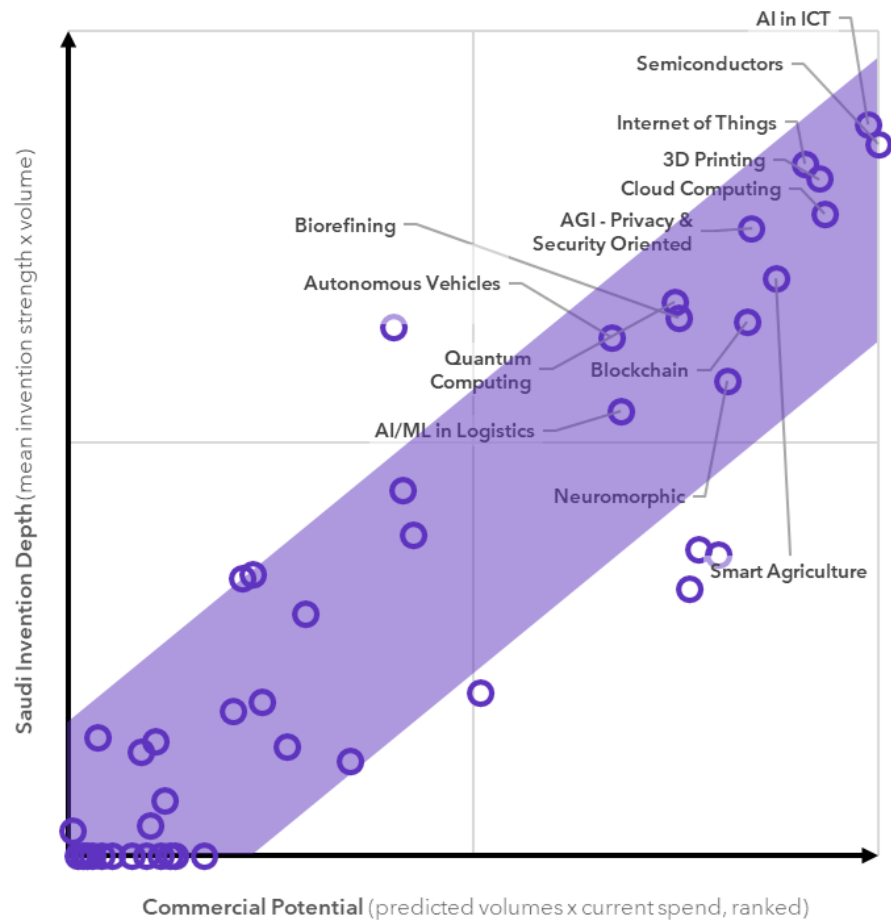


Figure 23: views Economies of the Future research topics arrayed by the level of Saudi Arabian research strength and depth vs the commercial potential of the research topic; high potential/high invention depth topics are labelled

Within the National Priority Area, the highest area of Saudi Arabian invention depth (measured as a combined measure of both the volume of inventions and their relative strength) is also AI in ICT and Semiconductor research., followed by the Internet of Things, 3D Printing and cloud computing.

Further summarising the commercialization directions potentially available to the Saudi research ecosystem was performed using the Technology Maturity/Technology Readiness spectrum against a hybrid metric that distils the desirability of research itself for Saudi Arabia.

Performed as a topic recommendation score, this metric combines the predicted commercial potential measured across the topics, the depth of Saudi Arabian research today, the level of academic-corporate partnership exhibited to date from Saudi Arabian activity and finally a check of expert opinion across the research topics as seen in Figure 23.

Arraying the topic recommendation against TRL levels provides a good decision matrix surrounding modes of research intervention.

For example, areas of low-level recommendation for Saudi Arabia, regardless of TRL level, can be de-prioritized for either ad hoc academic research selection or, if already highly mature, for the private sector to choose to intervene.

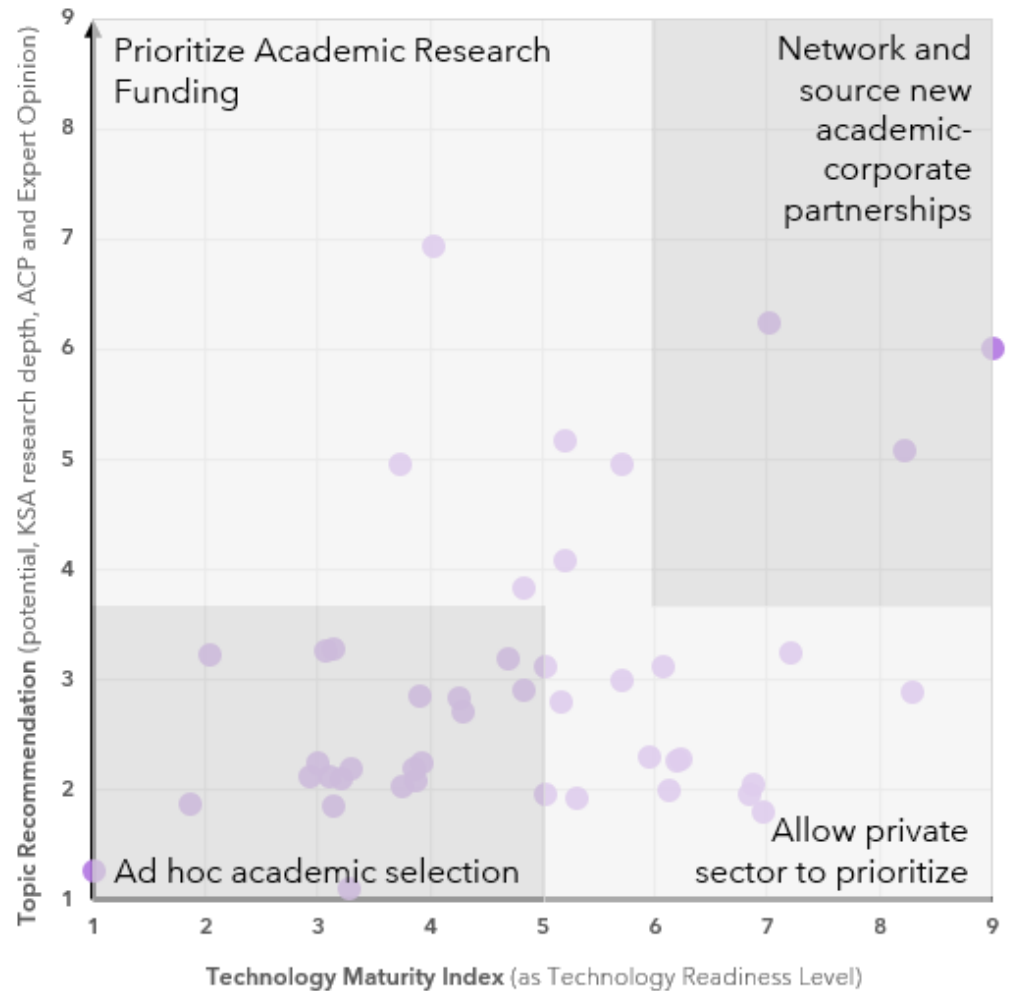


Figure 24: summary scatterplot view of the Part 3 recommendations of research topics based on the commercial potential measure, the depth of research within Saudi Arabia, the level of academic/corporate potential, and the views of RDIA experts for interest/impact; all arrayed on the Technology Maturity Index spectrum; limited to the Economies of the Future National Priority

Where research topics already exhibit a track record of applied research intensity in Saudi Arabia, the TRL spread can be used to recommend either the prioritization of further academic research (for more immature topics, where research is needed to transition to more maturity), or where occurring in more mature fields, the transfer of Saudi academic research to the private sector should be strengthened.

This view in Figure 24 is summarised here for the Economies of the Future national priority, and highlights:

1. Within earlier TRLs, a focus on applied research in AI and specifically the privacy/security-related concepts within AI. Also evident in this view is the potential for further commercial development of Smart Agriculture.
2. Within higher TRL areas, where the commercialization of existing research pathways should be prioritized via further partnership by Saudi Arabian academic researchers with private enterprise: 3D printing, Semiconductors and Cloud Computing. While these topics do have activity in Saudi Arabia today, we do highlight that it is lower than more traditional topics for the Saudi research ecosystem.

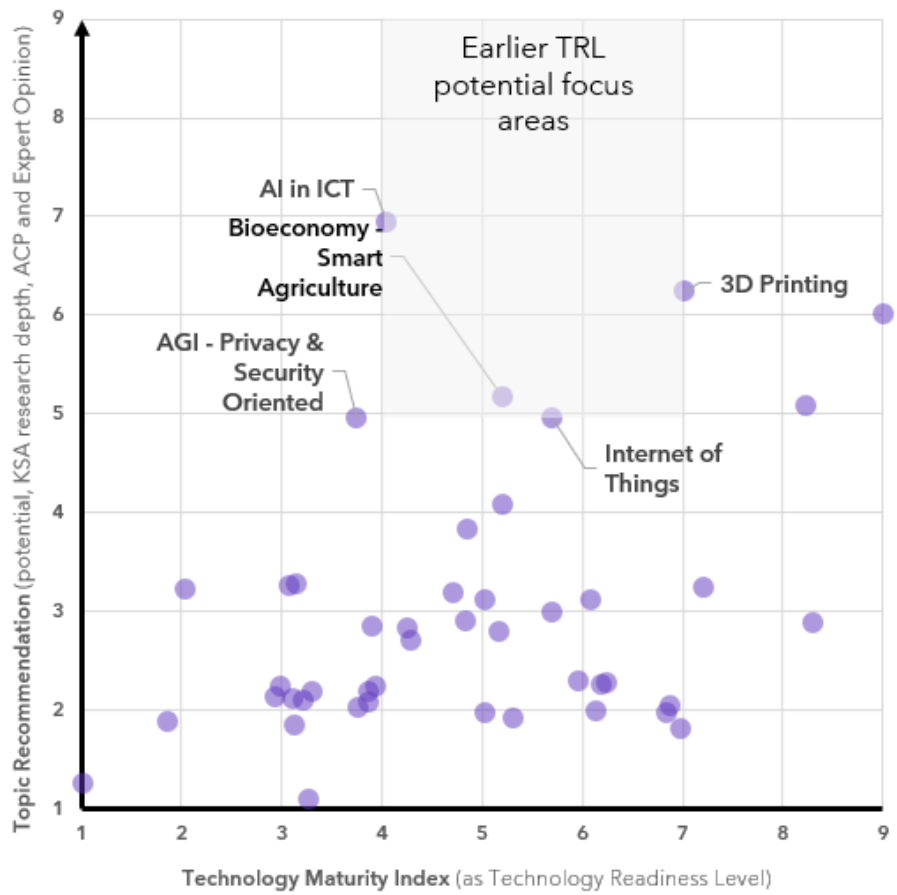


Figure 25: scatterplot of Technical Maturity Index versus Topic Recommendation in the Economies of the Future National Priority, annotation for research topics categories of >5 in recommendation and sitting in TRLs 4 - 7.

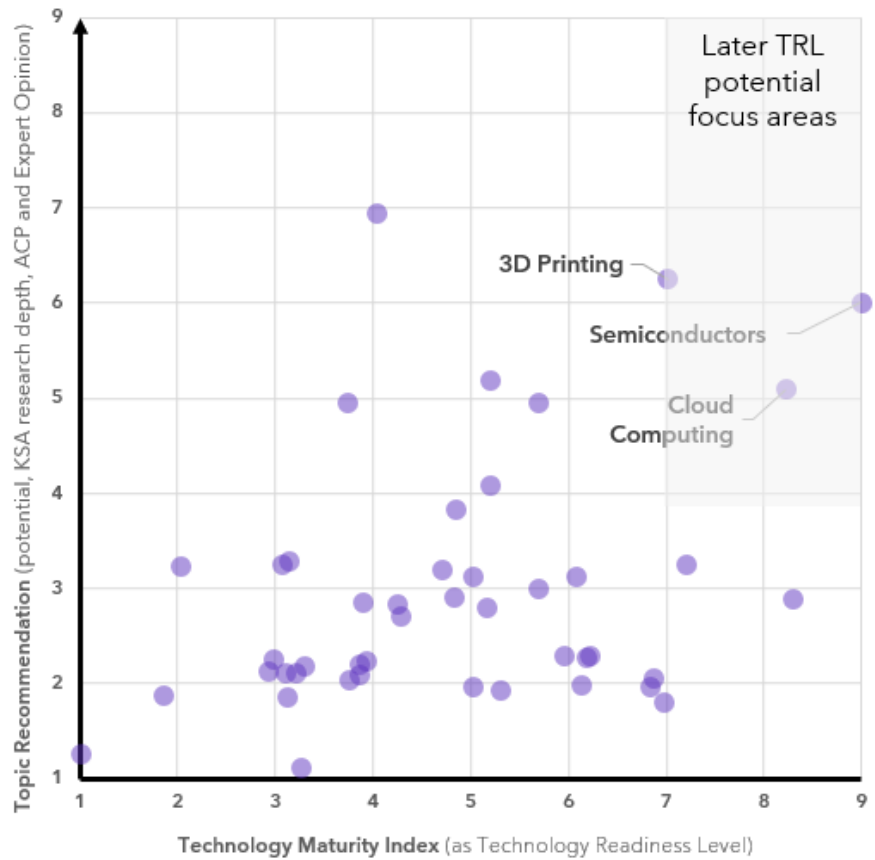


Figure 26: scatterplot of Technical Maturity Index versus Topic Recommendation in the Health & Wellness National Priority, annotation for research topics categories of >5 in recommendation and sitting in TRLs 8 - 9.

Finally in this section, the relative ranking and mode of research topics within the Economies of the Future National Priority is shown, ranked by the confluence of topic recommendation factors, and by action/recommendation quadrant they fall within based on the evaluated TRL level.

Table 5 - Outcome scorecard for Economies of the Future research topic categories, ranked by recommendation level; includes Technology Maturity Index/TRL score. Circle fill denotes a metric from highest quartile evidenced (full) to lowest quartile (single quarter).

Category	TMI as TRL	Commercial Potential	Saudi Arabia Research Depth	Level of Partnership	Expert Opinion	Recommended mode
AI in ICT	4	●	●	●	na	Prioritize academic funding
Semiconductors	9	●	●	●	na	Prioritize tech transfer
3D Printing	7	●	●	●	●	Prioritize tech transfer
AGI - Privacy & Security Oriented	4	●	●	●	●	Prioritize academic funding
Internet of Things	6	●	●	●	●	Prioritize tech transfer
Bioeconomy - Smart Agriculture	5	●	●	●	●	Prioritize academic funding
Cloud Computing	8	●	●	●	●	Prioritize tech transfer
Blockchain	5	●	●	●	●	Prioritize academic funding
Quantum Computing	5	●	●	●	●	Prioritize academic funding
Computing Stepchange - Neuromorphic	3	●	●	●	●	Ad hoc academic activity
Logistics - AI/ML	5	●	●	●	●	Ad hoc academic activity
Air Quality, Traffic, Energy or Resource Management	5	●	●	●	●	Ad hoc academic activity
Urban Architecture - Sustainable buildings	5	●	●	●	●	Ad hoc academic activity
Bioeconomy - Biorefining	8	●	●	●	●	Private sector led
Deep Sea - Autonomous Vehicles	4	●	●	●	●	Ad hoc academic activity
Autonomous Vehicles	7	●	●	●	●	Private sector led
Deep Sea - Telecoms	3	●	●	●	●	Ad hoc academic activity
Urban Architecture - Low Emission Materials	5	●	●	●	●	Ad hoc academic activity
AGI - Responsible AI	2	●	●	●	●	Ad hoc academic activity
Quantum Error Suppression & Correction or Codes (QECCs)	4	●	●	●	●	Ad hoc academic activity
Quantum Sensing	6	●	●	●	●	Private sector led
Sustainable 6G Energy Efficient Edge Infrastructure	4	●	●	●	●	Ad hoc academic activity
Sustainable 6G Materials	6	●	●	●	●	Private sector led
Net Zero Aviation	7	●	●	●	●	Private sector led
Citizen Engagement	3	●	●	●	●	Ad hoc academic activity
Predictive Analytics, Decision Algorithms	2	●	●	●	●	Ad hoc academic activity
Computing Stepchange - Analog AI	3	●	●	●	●	Ad hoc academic activity
Sustainable 6G Automatic Management	4	●	●	●	●	Ad hoc academic activity
Urban Architecture - Mobility as a Service	6	●	●	●	●	Private sector led
Data Ownership & Privacy	3	●	●	●	●	Ad hoc academic activity
Virtual Cities	3	●	●	●	●	Ad hoc academic activity
Deep Sea - Diving Suits	5	●	●	●	●	Ad hoc academic activity
Deep Sea - Mapping	4	●	●	●	●	Ad hoc academic activity
Deep Sea - Microbes	4	●	●	●	●	Ad hoc academic activity
Logistics - IoT in Supply Chains	3	●	●	●	●	Ad hoc academic activity
Logistics - Predictive Analytics	4	●	●	●	●	Ad hoc academic activity
Logistics - Warehouse Automation	6	●	●	●	●	Private sector led
Service Robots	7	●	●	●	●	Private sector led
Smart Textiles	6	●	●	●	●	Private sector led
Space Architecture Habitats	5	●	●	●	●	Ad hoc academic activity
Space Architecture Mining	3	●	●	●	●	Ad hoc academic activity
Urban Architecture - Last Mile Delivery	7	●	●	●	●	Private sector led
Urban Air Mobility	6	●	●	●	●	Private sector led
Deep Sea - eDNA Analytics	1	●	●	●	na	Ad hoc academic activity
OpenRAN	3	●	●	●	na	Ad hoc academic activity

This list (Table 5) can be used to assess the specificity of research topics to the Saudi Arabian research ecosystem at present, alongside the assessed technology maturity index of the global research within that same topic, so that areas where Saudi Arabia can contribute further innovation that produce competitive, commercial, technologies are identified.

4 Deep-dive into selected Economies of the Future research topics



Within this section, the following research topics, as they map to specific RDIA missions, will be explored in detail:

National Priority	Topic	4.1 Establish habitats on Mars by 2050					4.2 Establish permanent outputs on the Moon by 2040		4.3 Going beyond Smart Cities, establish 5 Cognitive Cities in KSA by 2040	4.4 Create a safe trustworthy General Intelligence that learns and realizes autonomous work in favor of humans by 2040		4.5 Develop fault tolerant quantum computer by 2040	4.10 Future of connectivity building sustainable 6G technologies by 2035
Economies of the Future	Air Quality, Traffic, Energy or Resource Management							✓					
	Virtual Cities							✓					
	Citizen Engagement							✓					
	Data Ownership & Privacy							✓					
	Predictive Analytics, Decision Algorithms							✓					
	Space Architecture - Mining	✓		✓									
	Space Architecture - Habitats	✓		✓									
	AI in ICT									✓			
	6G Sustainable - Material											✓	
	6G Sustainable - Automated Management											✓	
	6G Sustainable - Energy-Efficient edge Infrastructure											✓	
	Autonomous Vehicles											✓	
	Quantum Computing										✓		
	OpenRAN											✓	
	Semiconductors											✓	
	Urban Air Mobility											✓	

4.1 Research performance in the selected priority research topics

In this section we investigate the research output performance in Saudi Arabia as well as globally for selected priority research topics.

For each selected research topic, the research output performance for Saudi Arabia is investigated. First, the share of Saudi Arabia publications from the global publications published in the research topic is investigated. Investigating the share of publications shows the evolution of the number of Saudi Arabia publications relative to the global share. If the share is increasing, this means that the number of Saudi Arabia publications in the research topic is increasing on a rate higher than the global one and vice versa. We also investigate the citation impact of Saudi publications in the research topic by looking at the Category Normalized Citation Impact (CNCI). The metric provides information on the citation impact relative to the global average citation impact for publications of the same type, year of publication and subject area (For more information see Metrics). In general, a CNCI above 1.0 would reflect a citation impact performance above the global average.

Second, we investigate the top 10 countries collaborating with Saudi Arabia in the research topic, the top 20 funding organizations, the top 20 publishing organizations in Saudi Arabia, and the top 20 researchers in terms of the number of publications in the research topic. This will provide insights about the research ecosystem in Saudi Arabia around this specific research topic. Identifying key players from this ecosystem will support deriving targeted initiatives to enhance research performance in those research topics. Also, here all the indicators used are described in Metrics.

Third, we also investigate the top 10 global publishing countries, top 20 publishing entities globally, top 20 funding organizations globally and top 20 researchers globally in terms of the number of publications published on the research topic. This will provide insights about the research ecosystem globally around this specific research topic. Also here identifying key global players in the research ecosystem of a specific research topic will support enhancing Saudi Arabia research performance by aiming to collaborate with those key players.

Finally, we identify emerging topics globally and within Saudi Arabia research output in a specific research topic. This is identified by selecting the top topics regarding growth in number of publications from 2014 to 2023. Although, the Saudi Arabia research output within a research topic should focus on local and regional needs and priorities, it should not miss global trends that could become important in the future. Thus, we compare the emerging trends within Saudi Arabia to the global ones. The global trends provide insights to Saudi-affiliated researchers on topics that one should monitor and/or could also be of local importance.

Main Findings

- The share of Saudi Arabia publications in several of the research topics from the global publications in the research topic increased almost continuously in the period 2014-2023. This shows that for the majority of the research topics the growth in Saudi Arabia publications was higher than the global average.
- In Urban Air Mobility, Space Architecture Habitats, Space Architecture Mining, Data Ownership & Privacy and AI in ICT, we observe a similar trend but a slight decrease in the share in 2023.
- In Sustainable 6G Automatic Management and Sustainable 6G Energy Efficient Edge Infrastructure there are few publications globally and in Saudi Arabia. Also, in OpenRAN, there are very few publications globally and no Saudi Arabia publications.
- As the investigated research topics are RDI national priorities, one should aim at having a continuous increase in the research output while preserving a good research quality. One possibility to perform this is by collaborating with identified key publishing organizations and researchers and collaborating with top funding organizations identified in those research topics. This is especially the case for priority research topics with very few publications.

- In all the investigated research topics, except Citizen Engagement, at least five of the top 10 collaborators with Saudi Arabia in terms of number of publications, were also among the top 10 globally in terms of number of publications. This shows that Saudi Arabia is collaborating with key global players on those research topics.
- In almost all research topics, at least 9 of the Top 20 funders of Saudi Arabia publications in terms of number of publications are also among the top funders globally. This again shows that Saudi affiliated researchers are collaborating with key global players along the research topics and can attract funding from key global funders in those research topics.
- In several of the research topics we observe King Saud University, King Abdulaziz University, King Abdullah University of Science & Technology, King Fahd University of Petroleum & Minerals, Prince Sattam Bin Abdulaziz University and Umm Al Qura University among the top 5 publishing entities in Saudi Arabia.
- Considering that global emerging trends could become more important in the future, one should monitor identified trends and check their relevance to local priorities.

4.1.1 Air Quality, Traffic, Energy or Resource Management

4.1.1.1 Evolution of Saudi publication share of global publications in the research topic

The share of Saudi Arabia publications from global publications in the research topic increased almost continuously from 2014 till 2023 as shown in Figure 27. This indicates that Saudi Arabia was not only able to increase the number of publications in this research topic but also having a growth higher than the global growth rate.

This is evident as the share of Saudi Arabia publications in the research topic is growing. The CNCI of Saudi Arabia publications in this research topic were in all years higher than 1, indicating a citation impact performance higher than the global average. Although the CNCI decreased from 3.67 in 2015 to 1.11 in 2016 it increased to 2.15 in 2023, indicating a 115% higher citation impact performance than the global average.

Overall, Saudi Arabia publications increased with a higher growth rate than the global average in this research topic and had a relatively good citation impact as measured by the CNCI. Nevertheless, after this high growth rate in terms of publications, one should focus on increasing/preserving the relatively good citation impact.



Figure 27: The share of Saudi Arabia from global publications in the research topic and the CNCI of Saudi Arabia publications in the research topic Air Quality, Traffic, Energy or Resource Management in the period 2014-2023

4.1.1.2 Top 10 countries collaborating with Saudi Arabia

The top collaborating country with Saudi Arabia in this research topic in the period 2014-2023 are United Kingdom followed by Mainland China and United States with 215, 194 and 167 publications respectively as shown in Figure 28.

In terms of citation impact measured by the CNCI publications published in collaboration with Bangladesh followed by Mainland China and Malaysia had the

highest CNCI with 3.62, 3.29 and 3.08, respectively. Nevertheless, all publications with the top 10 collaborating countries had a CNCI higher than 1 reflecting a performance higher than the global average.

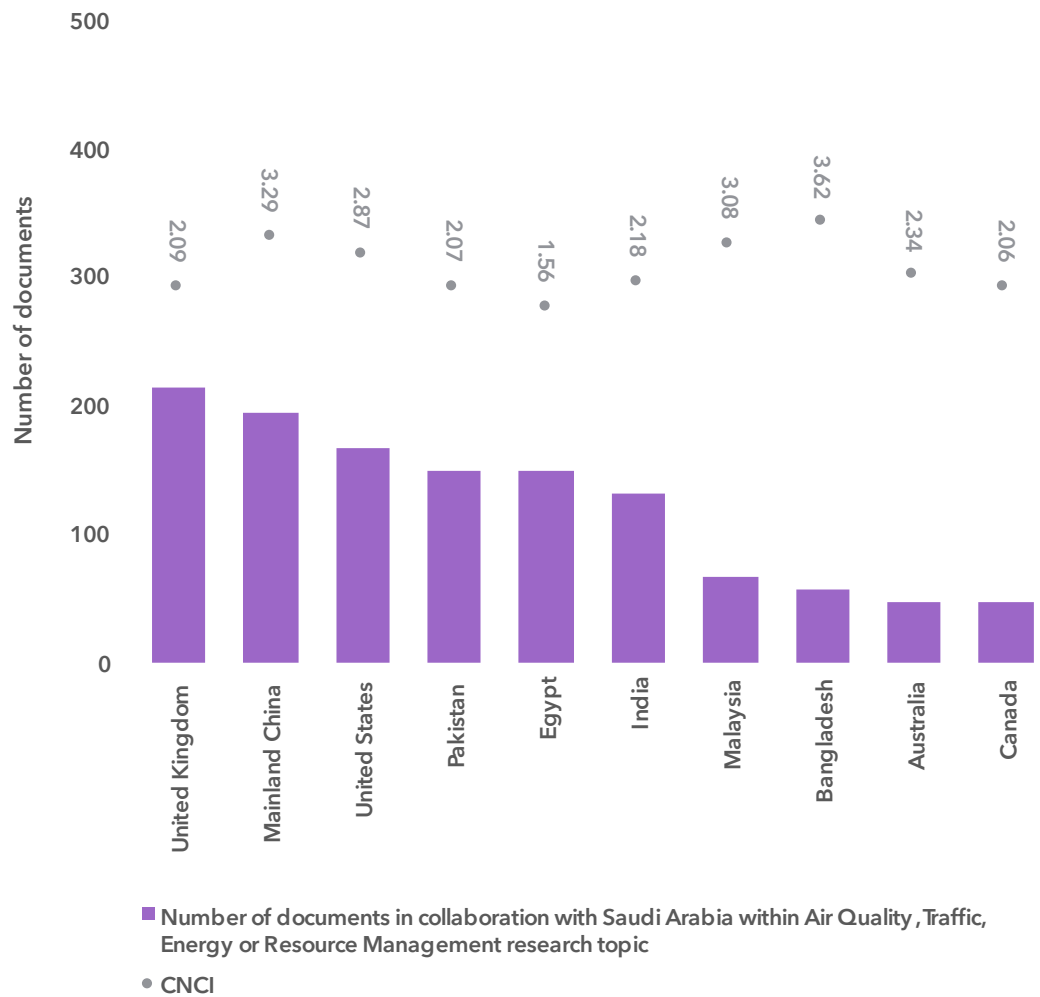


Figure 28: Top 10 collaborating countries with Saudi Arabia in terms of the number of publications in the research topic Air Quality, Traffic, Energy or Resource Management in the period 2014-2023

4.1.1.3 Top 20 funders of Saudi publications by number of publications

The top 3 funding organizations of Saudi Arabia publications in this research topic in terms of number of publications mentioning the organization in the funding text in the period 2014-2023 are UK Research & Innovation (UKRI) followed by King Saud University and Natural Environment Research Council (NERC) with 74, 73 and 54 publications respectively as shown in Figure 29.

Documents funded by European Research Council (ERC), followed by United States Department of Health & Human Services and National Institutes of Health (NIH) - USA with the same CNCI followed by Medical Research Council UK (MRC) had the highest citation impact measured by the CNCI with 11.26, 3.40 and 3.25, respectively.

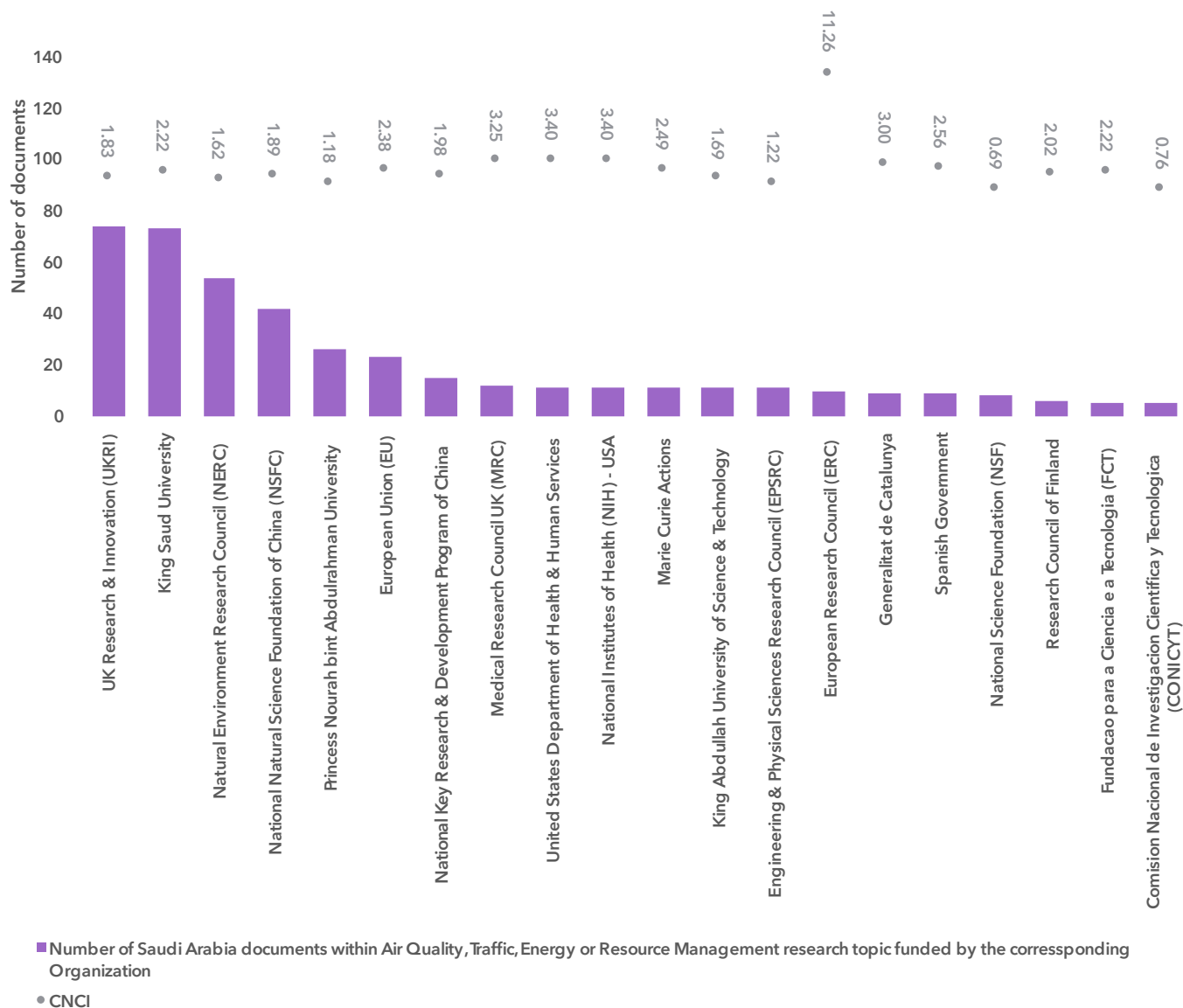


Figure 29: Top 20 funding organizations of Saudi Arabia publications in the research topic Air Quality, Traffic, Energy or Resource Management in terms of number of publications in the period 2014-2023

4.1.1.4 Top 20 Saudi Arabia organizations in terms of number of publications

The top 3 organizations in terms of publications published in this research topic and in the period 2014-2023 are King Abdulaziz University followed by King Saud University and King Fahd University of Petroleum & Minerals with 301, 151 and 91 publications respectively as shown in Figure 30.

In terms of citation impact as measured by the CNCI, the University of Jeddah followed by Prince Sattam Bin Abdulaziz University and King Saud University, had the highest CNCI with 2.90, 2.81 and 2.80, respectively.

Nevertheless, all top 20 organizations had a CNCI higher than 1, reflecting a citation impact performance higher than the global average.

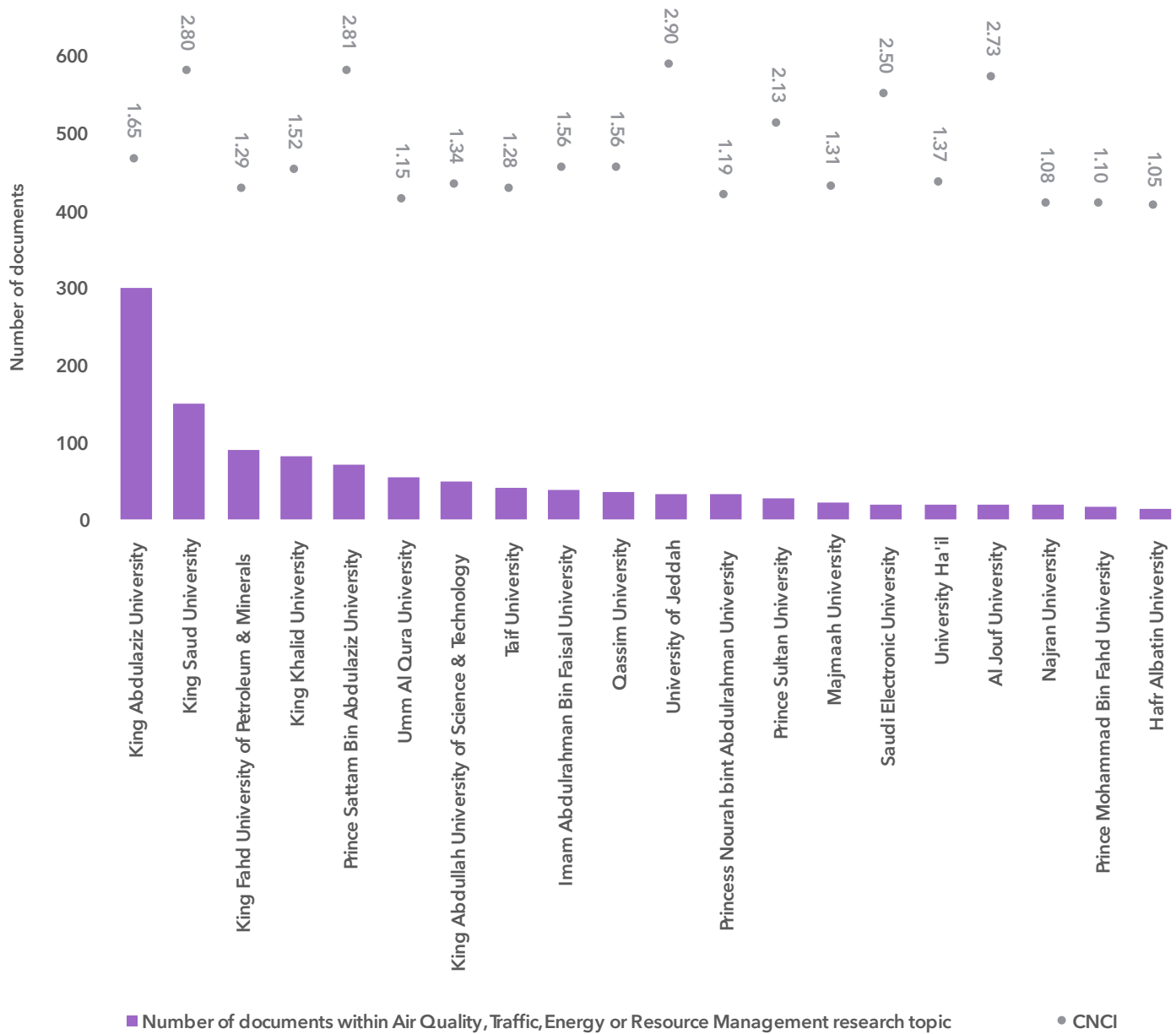


Figure 30: Top 20 Saudi organizations in terms of publications published in the research topic Air Quality, Traffic, Energy or Resource Management in the period 2014-2023 and their corresponding CNCI

4.1.1.5 Top 20 researchers affiliated to Saudi organizations in terms of number of publications

The highest number of publications are published by Abubakr M. Idris, affiliated to King Khalid University, followed by Mansour A. Alghamdi affiliated with King Abdulaziz University and R. M. Harrison affiliated to King Abdulaziz University with 19, 17 and 15 publications respectively as shown in Table 6.

The highest CNCI is achieved by publications published by Haider Mahmood, affiliated with Prince Sattam Bin Abdulaziz University, with a CNCI of 8.12. The latter researcher also has the highest number of Top 1% publications, amounting to 5 publications, and Top 10% publications, amounting to 10 publications. Suleman Sarwar, affiliated with the University of Jeddah, also had 10 Top 10% publications.

Table 6: Top 20 researchers affiliated with Saudi organizations in terms of the number of publications published in the research topic Air Quality, Traffic, Energy or Resource Management in the period 2014-2023

Name	Affiliation	Web of Science Publications	CNCI	Documents in the top 1%	Documents in the top 10%
Idris, Abubakr M.	King Khalid University	19	2.16	0	9
Alghamdi, Mansour A.	King Abdulaziz University	17	0.94	0	1
Harrison, R. M.	King Abdulaziz University	15	1.58	0	5
Sarwar, Suleman	University of Jeddah	13	4.91	2	10
Mahmood, Haider	Prince Sattam Bin Abdulaziz University	11	8.12	5	10
Hossain, M. Shamim	King Saud University	9	1.74	0	3
Almazroui, Mansour	King Abdulaziz University	9	1.55	0	2
Zeb, Jahan	Umm Al Qura University	8	1.05	0	1
Rahman, Syed Masiur	King Fahd University of Petroleum & Minerals	8	1.38	0	2
Hamza, Manar Ahmed	Prince Sattam Bin Abdulaziz University	7	0.49	0	0
Mallick, Javed	King Khalid University	7	1.39	0	2
Aziz, Ghazala	Saudi Electronic University	7	5.00	1	5
Khan, Uzma	Prince Sattam Bin Abdulaziz University	7	4.61	2	5
Khoder, Mamdouh I.	King Abdulaziz University	7	1.04	0	0
Mousa, Mustafa	King Abdullah University of Science & Technology	6	1.57	0	1
Khoder, M.	King Abdulaziz University	6	1.06	0	1
Koubaa, Anis	Prince Sultan University	6	1.97	1	2
Hoteit, Ibrahim	King Abdullah University of Science & Technology	6	0.79	0	0
Shamy, Magdy	King Abdulaziz University	6	1.38	0	1
Asif, Muhammad	King Fahd University of Petroleum & Minerals	6	1.43	0	1

4.1.1.6 Top 10 countries in terms of publications

The highest number of publications published in this research topic are published by Mainland China (22,033 publications) followed by United States (11,810 publications) and India (4,556 publications) as shown in Figure 31.

The highest citation impact measured by the CNCI is achieved by publications published by Australia, United Kingdom, and United States with a CNCI of 1.87, 1.65 and 1.64, respectively. Six of the top 10 countries in terms of number of publications published in the research topic are also among the top 10 collaborators with Saudi Arabia.

These are the United States, Mainland China, the United Kingdom, India, Australia, and Canada.

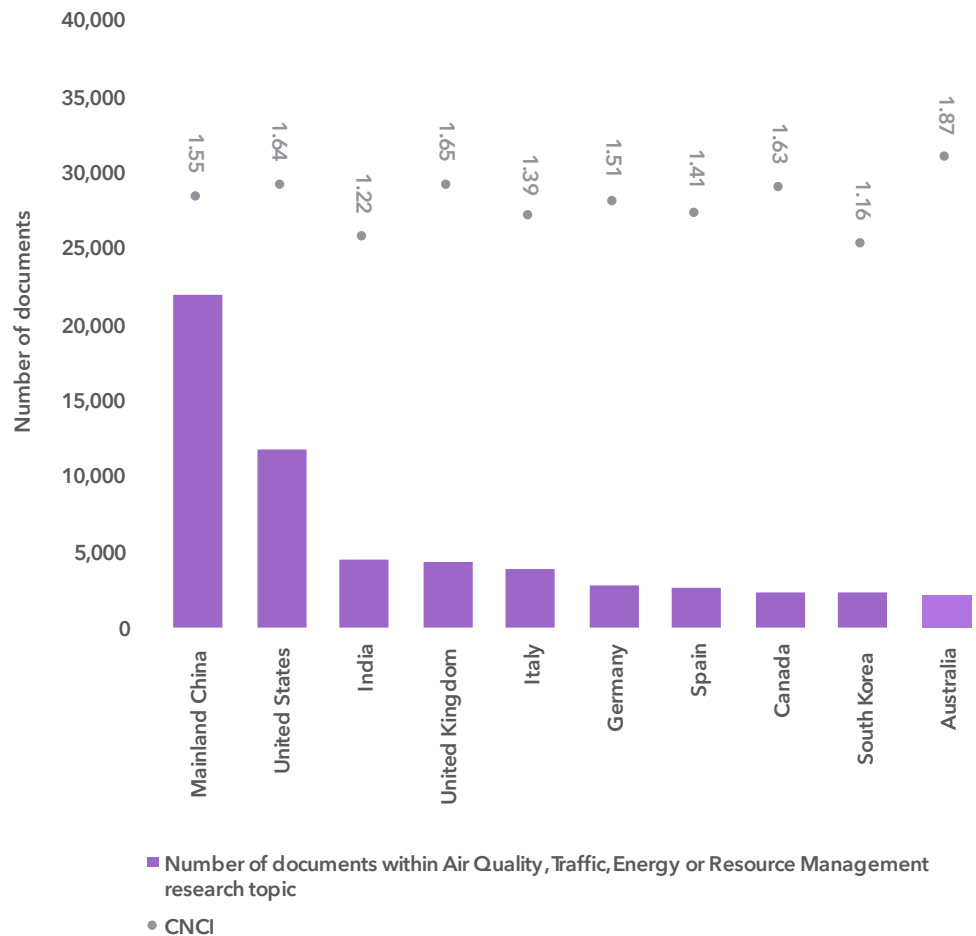


Figure 31: Top 10 countries in terms of the number of publications in the research topic Air Quality, Traffic, Energy or Resource Management in the period 2014-2023 and their corresponding CNCI

4.1.1.7 Top 20 organizations globally in terms of number of publications

The top 3 organizations in terms of number of publications published in this research topic in the period 2014-2023 are Chinese Academy of Sciences (3,675 publications) followed by University of Chinese Academy of Sciences, CAS (1,345 publications) and University of California System (1,236 publications) respectively as shown in Figure 32.

In terms of citation impact measured by the CNCI, Harvard University, followed by the University of London and Peking University, had the highest CNCI, with 2.65, 2.28 and 2.19, respectively.

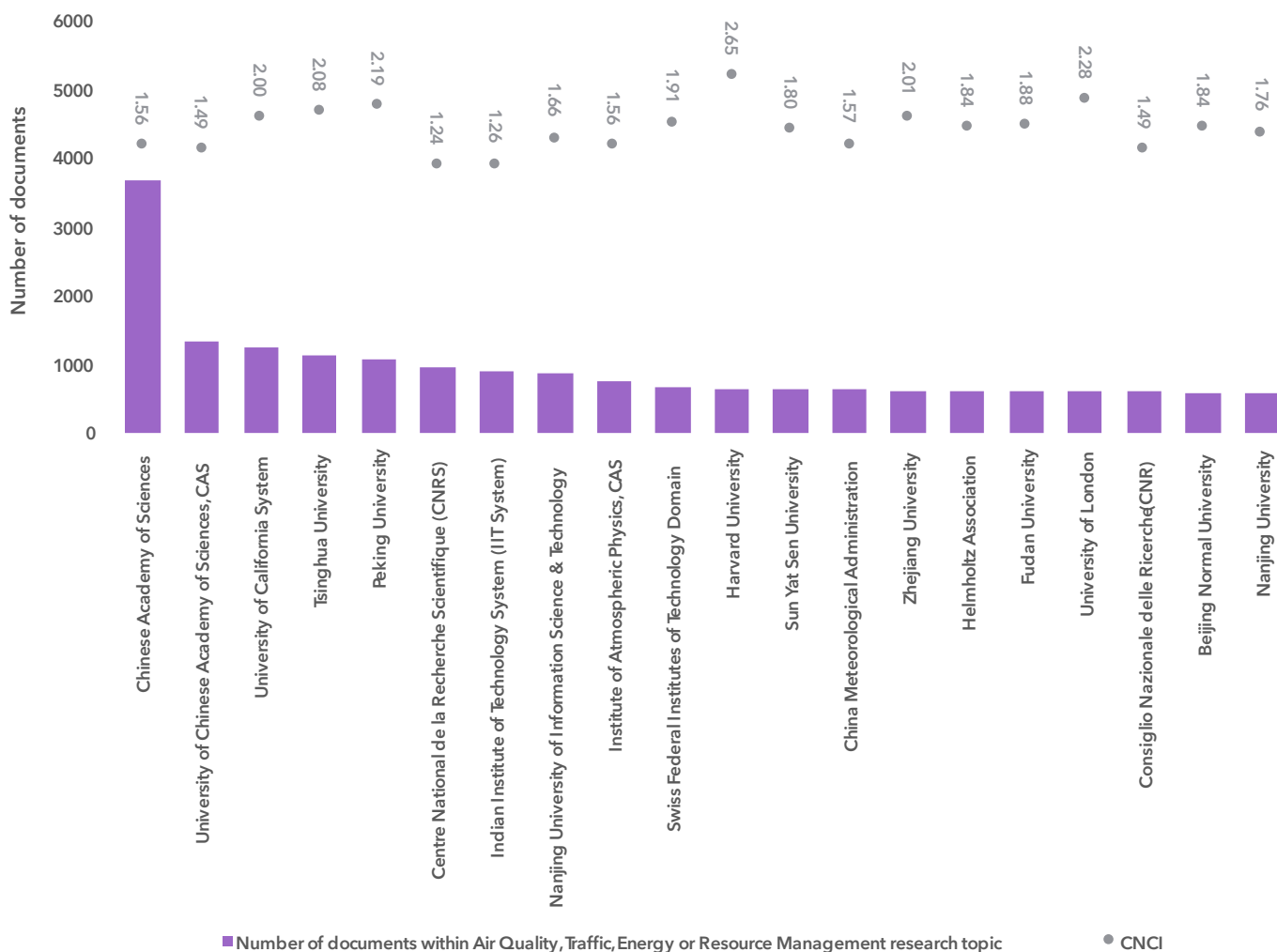


Figure 32: Top 20 organizations globally in terms of the number of publications published in the research topic Air Quality, Traffic, Energy or Resource Management in the period 2014-2023 and their corresponding CNCI

4.1.1.8 Top 20 researchers globally in terms of number of publications

The top 3 researchers globally in terms of the number of publications in this research topic are Junji Cao affiliated with the Chinese Academy of Sciences, with 227 publications, followed by Yele Sun, affiliated with the Chinese Academy of Sciences, with 158 publications, and Yuesi Wang, affiliated to the Chinese Academy of Sciences with 149 publications as shown in Table 7.

The highest CNCI among the top 20 researchers globally is achieved by Qiang Zhang affiliated to Tsinghua University with a CNCI of 3.66.

Haidong Kan affiliated to Fudan University has the highest Top 1% publications amounting to 8 publications and Top 10% publications amounting to 45 publications.

Table 7: Top 20 researchers globally in terms of the number of publications published in the research topic Air Quality, Traffic, Energy or Resource Management in the period 2014-2023

Name	Affiliation	Web of Science Publications	CNCI	Documents in the top 1%	Documents in the top 10%	Country
Cao, Junji	Chinese Academy of Sciences	227	1.47	2	44	Mainland China
Sun, Yele	Chinese Academy of Sciences	158	1.65	2	34	Mainland China
Wang, Yuesi	Chinese Academy of Sciences	149	1.82	2	44	Mainland China
Wang, Zifa	Chinese Academy of Sciences	133	1.59	3	26	Mainland China
Kumar, Prashant	University of Surrey	127	1.38	1	23	England
Querol, Xavier	Consejo Superior de Investigaciones Cientificas (CSIC)	116	1.91	4	30	Spain
Chen, Jianmin	Fudan University	110	2.35	6	31	Mainland China
Harrison, Roy M.	University of Birmingham	109	1.68	1	27	England
Wang, Xinming	Chinese Academy of Sciences	101	1.36	1	18	Mainland China
Hopke, Philip K.	Clarkson University	100	1.53	0	24	United States
Fu, Pingqing	Tianjin University	99	1.37	0	14	Mainland China
Hu, Min	Peking University	94	2.14	3	28	Mainland China
Kan, Haidong	Fudan University	88	3.48	8	45	Mainland China
Latif, Mohd Talib	Universiti Kebangsaan Malaysia	87	1.29	1	18	Malaysia
Prevot, Andre S. H.	Paul Scherrer Institute	85	2.88	2	23	Switzerland
Schauer, James J.	University of Wisconsin Madison	82	1.30	0	17	United States
Koutrakis, Petros	Harvard University	81	2.33	4	27	United States
Wang, Shuxiao	Tsinghua University	81	2.31	4	34	Mainland China
Liu, Zirui	Chinese Academy of Sciences	80	2.02	2	24	Mainland China
Zhang, Qiang	Tsinghua University	77	3.66	5	38	Mainland China

4.1.1.9 Top 20 global funders globally in terms of number of publications

The top 3 organizations in terms of funded publications in this research topic are National Natural Science Foundation of China (NSFC) with 12,272 publications followed by European Union (EU) with 1,931 publications and National Key Research & Development Program of China with 1903 publications as shown in Figure 33.

The highest citation impact measured by the CNCI is observed in publications funded by the National Basic Research Program of China followed by National Science Foundation (NSF) and Natural Environment Research Council (NERC) with 2.07, 1.98 and 1.96, respectively.

Among the top 20 global funding organizations, 10 are also among the top 20 funding organizations of Saudi publications in this research topic.

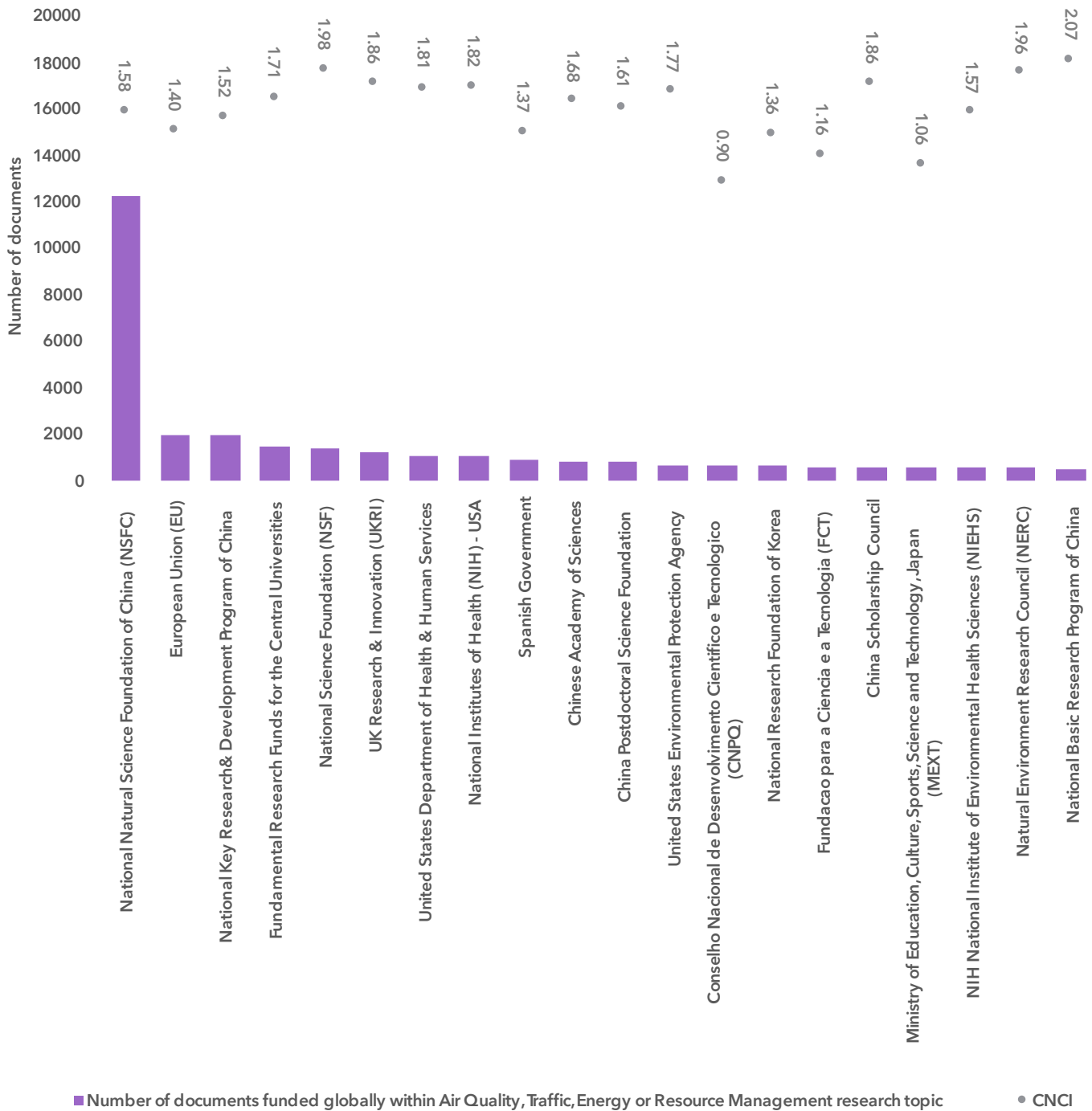


Figure 33: Top 20 funding organizations globally publications in the research topic Air Quality, Traffic, Energy or Resource Management in terms of number of publications in the period 2014-2023

4.1.1.10 Emerging trends in the research topic globally and in Saudi Arabia

In this section we investigate the emerging trends globally and in Saudi Arabia in the research topic Cognitive Cities: Air Quality, Traffic, Energy or Resource Management. For more information on the methodology used to identify emerging trends, please see the definition section Emerging Trends.

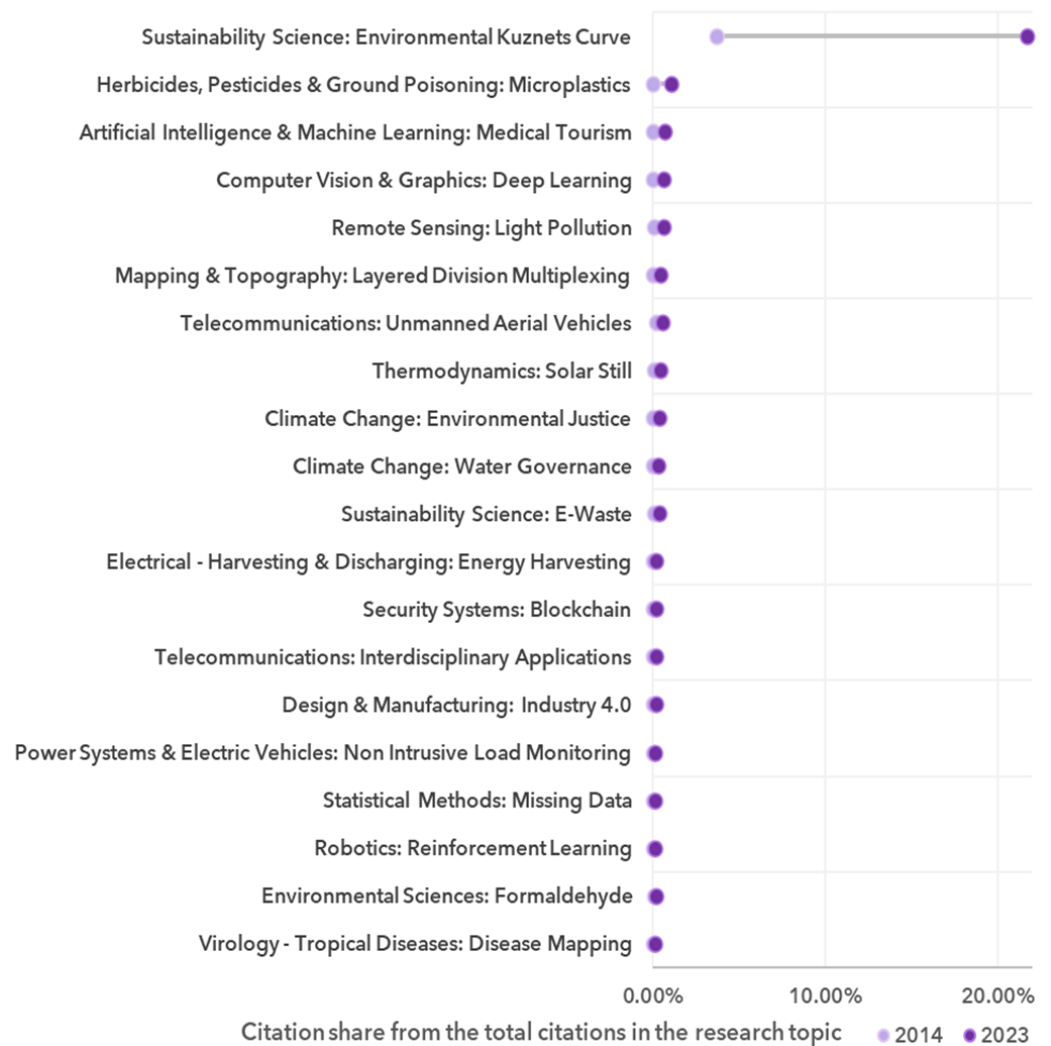


Figure 34: Top 20 emerging micro-topics globally in the research topic Air Quality, Traffic, Energy or Resource Management in the period 2014-2023

The top 3 emerging micro-topics globally in this research topic are Sustainability Science: Environmental Kuznets Curve followed by Herbicides, Pesticides & Ground Poisoning: Microplastics and Artificial Intelligence & Machine Learning: Medical Tourism as shown in Figure 34.

Table 8 shows the identified top 10 micro-topics in Saudi Arabia research output in this research topic.

Table 8: Top 10 Micro-topics identified in Saudi Arabia research output in the research topic Air Quality, Traffic, Energy or Resource Management in the period 2014-2023

Topic	Number of Saudi Arabia publications in the period 2014-2023
Air Quality, Traffic, Energy or Resource Management	1155
Environmental Sciences: Aerosols	220
Sustainability Science: Environmental Kuznets Curve	108
Transportation: Traffic Flow	70
Environmental Sciences: Air Pollution	61
Power Systems & Electric Vehicles: Unit Commitment	54
Telecommunications: Internet Of Things	47
Telecommunications: Vehicular ad hoc Networks	44
Power Systems & Electric Vehicles: MPPT	35
Sustainability Science: Thermal Comfort	33
Contamination & Phytoremediation: Heavy Metals	28

4.1.2 Virtual Cities

4.1.2.1 Evolution of Saudi publication share of global publications in the research topic

The share of Saudi Arabia publications from global publications in the research topic increased almost continuously from 2014 till 2023 as shown in Figure 35. This indicates that Saudi Arabia was not only able to increase the number of publications in this research topic but also having a growth higher than the global growth rate.

This is evident as the share of Saudi Arabian publications in the research topic is growing. The CNCI of Saudi Arabian publications in this research topic was several years ago lower than 1, indicating a citation impact performance lower than the global average.

Although the CNCI decreased from 1.81 in 2017 to 0.85 in 2020 it increased to 1.40 in 2022 and 1.16 in 2023. In high publication periods it is usually observed that the citation impact decreases as also observed in this case.

Overall, Saudi Arabia publications increased with a higher growth rate than the global average in this research topic and had a relatively low citation impact as measured by the CNCI. After this high growth rate in terms of publications, one should focus on increasing the citation impact, which shows a recovery in 2021-2023.

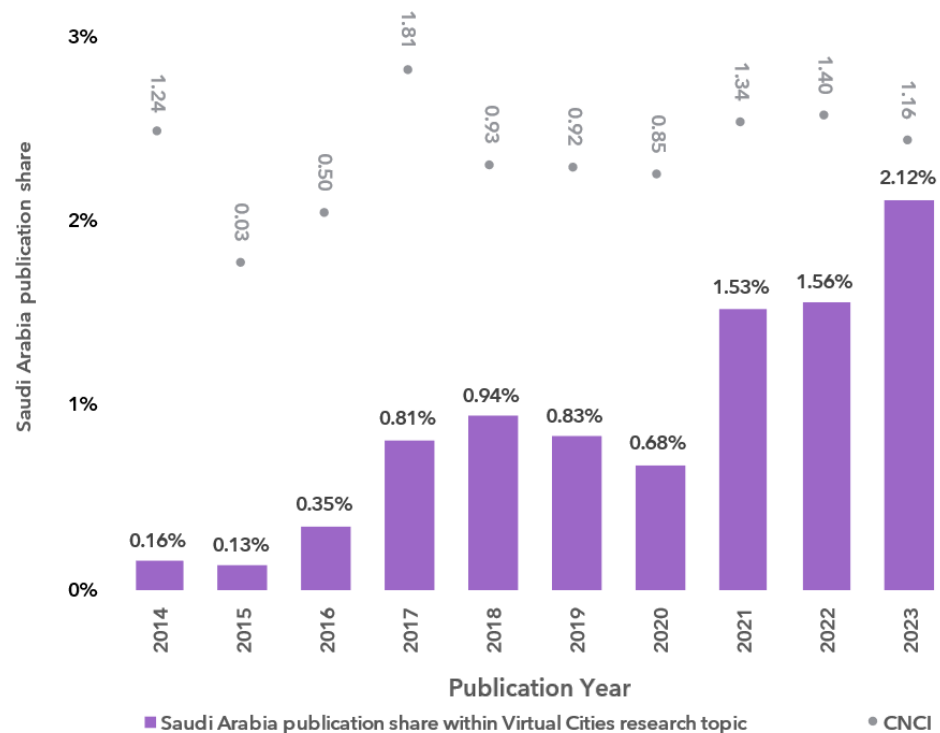


Figure 35: The share of Saudi Arabia from global publications in the research topic and the CNCI of Saudi Arabia publications in the research topic Virtual Cities in the period 2014-2023

4.1.2.2 Top 10 countries collaborating with Saudi Arabia

The top collaborating country with Saudi Arabia in this research topic in the period 2014-2023 is Egypt followed by the United States and United Kingdom, Pakistan and Mainland China sharing the same number of publications with 21, 16 and 10 publications respectively as shown in Figure 36.

In terms of citation impact measured by the CNCI publications published in collaboration with Tunisia followed by United Kingdom and Australia had the highest CNCI with 2.58, 2.28 and 2.05, respectively. Nevertheless, the CNCI exceeds 1 for

collaborations with 7 of the top 10 collaborating countries reflecting a performance higher than the global average.

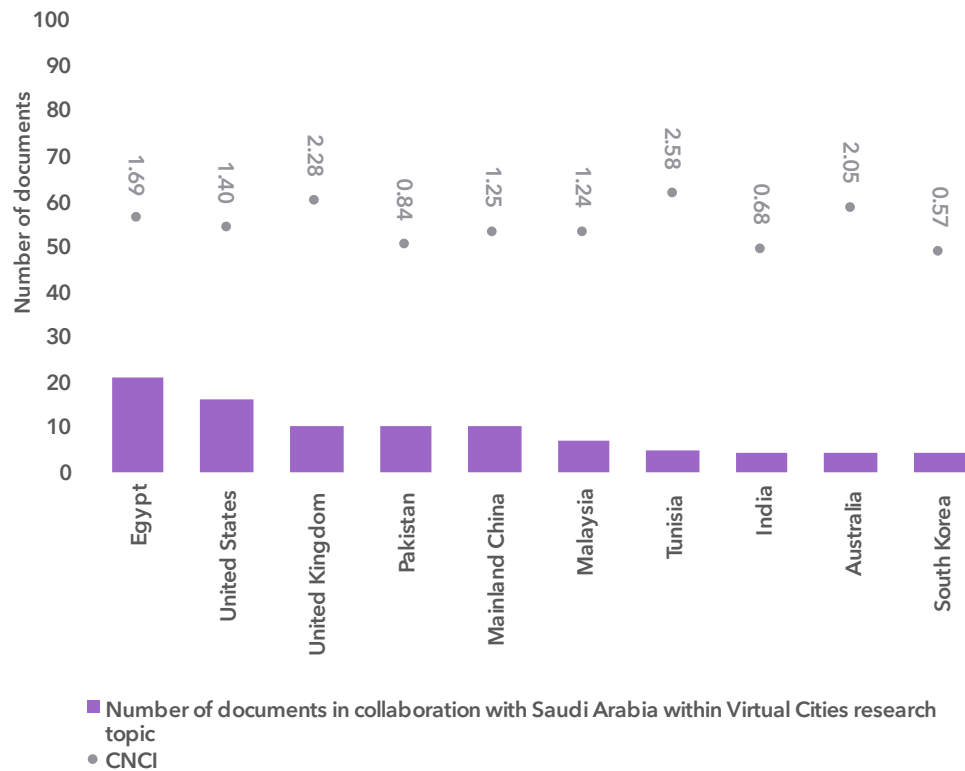


Figure 36: Top 10 collaborating countries with Saudi Arabia in terms of the number of publications in the research topic Virtual Cities in the period 2014-2023

4.1.2.3 Top 20 funders of Saudi publications by number of publications

The top 3 funding organizations of Saudi Arabia publications in this research topic in terms of number of publications mentioning the organization in the funding text in the period 2014-2023 are King Saud University followed by Princess Nourah bint Abdulrahman University followed by European Research Council (ERC), UK Research & Innovation (UKRI) and Engineering & Physical Sciences Research Council (EPSRC) sharing the same number of publications with 8, 5 and 3 publications respectively as shown in Figure 37.

Documents funded National Key Research & Development Program of China, followed by UK Research & Innovation (UKRI) and Engineering & Physical Sciences Research Council (EPSRC) sharing the same CNCI followed by Google Incorporated had the highest citation impact measured by the CNCI with 5.58, 2.92 and 2.24, respectively.

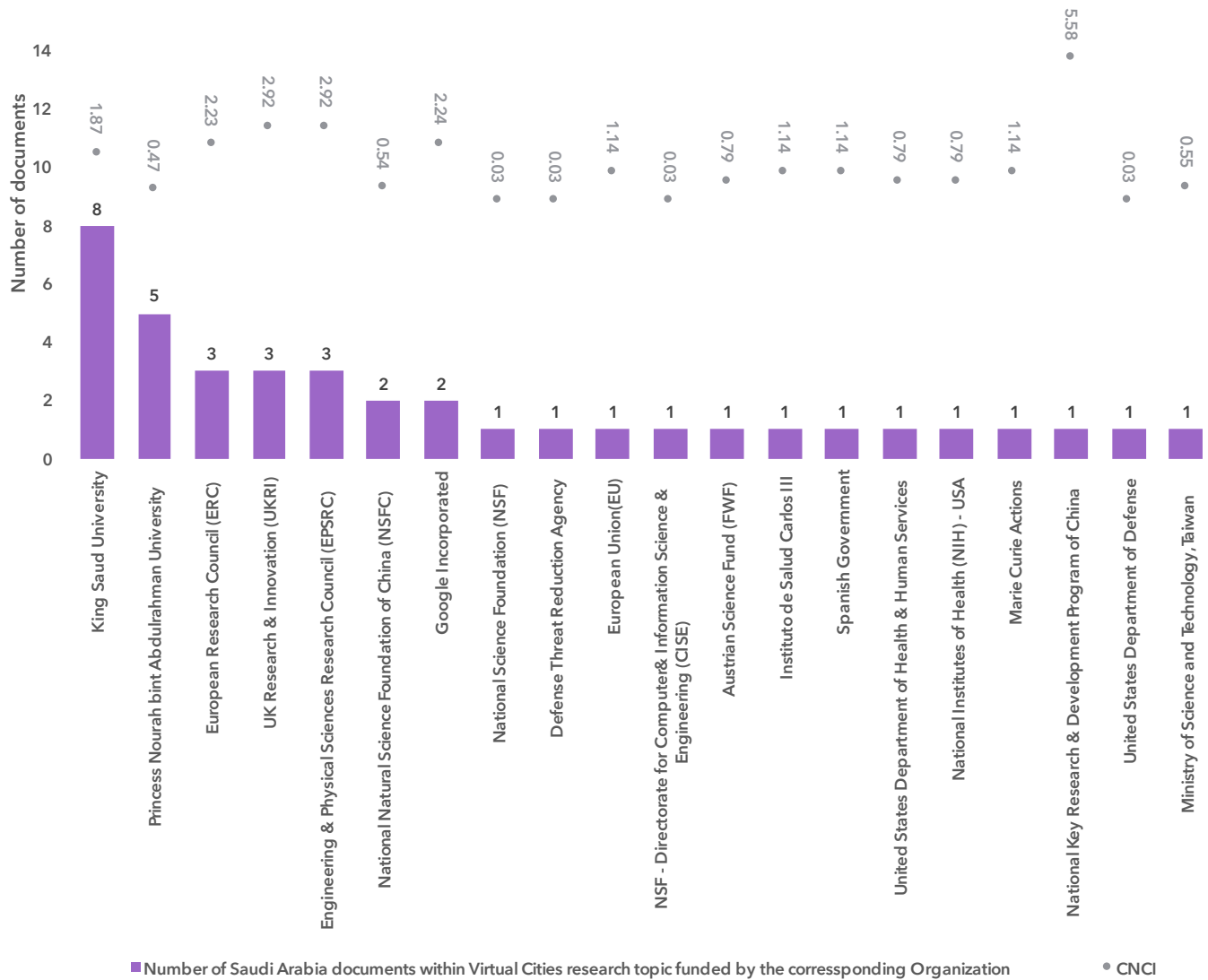


Figure 37: Top 20 funding organizations of Saudi Arabia publications in the research topic Virtual Cities in terms of number of publications in the period 2014-2023

4.1.2.4 Top 20 Saudi Arabia organizations in terms of number of publications

The top 3 organizations in terms of publications published in this research topic and the period 2014-2023 are King Abdulaziz University, followed by King Saud University and Umm Al Qura University, with 19, 15 and 11 publications, respectively, as shown in Figure 38.

In terms of citation impact as measured by the CNCI, the University of Bisha, followed by the University Ha'il and King Abdullah University of Science & Technology, had the highest CNCI, with 2.79, 2.63 and 1.87, respectively.

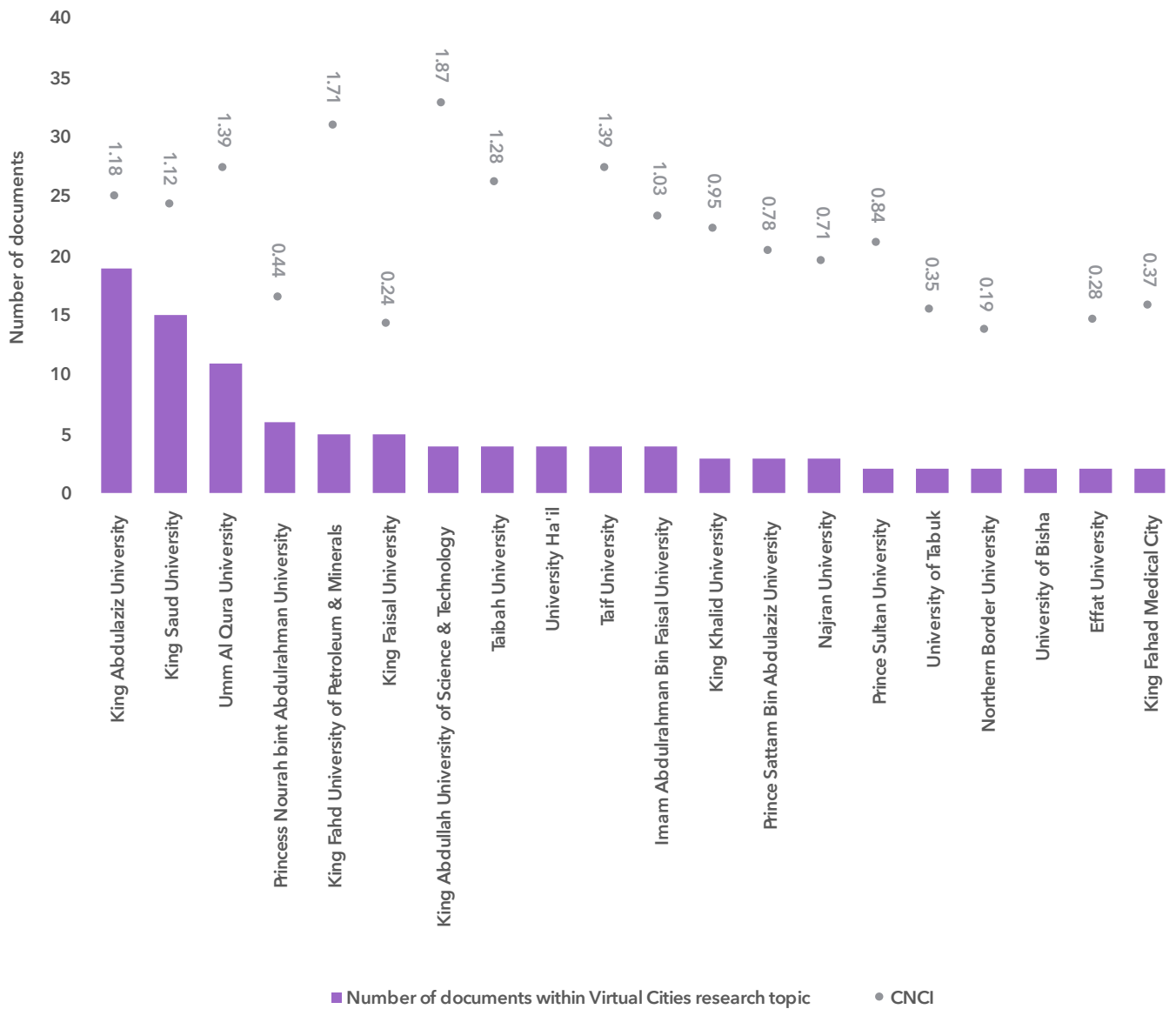


Figure 38: Top 20 Saudi organizations in terms of publications published in the research topic Virtual Cities in the period 2014-2023 and their corresponding CNCI

4.1.2.5 Top 20 researchers affiliated to Saudi organizations in terms of number of publications

The top 20 researchers can be categorized into three groups based on their number of Web of Science publications: Group 1 consists of researchers who each have three publications, Group 2 includes those with two publications each, and Group 3 comprises researchers who each have one publication as shown in Table 9.

The highest CNCI is achieved by publications published to Binash Inteyaz affiliated with King Fahd University of Petroleum & Minerals with a CNCI of 2.81 reflecting a citation impact performance 181% higher than the global average.

None of the researchers had publications among the top 1%, while only four researchers got publications among the top 10%.

Table 9: Top 20 researchers affiliated with Saudi organizations in terms of the number of publications published on the research topic Virtual Cities in the period 2014-2023

Name	Affiliation	Web of Science Publications	CNCI	Documents in the top 1%	Documents in the top 10%
Hasyimi, Valid	King Abdulaziz University	3	0.65	0	0
Khadidos, Adil O.	King Abdulaziz University	3	1.42	0	0
Othman, Abdullah	Umm Al Qura University	3	2.32	0	1
Wonka, Peter	King Abdullah University of Science & Technology	3	2.23	0	2
Alyoubi, Khaled H.	King Abdulaziz University	3	1.42	0	0
Khadidos, Alaa O.	King Abdulaziz University	3	1.42	0	0
Azizalrahman, Hossny	King Abdulaziz University	3	0.65	0	0
Imran, Muhammad	King Saud University	2	0.57	0	0
Hamza, Manar Ahmed	Prince Sattam Bin Abdulaziz University	2	0.98	0	0
Hussain, Riaz	King Faisal University	2	0.02	0	0
Zamani, Abu Sarwar	Prince Sattam Bin Abdulaziz University	2	0.98	0	0
Alshareef, Abdulrhman M.	King Abdulaziz University	2	1.07	0	0
Hassan, Mohammad Mehedi	King Saud University	2	2.17	0	1
Alali, Abdulrhman Fahmi	King Saud University	1	0.20	0	0
Jaad, Ahmed	Umm Al Qura University	1	2.11	0	0
Bakhsh, Ismail	King Fahad Medical City	1	0.75	0	0
Imteyaz, Binash	King Fahd University of Petroleum & Minerals	1	2.61	0	1
Abid, Naushad	King Faisal University	1	0.00	0	0
Fagih, Musa	King Fahad Medical City	1	0.75	0	0
Siraj, Mohammad	King Saud University	1	0.26	0	0

4.1.2.6 Top 10 countries in terms of publications

The highest number of publications published in this research topic are published by Mainland China (1,990 publications) followed by United States (1,882 publications) and United Kingdom (801 publications) as shown in Figure 39.

The highest citation impact measured by the CNCI is achieved by publications published by Australia, United Kingdom, and United States with a CNCI of 1.73, 1.66 and 1.61, respectively.

Five of the top 10 countries in terms of number of publications published in the research topic are also among the top 10 collaborators with Saudi Arabia. These are Mainland China, United States, United Kingdom, Australia, and India.

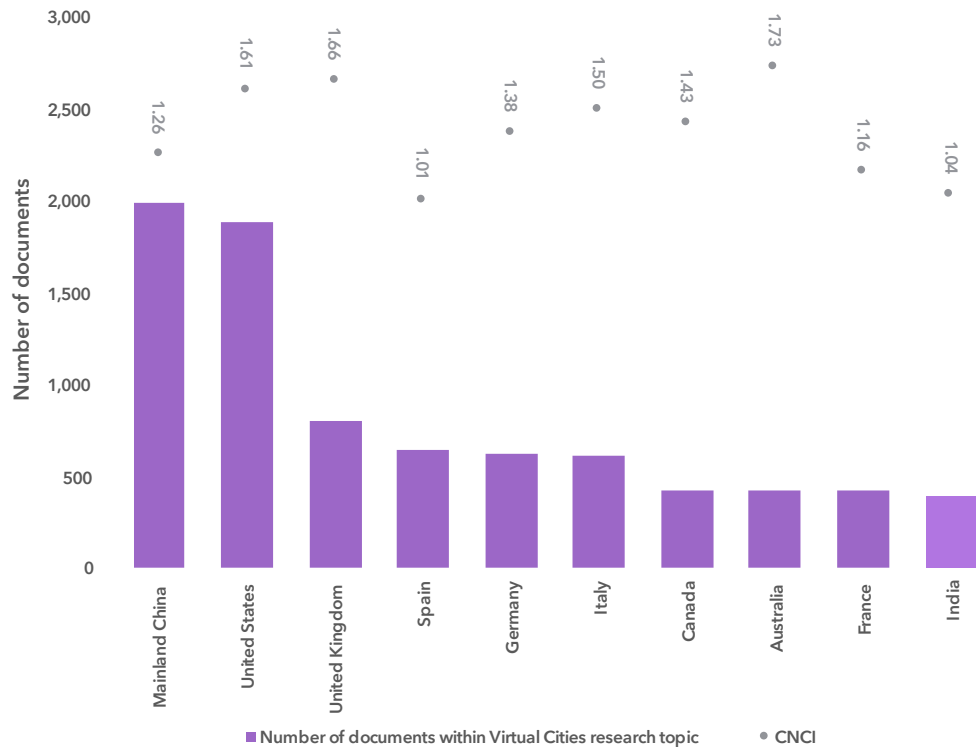


Figure 39: Top 10 countries in terms of the number of publications in the research topic Virtual Cities in the period 2014-2023 and their corresponding CNCI

4.1.2.7 Top 20 organizations globally in terms of number of publications

The top 3 organizations in terms of the number of publications published on this research topic in the period 2014-2023 are the Chinese Academy of Sciences (187 publications), followed by the University of California (163 publications) and the University of London (140 publications), respectively, as shown in Figure 40.

In terms of citation impact measured by the CNCI National University of Singapore followed by Harvard University and Sun Yat Sen University had the highest CNCI with 2.72, 2.71 and 2.25, respectively.

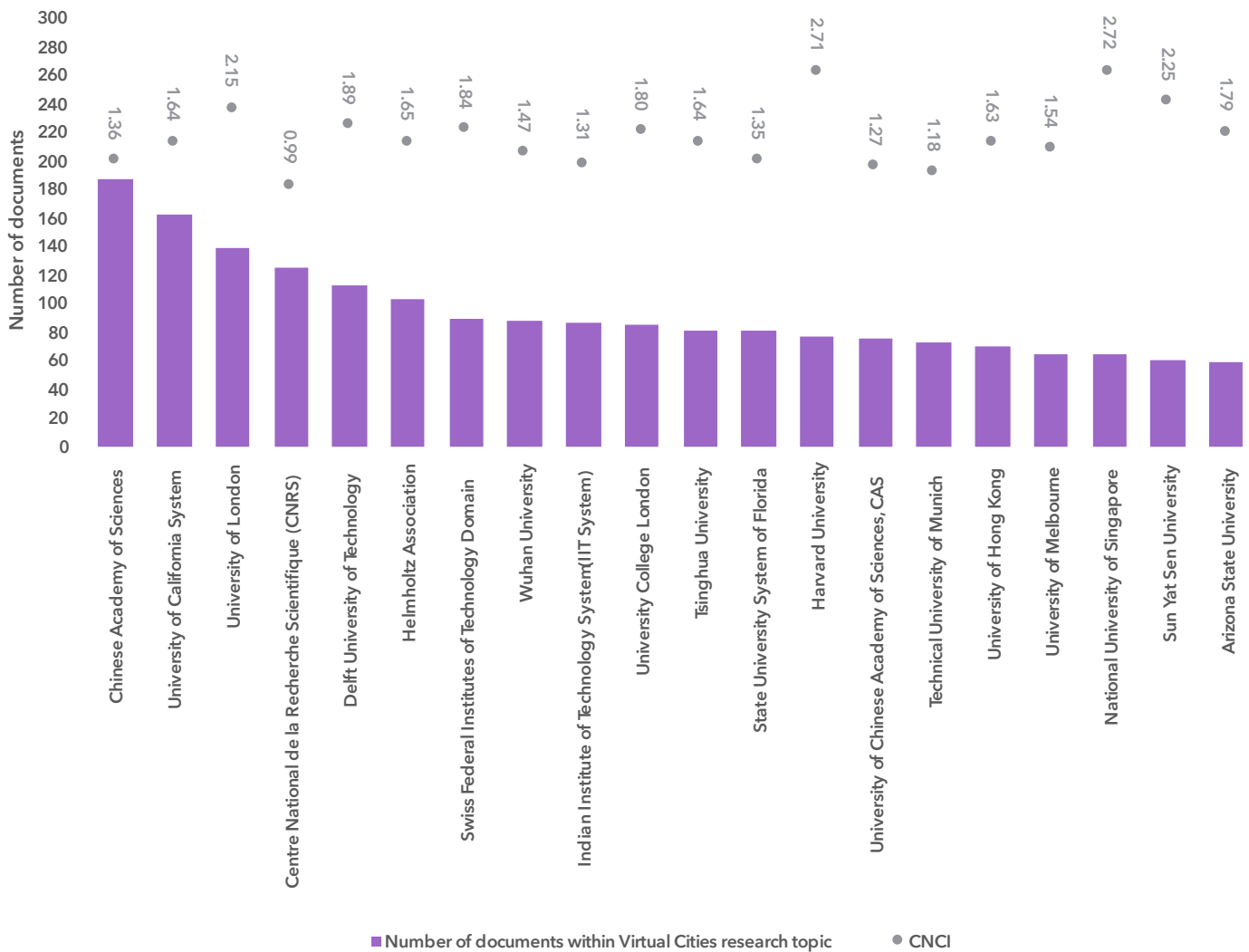


Figure 40: Top 20 organizations globally in terms of the number of publications published in the research topic Virtual Cities in the period 2014-2023 and their corresponding CNCI

4.1.2.8 Top 20 researchers globally in terms of number of publications

The top three researchers globally in terms of the number of publications in this research topic are Jantien Stoter, affiliated to Delft University of Technology, with 23 publications, Hugo Ledoux, affiliated to Delft University of Technology, with 18 publications, and Simon Elias Bibri, affiliated to Norwegian University of Science & Technology (NTNU), with 17 publications, as shown in Table 10.

Among the top 20 researchers globally, Yuming Guo from Monash University has the highest CNCI. Haidong Kan from Fudan University has the highest number of publications in the top 1% globally. In comparison, Simon Elias Bibri from the Norwegian University of Science & Technology (NTNU) has the highest number of publications in the top 10%.

Table 10: Top 20 researchers globally in terms of the number of publications published on the research topic Virtual Cities in the period 2014-2023

Name	Affiliation	Web of Science Publications	CNCI	Documents in top 1%	Documents in the top 10%	Country
Stoter, Jantien	Delft University of Technology	23	2.62	1	11	Netherlands
Ledoux, Hugo	Delft University of Technology	18	2.46	1	7	Netherlands
Bibri, Simon Elias	Norwegian University of Science & Technology (NTNU)	17	5.38	4	11	Norway
Kolbe, Thomas H.	Technical University of Munich	12	1.73	0	3	Germany
Zhu, Xiao Xiang	Technical University of Munich	12	1.64	0	3	Germany
Gesquiere, Gilles	Institut National des Sciences Appliquees de Lyon - INSA Lyon	11	0.79	0	1	France
Biljecki, Filip	Delft University of Technology	11	3.03	1	6	Netherlands
Hsu, Li-Ta	Hong Kong Polytechnic University	11	1.88	0	3	Hong Kong
Krogstie, John	Norwegian University of Science & Technology (NTNU)	10	6.19	3	7	Norway
Kan, Haidong	Fudan University	10	5.97	4	6	Mainland China
Ohori, Ken Arroyo	Delft University of Technology	10	1.40	0	3	Netherlands
Zhou, Maigeng	Chinese Center for Disease Control & Prevention	10	4.96	3	6	Mainland China
Guo, Yuming	Monash University	10	7.00	3	7	Australia
Ojala, Timo	University of Oulu	9	1.62	0	2	Finland
Stoter, J.	Delft University of Technology	9	3.28	1	4	Netherlands
Rui, Jia	Xiamen University	9	0.59	0	0	Mainland China
Kolbe, T. H.	Technical University of Munich	9	1.07	0	1	Germany
Chen, Tianmu	Xiamen University	9	0.42	0	0	Mainland China
Harrie, Lars	Lund University	9	1.43	0	2	Sweden
Li, Yuguo	University of Hong Kong	8	0.85	0	0	Hong Kong

4.1.2.9 Top 20 global funders globally in terms of number of publications

The top 3 organizations in terms of funded publications in this research topic are National Natural Science Foundation of China (NSFC) with 829 publications followed by European Union (EU) with 282 publications and National Science Foundation (NSF) with 233 publications as shown in Figure 41.

The highest citation impact measured by the CNCI is observed in publications funded by Economic & Social Research Council (ESRC), National Science Foundation (NSF) and National Institutes of Health (NIH) - USA with 2.37, 2.27 and 2.02, respectively.

Among the top 20 global funding organizations, 10 are also among the top 20 funding organizations of Saudi publications in this research topic.

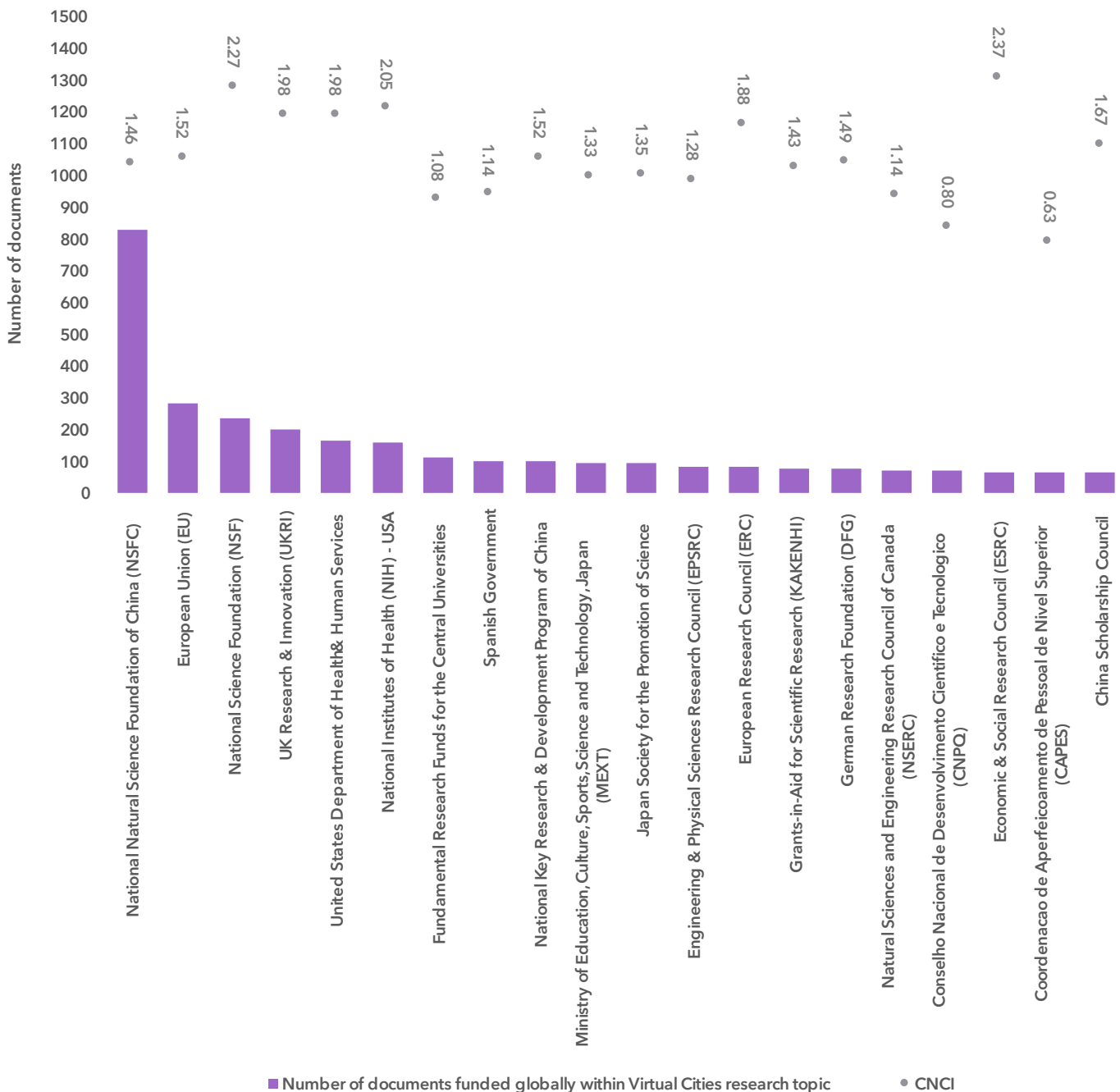


Figure 41: Top 20 funding organizations globally publications in the research topic Virtual Cities in terms of number of publications in the period 2014-2023

4.1.2.10 Emerging trends in the research topic globally and in Saudi Arabia

In this section we investigate the emerging trends globally and in Saudi Arabia in the research topic Virtual Cities. For more information on the methodology used to identify emerging trends, please see the definition section Emerging Trends.

The top 3 emerging micro-topics globally in this research topic are Design & Manufacturing: Industry 4.0 followed by Hospitality, Leisure, Sport & Tourism: Place Attachment and Security Systems: Blockchain as shown in Figure 42. Saudi Arabia has very few publications on this research topic, such that it was not meaningful to identify emerging micro-topics. Table 11 shows the identified top 10 micro-topics in Saudi Arabia research output in this research topic.



Figure 42: Top 20 emerging micro-topics globally in the research topic Virtual Cities in the period 2014-2023

Table 11: Top 10 Micro-topics identified in Saudi Arabia research output in the research topic Virtual Cities in the period 2014-2023

Topic	Number of Saudi Arabia publications in the period 2014-2023
Virtual Cities	108
Telecommunications: Internet Of Things	17
Management: Technology Acceptance Model	5
Artificial Intelligence & Machine Learning: Intrusion Detection	5
Power Systems & Electric Vehicles: MPPT	4
Sustainability Science: Environmental Kuznets Curve	4
Telecommunications: Vehicular ad hoc Networks	4

Computer Vision & Graphics: Volume Rendering	3
Climate Change: Climate Change Adaptation	3
Forestry: Ecosystem Services	3
Security Systems: Blockchain	2

4.1.3 Citizen Engagement

4.1.3.1 Evolution of Saudi publication share of global publications in the research topic

The share of Saudi Arabia publications from global publications in the research topic increased almost continuously from 2014 till 2023 as shown in Figure 43. This shows that Saudi Arabia was not only able to increase the number of publications in this research topic but also having a growth higher than the global growth rate.

This is evident as the share of Saudi Arabia publications in the research topic is growing. The CNCI of Saudi Arabia publications in this research topic was in several years higher than 1, indicating a citation impact performance higher than the global average. Although the CNCI dropped significantly from 1.73 in 2014 to 0.36 in 2015, it surged to 2.71 in 2016, reflecting a 171% higher citation impact performance than the global average.

However, by 2023, the CNCI had decreased to 0.81, which is 19% below the world average. Overall, Saudi Arabia publications increased with a higher growth rate than the global average in this research topic and had a fluctuating citation impact between good and poor as measured by the CNCI.

Nevertheless, after this high growth rate in terms of publications, one should focus on increasing/stabilizing the fluctuating citation impact.

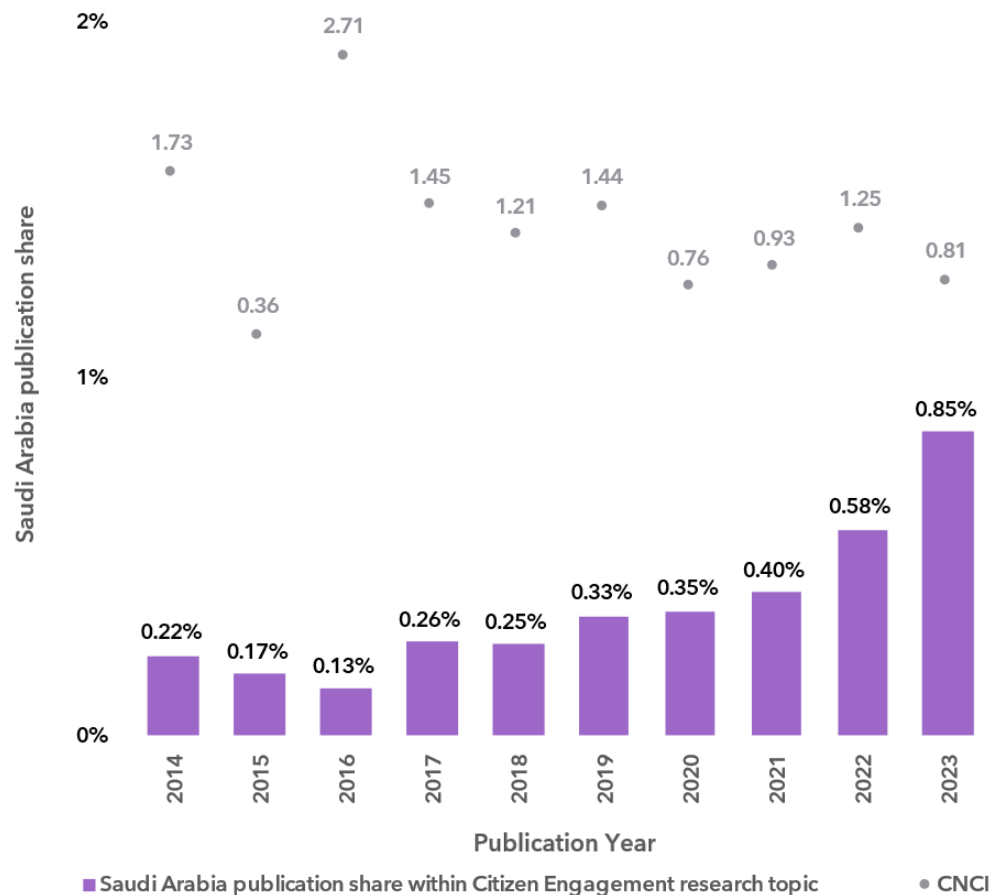


Figure 43: The share of Saudi Arabia from global publications in the research topic and the CNCI of Saudi Arabia publications in the research topic Citizen Engagement in the period 2014-2023

4.1.3.2 Top 10 countries collaborating with Saudi Arabia

The top collaborating countries with Saudi Arabia in this research topic in the period 2014-2023 are the United States, followed by the United Kingdom and Australia with 28, 26 and 22 publications, respectively as shown in Figure 44 and terms of citation impact measured by the CNCI publications published in collaboration with Mainland China, Canada and the United Kingdom had the highest CNCI with 2.16, 2.13 and

1.98, respectively. Nevertheless, all publications with the top 10 collaborating countries except the Netherlands had a CNCI higher than 1, reflecting a performance higher than the global average.

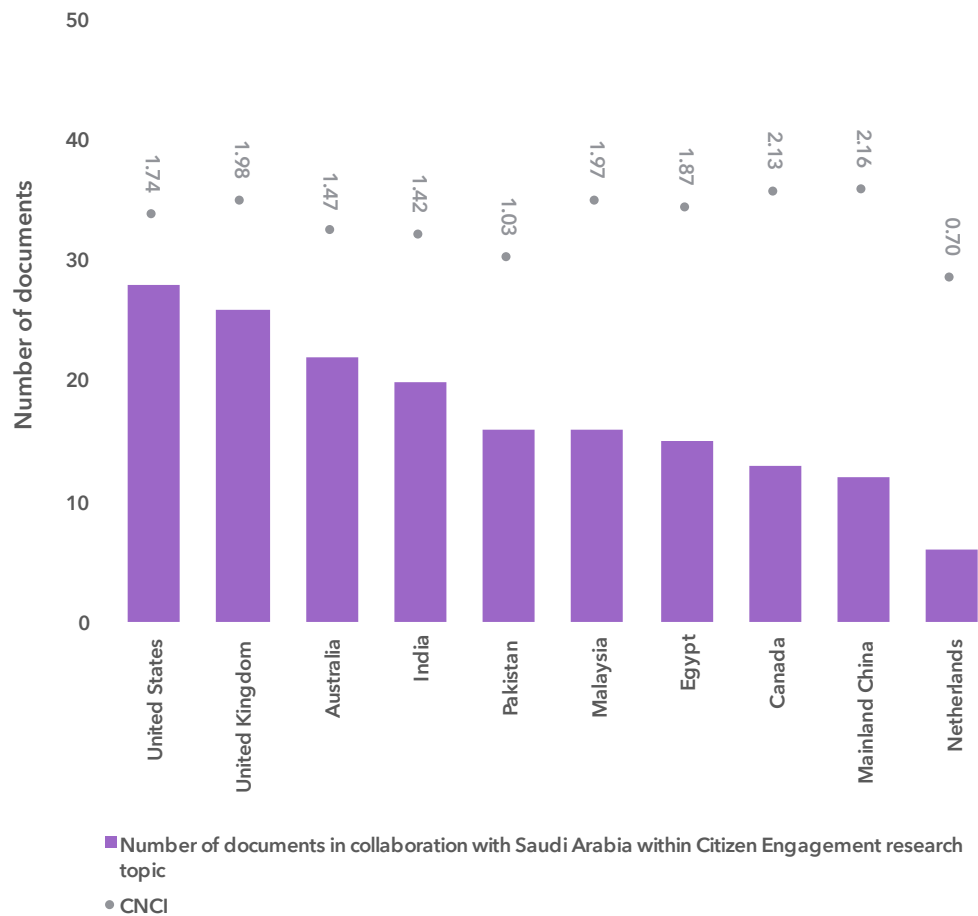


Figure 44: Top 10 collaborating countries with Saudi Arabia in terms of the number of publications in the research topic Citizen Engagement in the period 2014-2023

4.1.3.3 Top 20 funders of Saudi publications by number of publications

The top 3 funding organizations of Saudi Arabia publications in this research topic in terms of number of publications mentioning the organization in the funding text in the period 2014-2023 are King Saud University followed by Princess Nourah bint Abdulrahman University and National Health & Medical Research Council (NHMRC) of Australia with 9, 4 and 3 publications respectively as shown in Figure 45.

Documents funded by AstraZeneca, Boehringer Ingelheim and Sanofi-Aventis with the same CNCI followed by Canadian Institutes of Health Research (CIHR) and National Natural Science Foundation of China (NSFC) had the highest citation impact measured by the CNCI with 6.88, 4.26 and 3.26, respectively.

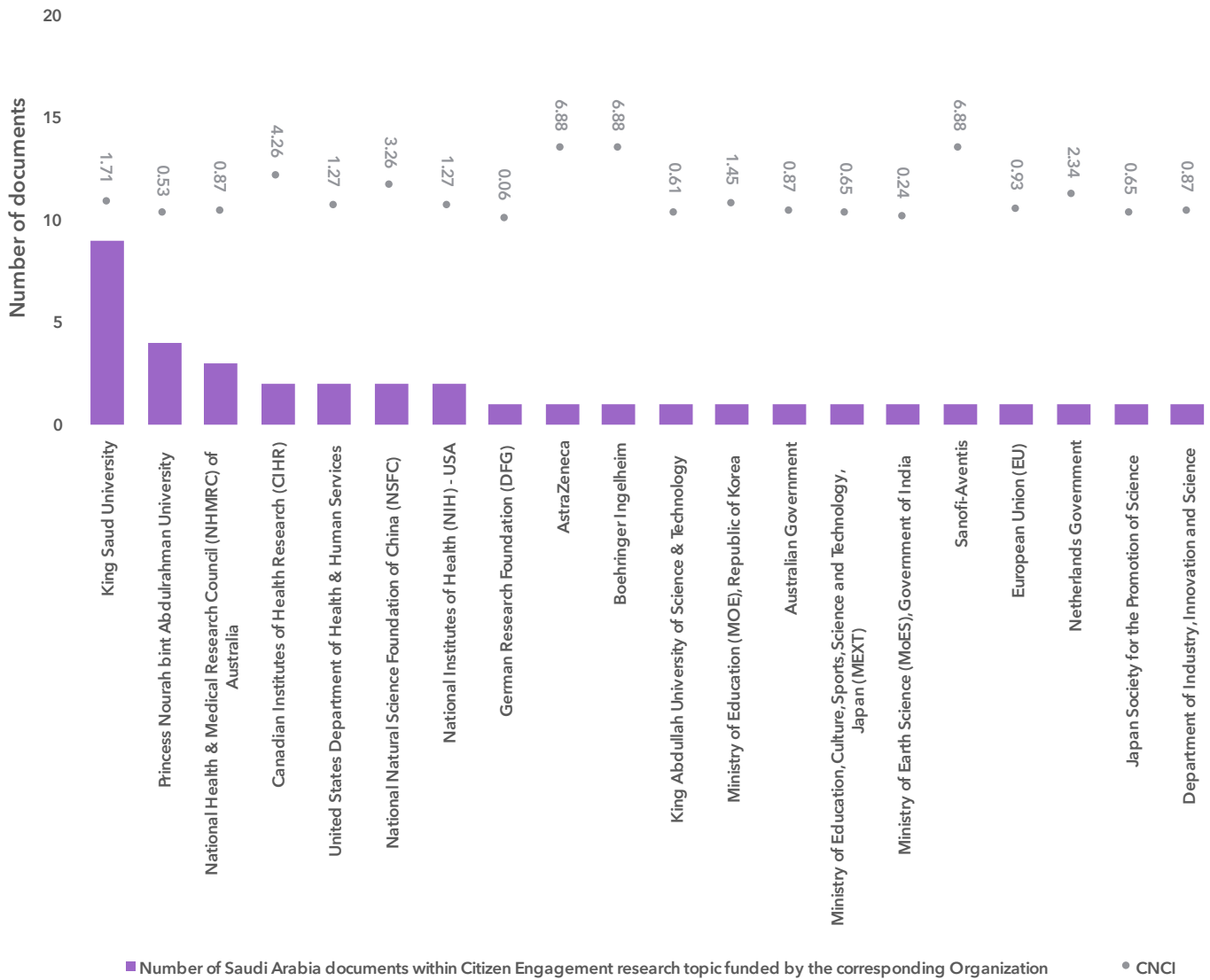


Figure 45: Top 20 funding organizations of Saudi Arabia publications in the research topic Citizen Engagement in terms of number of publications in the period 2014-2023

4.1.3.4 Top 20 Saudi Arabia organizations in terms of number of publications

The top 3 organizations in terms of publications published in this research topic and in the period 2014-2023 are King Saud University followed by King Abdulaziz University and Princess Nourah bint Abdulrahman University with 44, 22 and 15 publications respectively as shown in Figure 46.

In terms of citation impact as measured by the CNCI, King Abdullah University of Science & Technology followed by Prince Sattam Bin Abdulaziz University and Prince Sultan University had the highest CNCI with 2.29, 1.91 and 1.83, respectively.

Nevertheless, 9 out of the top 20 organizations had a CNCI higher than 1, reflecting a citation impact performance higher than the global average.

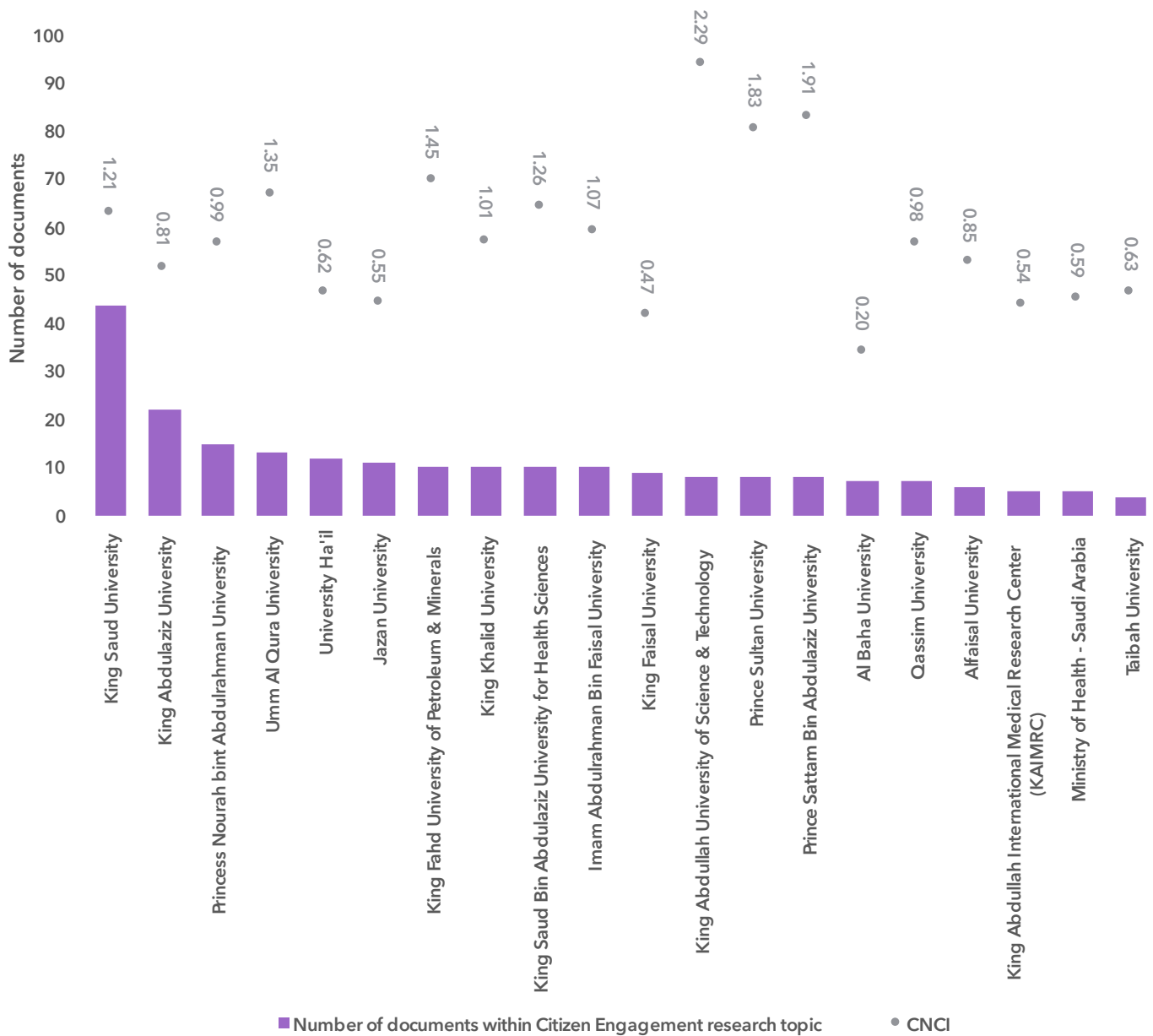


Figure 46: Top 20 Saudi organizations in terms of publications published in the research topic Citizen Engagement in the period 2014-2023 and their corresponding CNCI

4.1.3.5 Top 20 researchers affiliated to Saudi organizations in terms of number of publications

The highest number of publications are published by Abood Khaled Alamoudi affiliated to Imam Abdulrahman Bin Faisal University with four publications as shown in Table 12.

Carlos M. Duarte, affiliated with King Abdullah University of Science & Technology, achieved the highest CNCI, documents in the top 1%, and documents in the top 10% with a CNCI of 4.59, two publications in the top 1% and two publications in the top 10%.

Table 12: Top 20 researchers affiliated with Saudi organizations in terms of the number of publications published on the research topic Citizen Engagement in the period 2014-2023

Name	Affiliation	Web of Science Publications	CNCI	Documents in the top 1%	Documents in the top 10%
Alamoudi, Abood Khaled	Imam Abdulrahman Bin Faisal University	4	1.32	0	0
Alouini, Mohamed-Slim	King Abdullah University of Science & Technology	3	0.43	0	0
Duarte, Carlos M.	King Abdullah University of Science & Technology	3	4.59	2	2
Visvizi, Anna	Effat University	3	3.45	0	1
Alshahrani, Sultan M.	King Khalid University	2	0.31	0	0
Aloudah, Nouf M.	King Saud University	2	0.58	0	0
Obeed, Mohanad	King Fahd University of Petroleum & Minerals	2	0.93	0	0
Alhawassi, Tariq M.	King Saud University	2	0.58	0	0
Alqahtani, Saad S.	Jazan University	2	0.52	0	0
Bouregh, Adel Saleh	Imam Abdulrahman Bin Faisal University	2	2.00	0	1
Azim, Mohammad Tahlil	King Abdulaziz University	2	1.07	0	0
Khan, Abdul Sattar	King Faisal University	2	0.00	0	0
Alabdulqader, Ebtisam	King Saud University	2	1.07	0	0
Altameem, Ayman	King Saud University	2	0.82	0	0
Alrasheedy, Alian A.	Qassim University	2	1.50	0	0
Zummo, Salam A.	King Fahd University of Petroleum & Minerals	2	0.93	0	0
Lytras, Miltiadis D.	King Abdulaziz University	2	4.40	0	1
Trigunarsyah, Bambang	King Fahd University of Petroleum & Minerals	2	1.72	0	1
Salhab, Anas M.	King Fahd University of Petroleum & Minerals	2	0.93	0	0
Algarni, Abeer	Princess Nourah bint Abdulrahman University	2	0.00	0	0

4.1.3.6 Top 10 countries in terms of publications

The highest number of publications in this research topic were published by the United States (21,604 publications), followed by the United Kingdom (6,604 publications) and Australia (5,257 publications), as shown in Figure 47.

The highest citation impact measured by the CNCI is achieved by publications published in the Netherlands and Germany, which share the same CNCI. This is followed by the United Kingdom and Mainland China, which have CNCI of 1.53, 1.49 and 1.44, respectively.

Four of the top 10 countries in terms of the number of publications published on the research topic are also among the top 10 collaborators with Saudi Arabia: the United Kingdom, Australia, Canada, and the Netherlands.

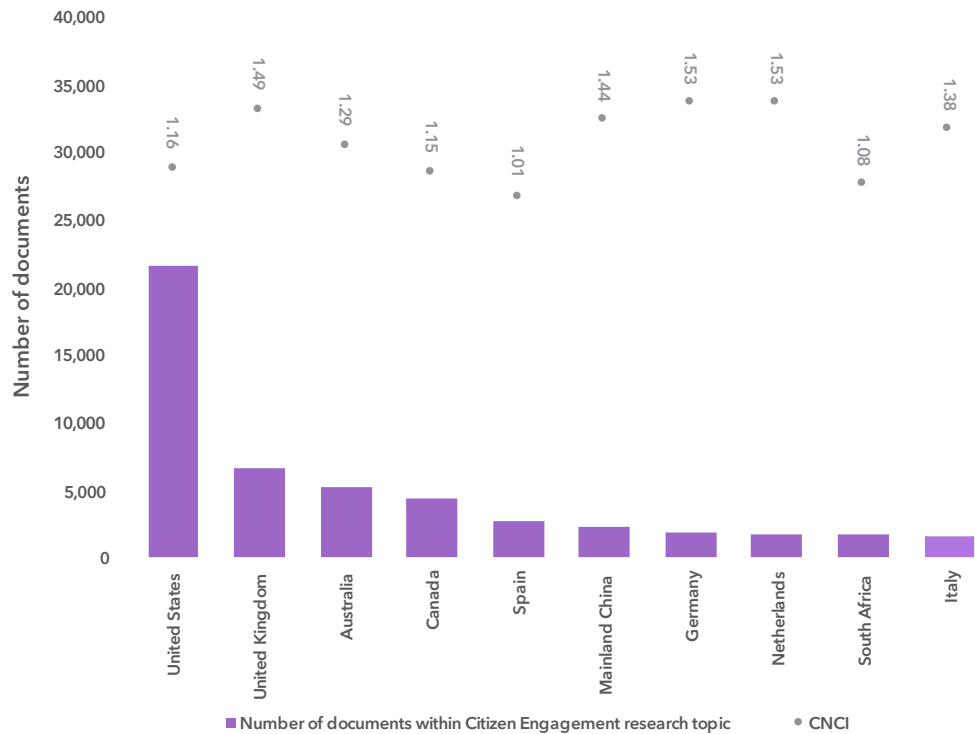


Figure 47: Top 10 countries in terms of the number of publications in the research topic Citizen Engagement in the period 2014-2023 and their corresponding CNCI

4.1.3.7 Top 20 organizations globally in terms of number of publications

The top 3 organizations in terms of the number of publications published on this research topic in the period 2014-2023 are the University of California (1,868 publications), the University of London (1,361 publications), and the University of North Carolina (976 publications) respectively, as shown in Figure 48.

In terms of citation impact measured by the CNCI, University College London, followed by the University of London and the University of Washington Seattle, had the highest CNCI, with 1.96, 1.71 and 1.64, respectively.

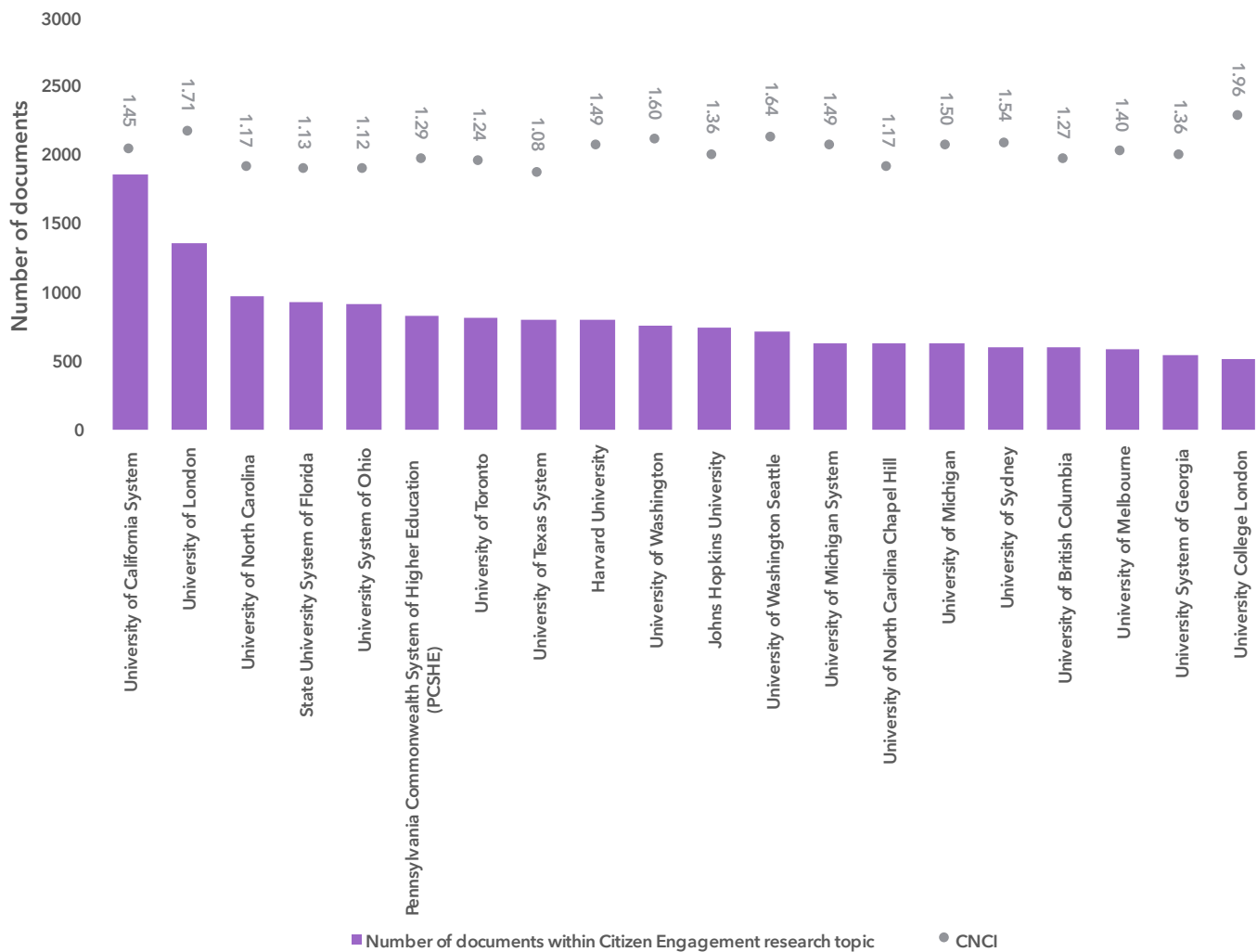


Figure 48: Top 20 organizations globally in terms of the number of publications published in the research topic Citizen Engagement in the period 2014-2023 and their corresponding CNCI

4.1.3.8 Top 20 researchers globally in terms of number of publications

The top 3 researchers globally in terms of the number of publications in this research topic are Christi A. Patten, affiliated with Mayo Clinic, with 40 publications, followed by Joseph D. Tucker, to the University of North Carolina Chapel Hill, with 39 publications, and Nina Wallerstein, affiliated with the University of New Mexico with 37 publications as shown in Table 13.

The highest CNCI, Documents in top 1% and Documents in top 10% among the top 20 researchers globally is achieved by Nina Wallerstein affiliated to University of New Mexico with a CNCI of 3.96, 4 publications in top 1% and 21 publications in top 10%.

Table 13: Top 20 researchers globally in terms of the number of publications published on the research topic Citizen Engagement in the period 2014-2023

Name	Affiliation	Web of Science Publications	CNCI	Documents in the top 1%	Documents in the top 10%	Country
Patten, Christi A.	Mayo Clinic	40	1.34	1	6	United States
Tucker, Joseph D.	University of North Carolina Chapel Hill	39	0.82	0	3	United States
Wallerstein, Nina	University of New Mexico	37	3.96	4	21	United States
Salzer, Mark S.	Temple University	36	1.08	1	4	United States
Wieland, Mark L.	Mayo Clinic	36	1.24	0	6	United States
Rhodes, Scott D.	Wake Forest University	35	1.54	0	9	United States
Dong, XinQi	Rush University	34	0.92	0	3	United States
Sia, Irene G.	Mayo Clinic	34	1.27	0	6	United States
McElfish, Pearl A.	University of Arkansas Medical Sciences	34	0.62	0	1	Japan
Kondo, Katsunori	Chiba University	33	1.62	2	7	United States
Corbie-Smith, Giselle	University of North Carolina Chapel Hill	32	1.24	0	6	United States
Chung, Bowen	University of California Los Angeles	31	0.43	0	0	Australia
Allender, Steven	Deakin University	31	2.07	1	8	United States
Cottler, Linda B.	University of Florida	30	0.88	0	2	Netherlands
Vanclay, Frank	University of Groningen	28	1.84	0	8	United States
Wells, Kenneth B.	University of California Los Angeles	28	0.57	0	0	United States
King, Abby C.	Stanford University	26	1.58	0	6	United States
Simon, Melissa A.	Northwestern University	25	0.90	0	2	United States
Brusilovskiy, Eugene	Temple University	24	1.12	0	3	United States
Ingram, Maia	University of Arizona	24	0.67	0	1	United States

4.1.3.9 Top 20 global funders globally in terms of number of publications

The top 3 organizations in terms of funded publications in this research topic are the United States Department of Health & Human Services with 4,066 publications, followed by the National Institutes of Health (NIH) - USA with 3,550 publications, and the UK Research & Innovation (UKRI) with 1,087 publications as shown in Figure 49.

The highest citation impact measured by the CNCI is observed in publications funded by the Economic & Social Research Council (ESRC) and UK Research & Innovation (UKRI), sharing the same CNCI followed by the Australian Research Council and National Science Foundation (NSF) with 2.01, 1.96 and 1.88, respectively.

Among the top 20 global funding organizations, nine are also among the top 20 funding organizations of Saudi publications in this research topic.

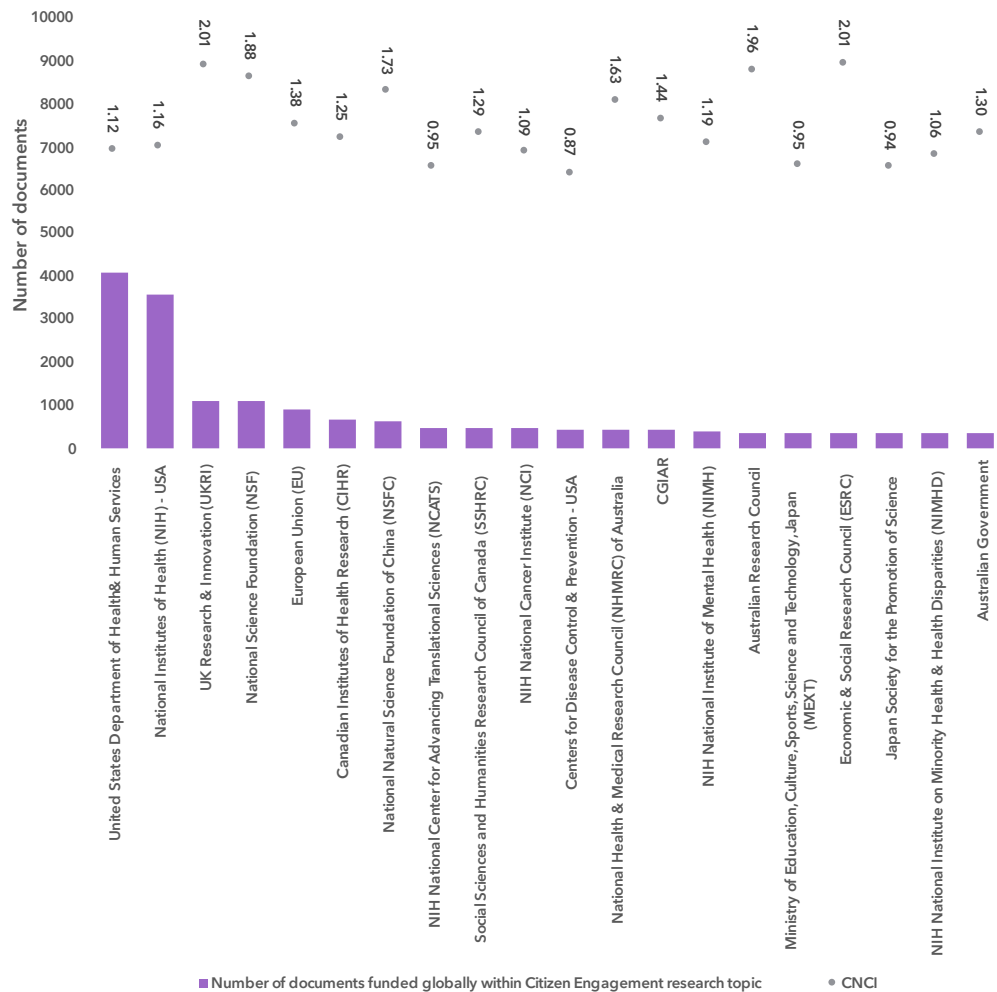


Figure 49: Top 20 funding organizations globally publications in the research topic Citizen Engagement in terms of number of publications in the period 2014-2023

4.1.3.10 Emerging trends in the research topic globally and in Saudi Arabia

In this section we investigate the emerging trends globally and in Saudi Arabia in the research topic Cognitive Cities: Citizen Engagement. For more information on the methodology used to identify emerging trends, please see the definition section Emerging Trends.

The top 3 emerging micro-topics globally in this research topic are Virology - General: Vaccine Hesitancy followed by Sustainability Science: Municipal Solid Waste and Micro & Long Noncoding RNA: Exosomes, as shown in Figure 50.

Saudi Arabia has very few publications on this research topic, such that it was not meaningful to identify emerging micro-topics. Table 14 shows the identified top 10 micro-topics in Saudi Arabia research output in this research topic.

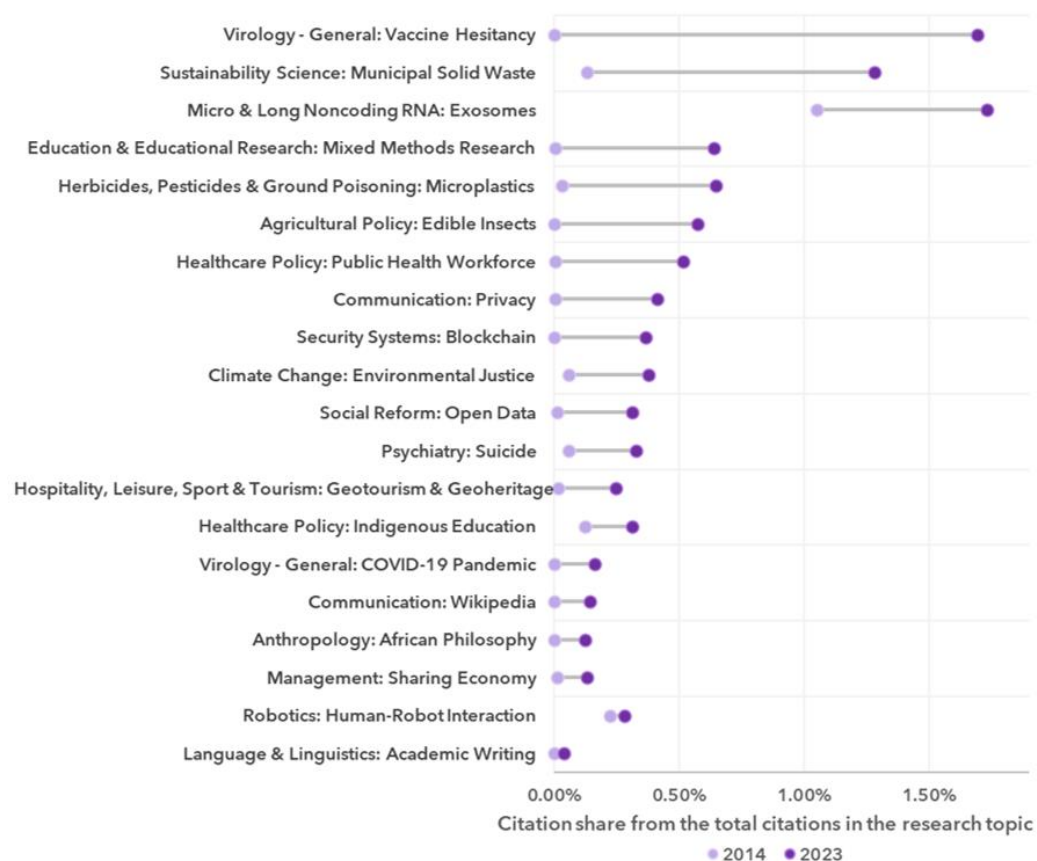


Figure 50: Top 20 emerging micro-topics globally in the research topic Citizen Engagement in the period 2014-2023

Table 14: Top 10 Micro-topics identified in Saudi Arabia research output in the research topic Citizen Engagement in the period 2014-2023

Topic	Number of Saudi Arabia publications in the period 2014-2023
Citizen Engagement research topic	227
Nursing: Medication Errors	13
Management: Technology Acceptance Model	12
Telecommunications: Internet Of Things	11
Management: Customer Satisfaction	10
Management: Corporate Social Responsibility	8
Health Literacy & Telemedicine: Health Literacy	8
Hospitality, Leisure, Sport & Tourism: Tourism	7
Climate Change: Climate Change Adaptation	6
Language & Linguistics: Language Policy	5
Computer Vision & Graphics: Action Recognition	4

4.1.4 Data Ownership & Privacy

4.1.4.1 Evolution of Saudi publication share of global publications in the research topic

The share of Saudi Arabia publications from global publications in the research topic increased almost continuously from 2014 till 2023 as shown in Figure 51. This indicates that Saudi Arabia was not only able to increase the number of publications in this research topic but also having a growth higher than the global growth rate.

This is evident as the share of Saudi Arabian publications in the research topic is growing. The CNCI of Saudi Arabian publications in this research topic was several years ago higher than 1, indicating a citation impact performance higher than the global average.

Although the CNCI decreased from 1.29 in 2014 to 0.9 in 2015, it increased to 1.39 in 2023, indicating a 39% higher citation impact performance than the global average.

Overall, Saudi Arabia's publications increased with a higher growth rate than the global average in this research topic and had a relatively good citation impact, as measured by the CNCI. Nevertheless, after this high growth rate in terms of publications, one should focus on increasing/preserving the relatively good citation impact.

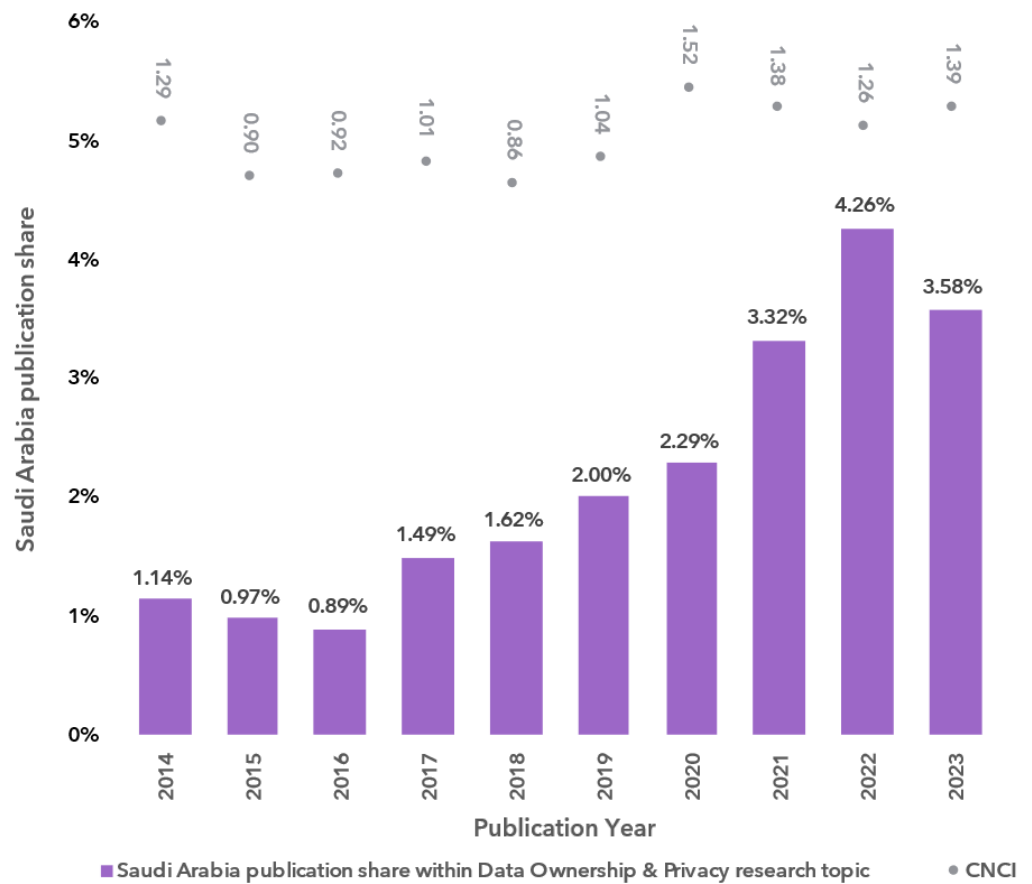


Figure 51: The share of Saudi Arabia from global publications in the research topic and the CNCI of Saudi Arabia publications in the research topic Data Ownership & Privacy in the period 2014-2023

4.1.4.2 Top 10 countries collaborating with Saudi Arabia

The top collaborating countries with Saudi Arabia in this research topic in the period 2014-2023 are Pakistan, followed by India and Mainland China with 151, 147 and 105 publications, respectively as shown in Figure 52. In terms of citation impact measured by the CNCI publications published in collaboration with Canada followed by United States and Egypt had the highest CNCI with 2.35, 2.13 and 1.81, respectively.

Nevertheless, all publications with the top 10 collaborating countries had a CNCI higher than 1 reflecting a performance higher than the global average.

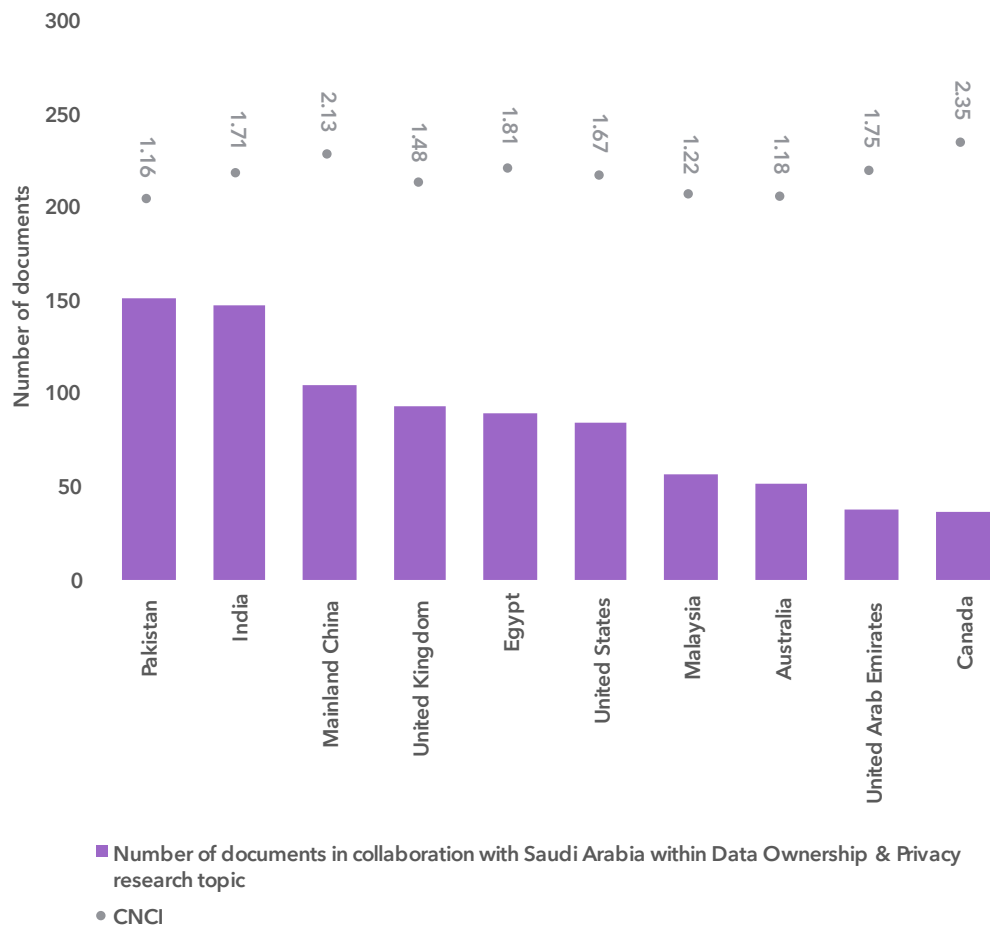


Figure 52: Top 10 collaborating countries with Saudi Arabia in terms of the number of publications in the research topic Data Ownership & Privacy in the period 2014-2023

4.1.4.3 Top 20 funders of Saudi publications by number of publications

The top 3 funding organizations of Saudi Arabia publications in this research topic in terms of number of publications mentioning the organization in the funding text in the period 2014-2023 are King Saud University followed by National Natural Science Foundation of China (NSFC) and Princess Nourah bint Abdulrahman University with 81, 39 and 29 publications respectively as shown in Figure 53.

Documents funded by European Research Council (ERC), Documents funded by National Natural Science Foundation of China (NSFC) followed by Natural Science Foundation of Shandong Province and Natural Science Foundation of Hubei Province had the highest citation impact measured by the CNCI with 2.2, 2.1 and 2, respectively.

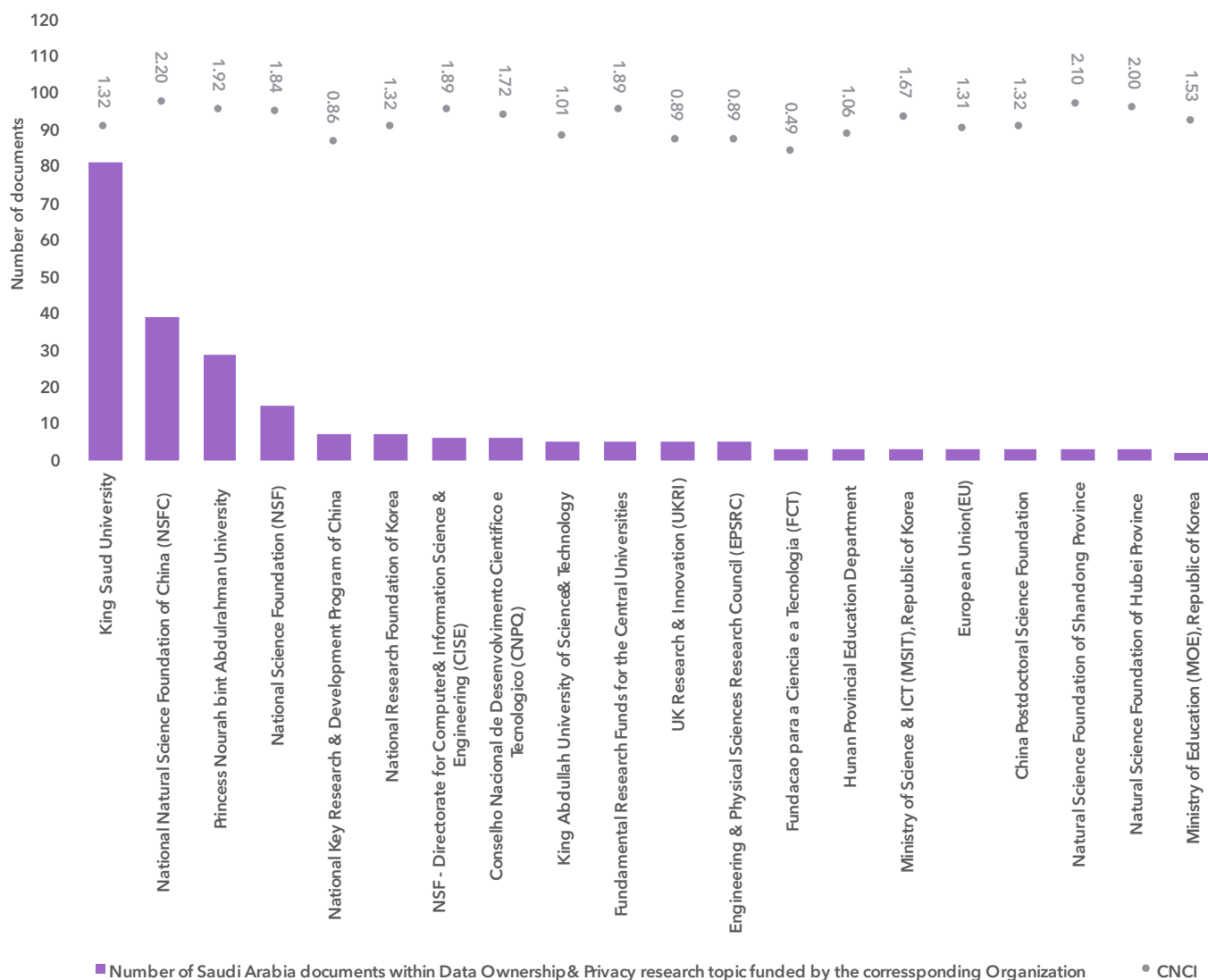


Figure 53: Top 20 funding organizations of Saudi Arabia publications in the research topic Data Ownership & Privacy in terms of number of publications in the period 2014-2023

4.1.4.4 Top 20 Saudi Arabia organizations in terms of number of publications

The top 3 organizations in terms of publications published in this research topic and the period 2014-2023 are King Saud University, followed by King Abdulaziz University and Umm Al Qura University, with 208, 132 and 74 publications, respectively, as shown in Figure 54.

In terms of citation impact as measured by the CNCI, Prince Sultan University, followed by University Ha'il and Princess Nourah bint Abdulrahman University had the highest CNCI with 2.11, 1.89 and 1.86, respectively. Nevertheless, 14 of the top 20 organizations had a CNCI higher than 1, reflecting a citation impact performance higher than the global average.

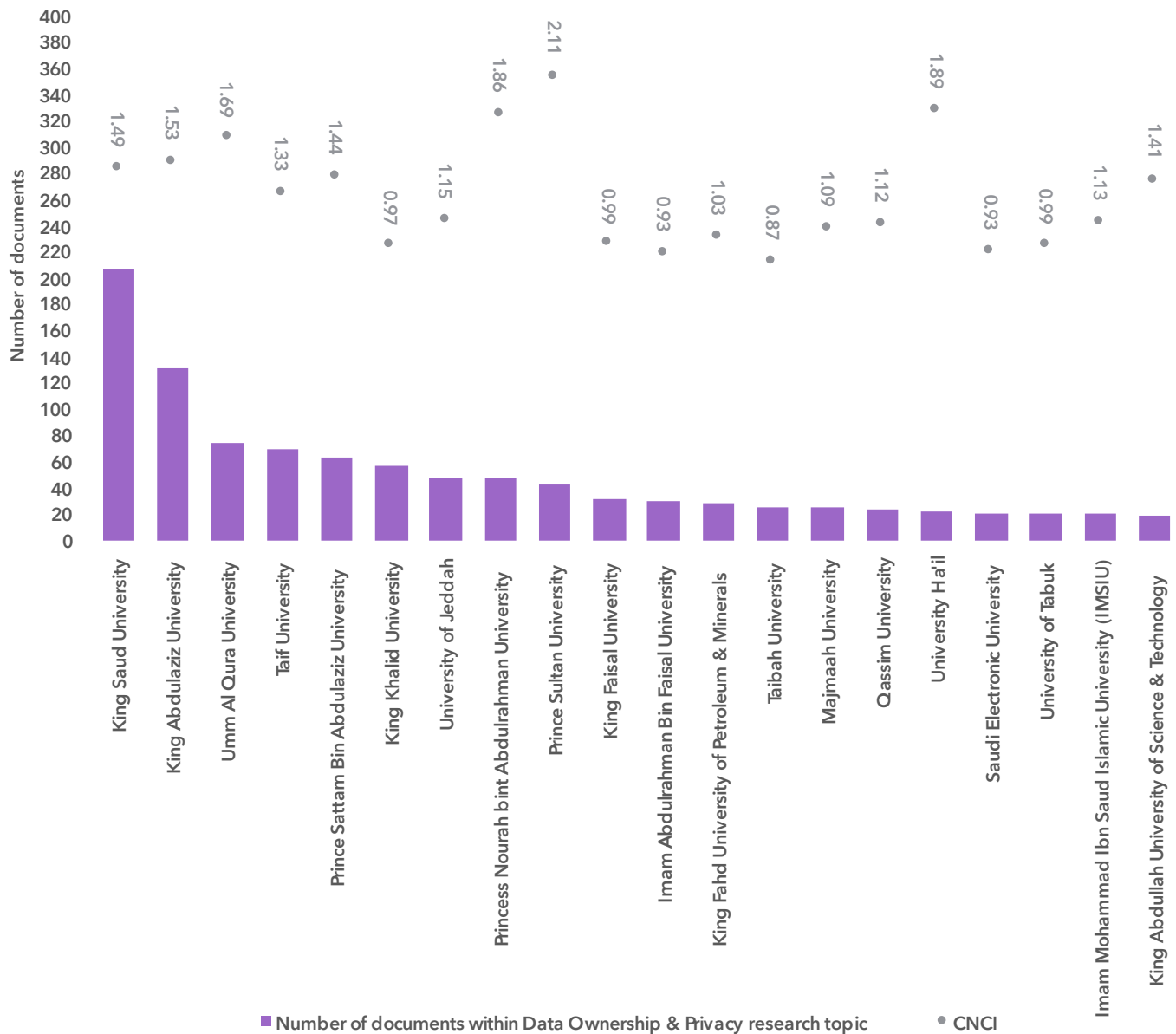


Figure 54: Top 20 Saudi organizations in terms of publications published in the research topic Data Ownership & Privacy in the period 2014-2023 and their corresponding CNCI

4.1.4.5 Top 20 researchers affiliated with Saudi organizations in terms of number of publications.

Adnan Gutub, affiliated with Umm Al Qura University, has published the most publications, followed by Muhammad Khurram Khan, affiliated with King Saud University, and Sajjad Shaukat Jamal, affiliated with King Khalid University, with 24, 22 and 16 publications, respectively, as shown in Table 15.

The highest CNCI and Documents in the top 10% are achieved by publications published by Adnan Gutub, affiliated with Umm Al Qura University, with a CNCI of 2.77.

The highest number of Top 1% is achieved by Muhammad Khurram Khan affiliated to King Saud University and Ahmad Almogren affiliated to King Saud University with 1 document each in the top 1%.

Table 15: Top 20 researchers affiliated with Saudi organizations in terms of the number of publications published in the research topic Data Ownership & Privacy in the period 2014-2023

Name	Affiliation	Web of Science Publications	CNCI	Documents in the top 1%	Documents in the top 10%
Gutub, Adnan	Umm Al Qura University	24	2.77	0	11
Khan, Muhammad Khurram	King Saud University	22	1.73	1	5
Jamal, Sajjad Shaukat	King Khalid University	16	0.64	0	0
Hossain, M. Shamim	King Saud University	12	2.40	0	4
Almogren, Ahmad	King Saud University	12	2.46	1	4
Hazzazi, Mohammad Mazyad	King Khalid University	11	0.99	0	0
Masud, Mehedi	Taif University	9	0.92	0	1
Saleem, Kashif	King Saud University	8	1.24	0	2
Alroobaea, Roobaea	Taif University	6	0.35	0	0
Almaiah, Mohammed Amin	King Faisal University	6	2.49	0	3
Saeed, Saqib	Imam Abdulrahman Bin Faisal University	6	1.31	0	2
Faragallah, Osama S.	Taif University	6	0.77	0	0
Alharbi, Adel R.	University of Tabuk	6	0.85	0	0
Al-Muhtadi, Jalal	King Saud University	6	0.66	0	1
Saba, Tanzila	Prince Sultan University	6	1.00	0	0
Alshaikh, Moneer	University of Jeddah	6	1.05	0	1
Alsuhibany, Suliman A.	Qassim University	6	0.18	0	0
Alsubhi, Khalid	King Abdulaziz University	5	0.80	0	0
Derhab, Abdelouahid	King Saud University	5	0.89	0	1
Alhakami, Hosam	Umm Al Qura University	5	0.94	0	0

4.1.4.6 Top 10 countries in terms of publications

The highest number of publications published in this research topic are published by Mainland China (11,736 publications) followed by United States (9,925 publications) and India (3,552 publications) as shown in Figure 55.

The highest citation impact measured by the CNCI is achieved by publications published by Canada, United States and United Kingdom with a CNCI of 1.64, 1.53 and 1.47, respectively. Five of the top 10 countries in terms of number of publications published in the research topic are also among the top 10 collaborators with Saudi Arabia. These are India, United Kingdom, Australia, South Korea, and Canada.

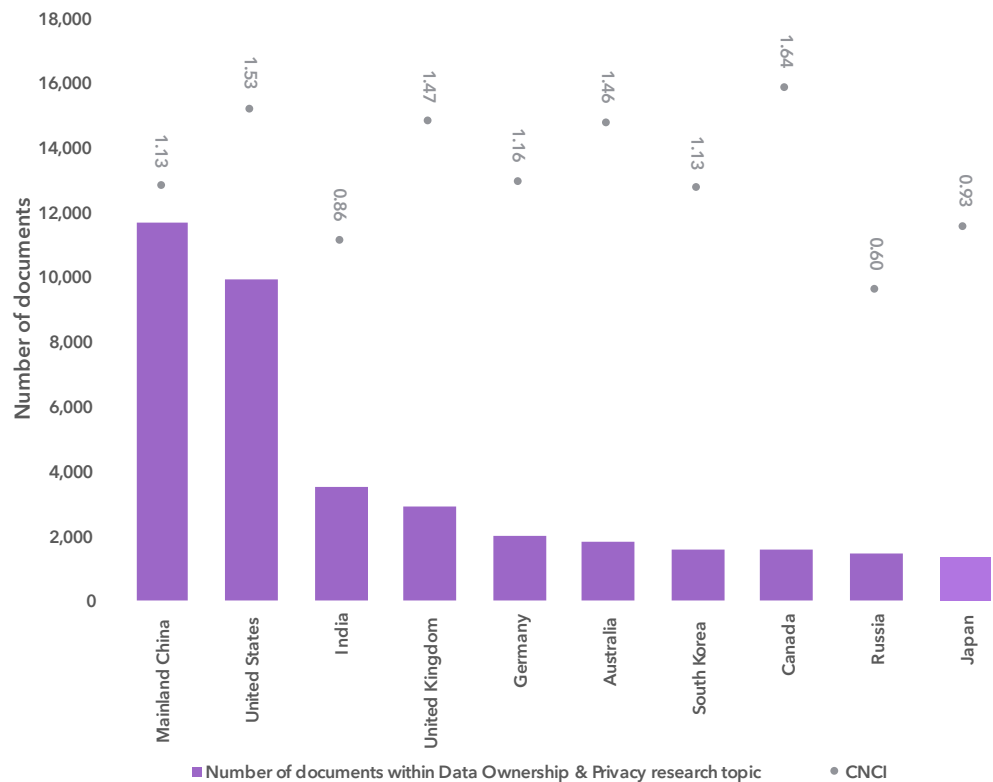


Figure 55: Top 10 countries in terms of the number of publications in the research topic Data Ownership & Privacy in the period 2014-2023 and their corresponding CNCI

4.1.4.7 Top 20 organizations globally in terms of number of publications

The top 3 organizations in terms of the number of publications published on this research topic in the period 2014-2023 are the Chinese Academy of Sciences (825 publications) followed by the University of California System (704 publications) and the University of Texas System (482 publications) respectively as shown in Figure 56.

Regarding citation impact measured by the CNCI, Tsinghua University, followed by Harvard University and Pennsylvania Commonwealth System of Higher Education (PCSHE) had the highest CNCI with 1.91, 1.9 and 1.8, respectively.

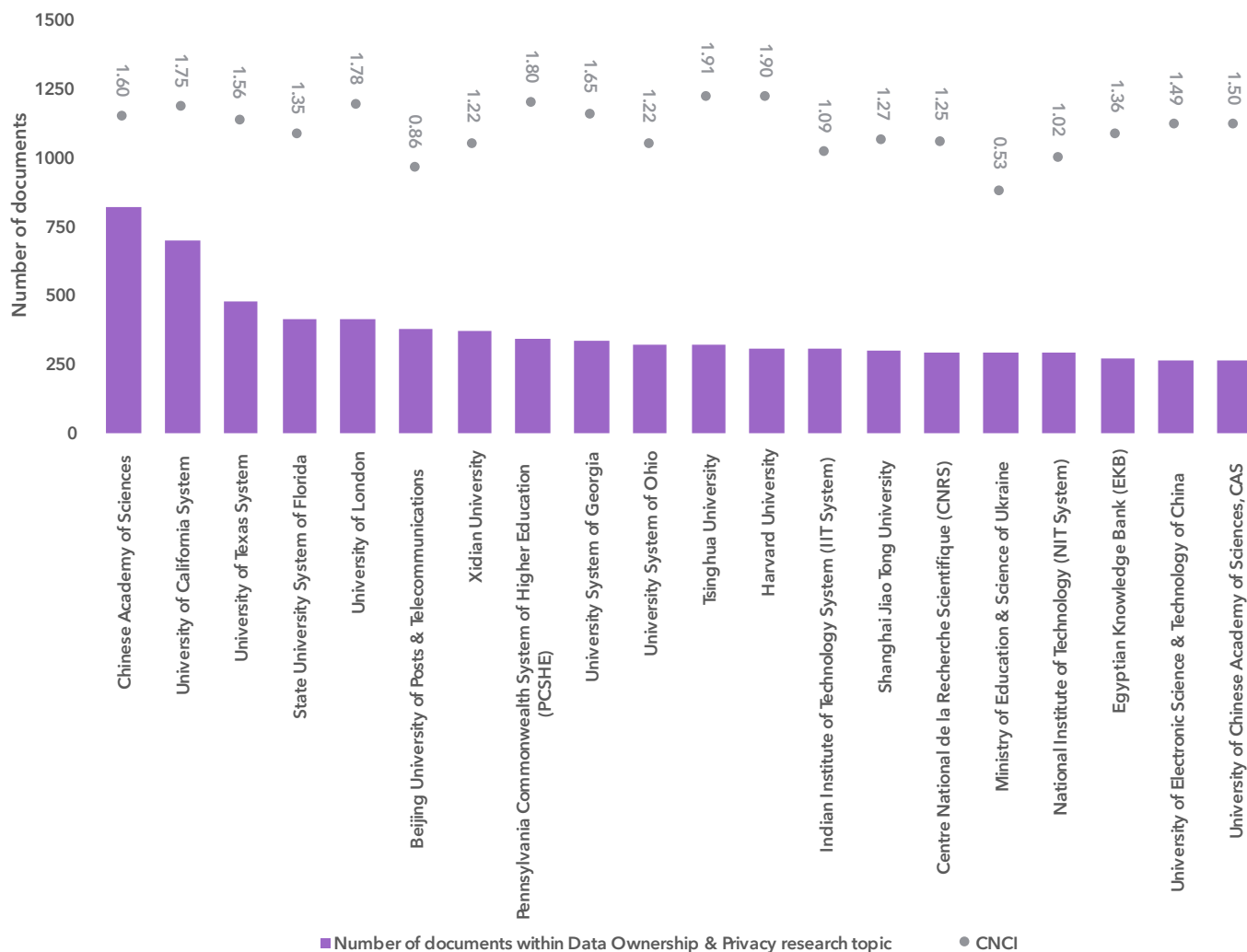


Figure 56: Top 20 organizations globally in terms of the number of publications published in the research topic Data Ownership & Privacy in the period 2014-2023 and their corresponding CNCI

4.1.4.8 Top 20 researchers globally in terms of number of publications

The top 3 researchers globally in terms of the number of publications in this research topic are Hui Li affiliated with Xidian University, with 53 publications, followed by Jianfeng Ma, affiliated with Xidian University, with 49 publications, and Sennur Ulukus, affiliated to the University of Maryland College Park, with 43 publications as shown in Table 16.

The highest CNCI and Document in top 1% among the top 20 researchers globally is achieved by Gautam Srivastava affiliated to Brandon University with a CNCI of 3.83 and 5 publications in top 1%. Neeraj Kumar affiliated to Thapar Institute of Engineering & Technology has the highest Top 10% publications amounting to 17 publications.

Table 16: Top 20 researchers globally in terms of number of publications published in the research topic Data Ownership & Privacy in the period 2014-2023

Name	Affiliation	Web of Science Publications	CNCI	Documents in top 1%	Documents in top 10%	Country
Li, Hui	Xidian University	53	1.52	2	9	Mainland China
Ma, Jianfeng	Xidian University	49	0.93	0	6	Mainland China
Ulukus, Sennur	University of Maryland College Park	43	1.51	1	10	United States
Akbari, Ashley	Swansea University	43	1.43	1	7	Wales
Kotenko, Igor	Russian Academy of Sciences	42	0.60	0	3	Russia
Warkentin, Merrill	Mississippi State University	41	2.37	1	14	United States
Lyons, Ronan A.	Swansea University	40	1.43	0	8	Wales
Han, Zhu	University of Houston	36	0.79	0	3	United States
Choo, Kim-Kwang Raymond	University of Texas at San Antonio (UTSA)	35	1.64	1	11	United States
Lu, Rongxing	University of New Brunswick	34	1.16	0	5	Canada
Sun, Hua	University of North Texas Denton	34	1.48	0	9	United States
Zhu, Liehuang	Beijing Institute of Technology	33	2.07	1	12	Mainland China
Ogiela, Lidia	AGH University of Krakow	33	0.97	0	4	Poland
Chang, Chin-Chen	Feng Chia University	31	0.55	0	2	Taiwan
Kumar, Neeraj	Thapar Institute of Engineering & Technology	31	3.80	3	17	India
Ahmad, Tohari	Institut Teknologi Sepuluh Nopember	31	0.59	0	2	Indonesia
Ogiela, Marek R.	AGH University of Krakow	31	0.90	0	4	Poland
Miloslavskaya, Natalia	National Research Nuclear University MEPhI (Moscow Engineering Physics Institute)	28	0.76	0	2	Russia
Srivastava, Gautam	Brandon University	28	3.83	5	13	Canada
Shen, Jian	Nanjing University of Information Science & Technology	27	2.02	2	8	Mainland China

4.1.4.9 Top 20 global funders globally in terms of number of publications

The top 3 organizations in terms of funded publications in this research topic are National Natural Science Foundation of China (NSFC) with 5,876 publications followed by National Science Foundation (NSF) with 1,688 publications and Fundamental Research Funds for the Central Universities with 867 publications as shown in Figure 57.

The highest citation impact measured by the CNCI is observed in publications funded by NSF - Directorate for Computer & Information Science & Engineering (CISE) followed by Natural Sciences and Engineering Research Council of Canada (NSERC) and National Science Foundation (NSF) with 2.43, 2.38 and 2.13, respectively. Among

the top 20 global funding organizations, 10 are also among the top 20 funding organizations of Saudi publications in this research topic.

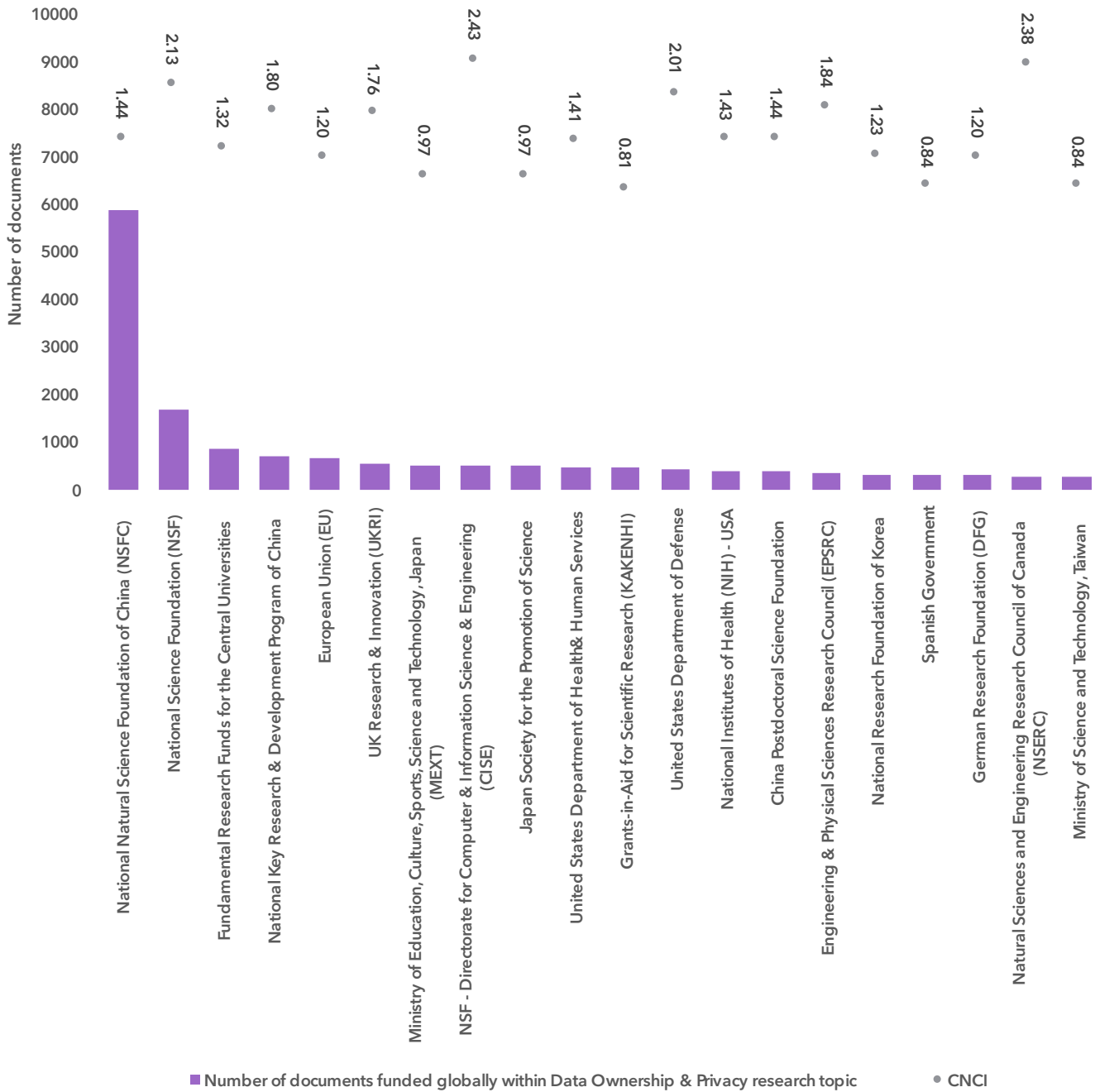


Figure 57: Top 20 funding organizations globally publications in the research topic Data Ownership & Privacy in terms of number of publications in the period 2014-2023

4.1.4.10 Emerging trends in the research topic globally and in Saudi Arabia

In this section we investigate the emerging trends globally and in Saudi Arabia in the research topic Cognitive Cities: Data Ownership & Privacy. For more information on the methodology used to identify emerging trends, please see the definition section Emerging Trends.

The top 3 emerging micro-topics globally in this research topic are Security Systems: Blockchain followed by Wireless Technology: Microwave Absorption and Pigments, Sensors & Probes: Chemosensor as shown in Figure 58. Table 17 shows the identified top 10 micro-topics in Saudi Arabia research output in this research topic.

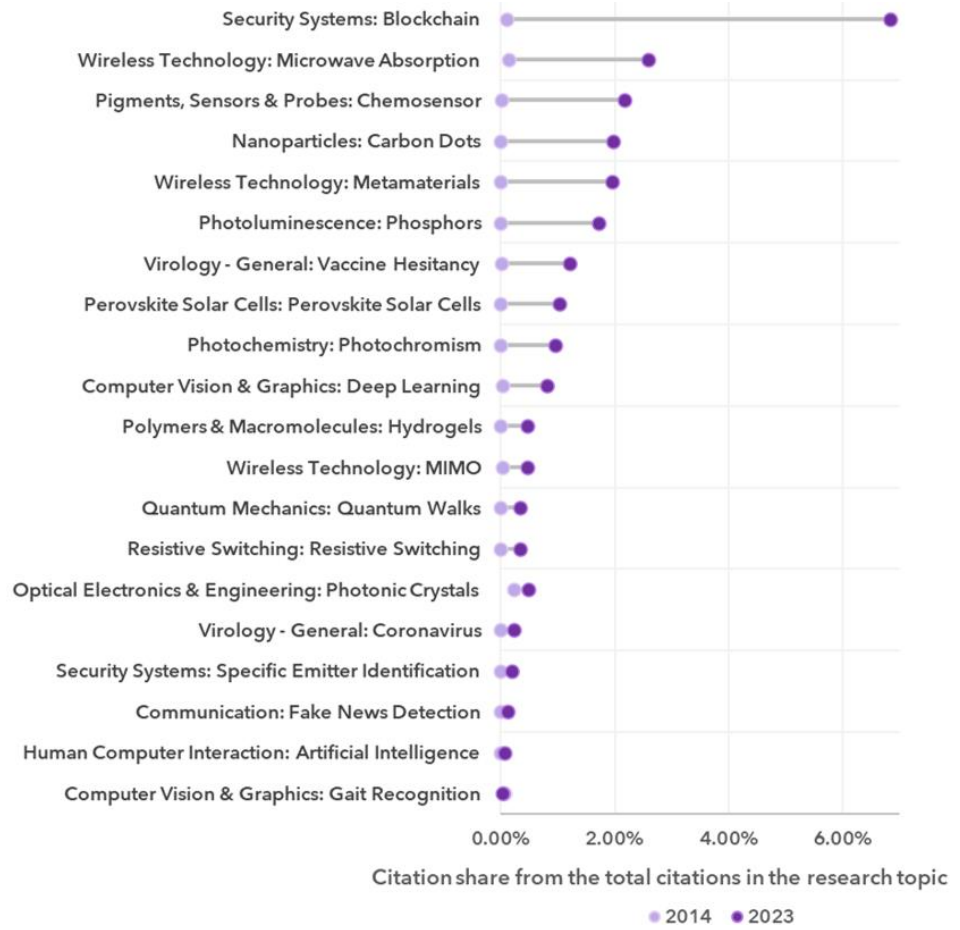


Figure 58: Top 20 emerging micro-topics globally in the research topic Data Ownership & Privacy in the period 2014-2023

Table 17: Top 10 Micro-topics identified in Saudi Arabia research output in the research topic Data Ownership & Privacy in the period 2014-2023

Topic	Number of Saudi Arabia publications in the period 2014-2023
Data Ownership & Privacy	1026
Security Systems: Phishing	107
Security, Encryption & Encoding: Watermarking	79
Security, Encryption & Encoding: Image Encryption	77
Artificial Intelligence & Machine Learning: Intrusion Detection	76
Security Systems: Blockchain	66
Security Systems: Random Oracle Model	58
Telecommunications: Internet Of Things	48
Security Systems: Differential Privacy	43
Communication: Privacy	26
Security Systems: Malware	25

4.1.5 Predictive Analytics, Decision Algorithms

4.1.5.1 Evolution of Saudi publication share of global publications in the research topic

The share of Saudi Arabia publications from global publications in the research topic increased almost continuously from 2014 till 2023 as shown in Figure 59. This shows that Saudi Arabia was not only able to increase the number of publications in this research topic but also having a growth higher than the global growth rate.

This is evident as the share of Saudi Arabia publications in the research topic is growing. The CNCI of Saudi Arabia publications in this research topic were in all years higher than 1, indicating a citation impact performance higher than the global average.

Overall, Saudi Arabia publications increased with a higher growth rate than the global average in this research topic and had a relatively good citation impact as measured by the CNCI. Nevertheless, after this high growth rate in terms of publications, one should focus on increasing/preserving the relatively good citation impact.

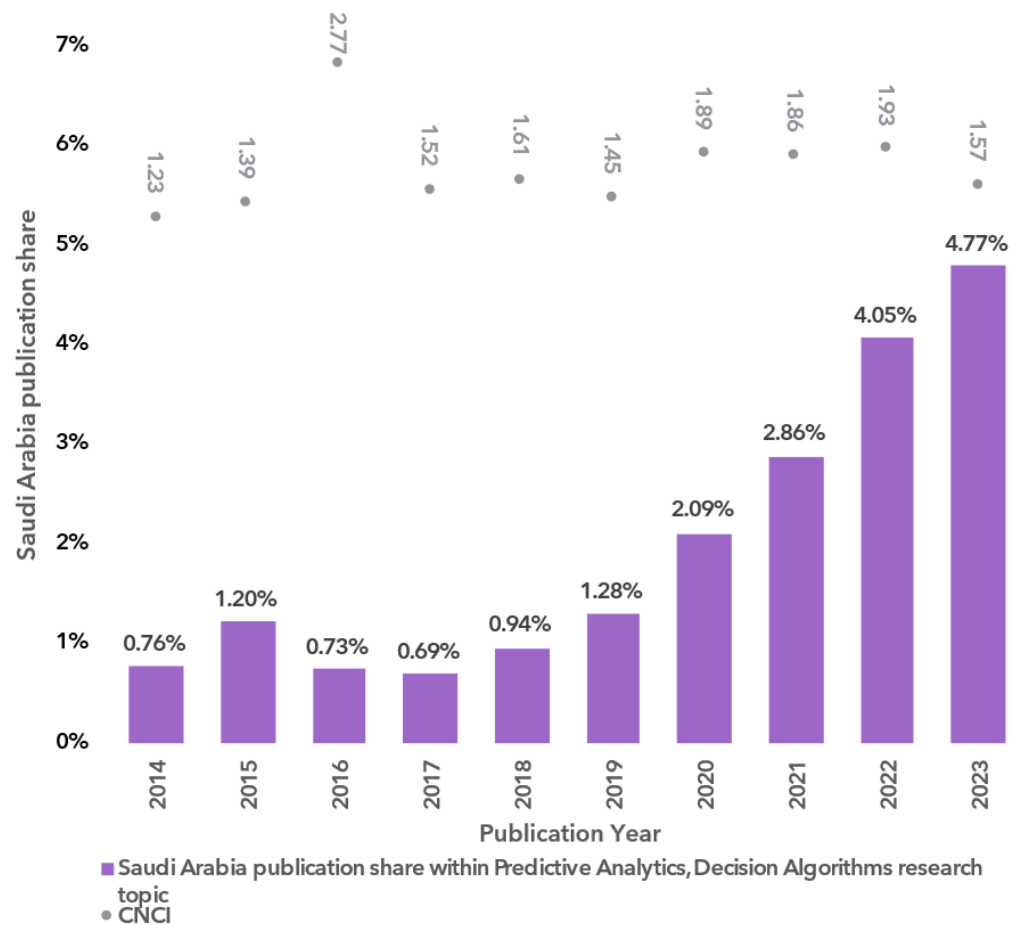


Figure 59: The share of Saudi Arabia from global publications in the research topic and the CNCI of Saudi Arabia publications in the research topic Predictive Analytics, Decision Algorithms in the period 2014-2023

4.1.5.2 Top 10 countries collaborating with Saudi Arabia

The top collaborating country with Saudi Arabia in this research topic in the period 2014-2023 are Pakistan followed by India and Egypt with 266, 255 and 197 publications respectively as shown in Figure 60.

In terms of citation impact measured by the CNCI publications published in collaboration with Mainland China followed by United Kingdom and Canada had the highest CNCI with 2.54, 2.53 and 2.23, respectively.

Nevertheless, all publications with the top 10 collaborating countries had a CNCI higher than 1 reflecting a performance higher than the global average.

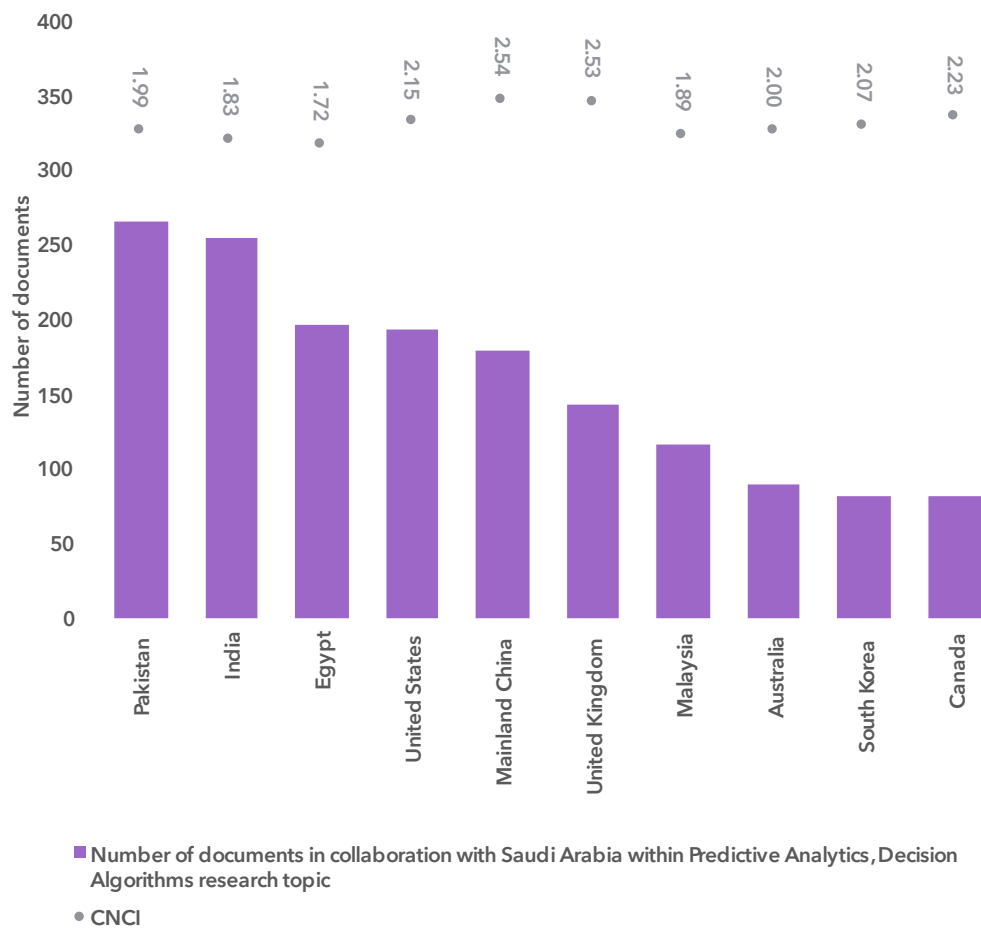


Figure 60: Top 10 collaborating countries with Saudi Arabia in terms of number of publications in the research topic Predictive Analytics, Decision Algorithms in the period 2014-2023

4.1.5.3 Top 20 funders of Saudi publications by number of publications

The top 3 funding organizations of Saudi Arabia publications in this research topic in terms of number of publications mentioning the organization in the funding text in the period 2014-2023 are King Saud University followed by Princess Nourah bint Abdulrahman University and National Natural Science Foundation of China (NSFC) with 141, 70 and 38 publications respectively as shown in Figure 61.

Documents funded by Fundacao para a Ciencia e a Tecnologia (FCT) followed by Conselho Nacional de Desenvolvimento Cientifico e Tecnologico (CNPQ) and Engineering & Physical Sciences Research Council (EPSRC) had the highest citation impact measured by the CNCI with 7.44, 4.60 and 4.05, respectively.

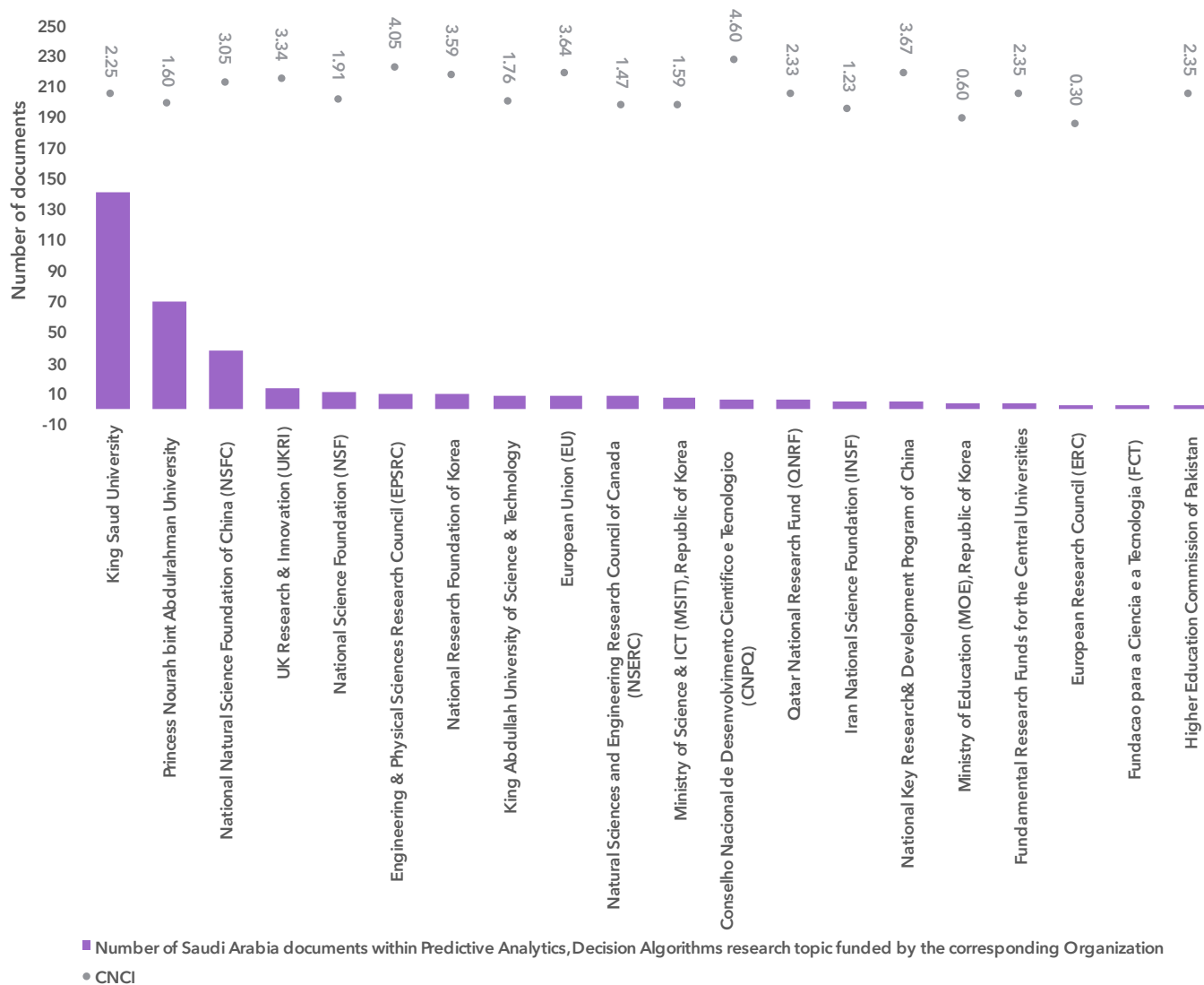


Figure 61: Top 20 funding organizations of Saudi Arabia publications in the research topic Predictive Analytics, Decision Algorithms in terms of number of publications in the period 2014-2023

4.1.5.4 Top 20 Saudi Arabia organizations in terms of number of publications

The top 3 organizations in terms of publications published in this research topic and in the period 2014-2023 are King Saud University followed by King Abdulaziz University and Prince Sattam Bin Abdulaziz University with 281, 232 and 131 publications respectively as shown in Figure 62.

In terms of citation impact as measured by the CNCI, King Fahd University of Petroleum & Minerals followed by King Abdulaziz University and Imam Abdulrahman Bin Faisal University had the highest CNCI with 2.18, 2.14 and 2.01, respectively.

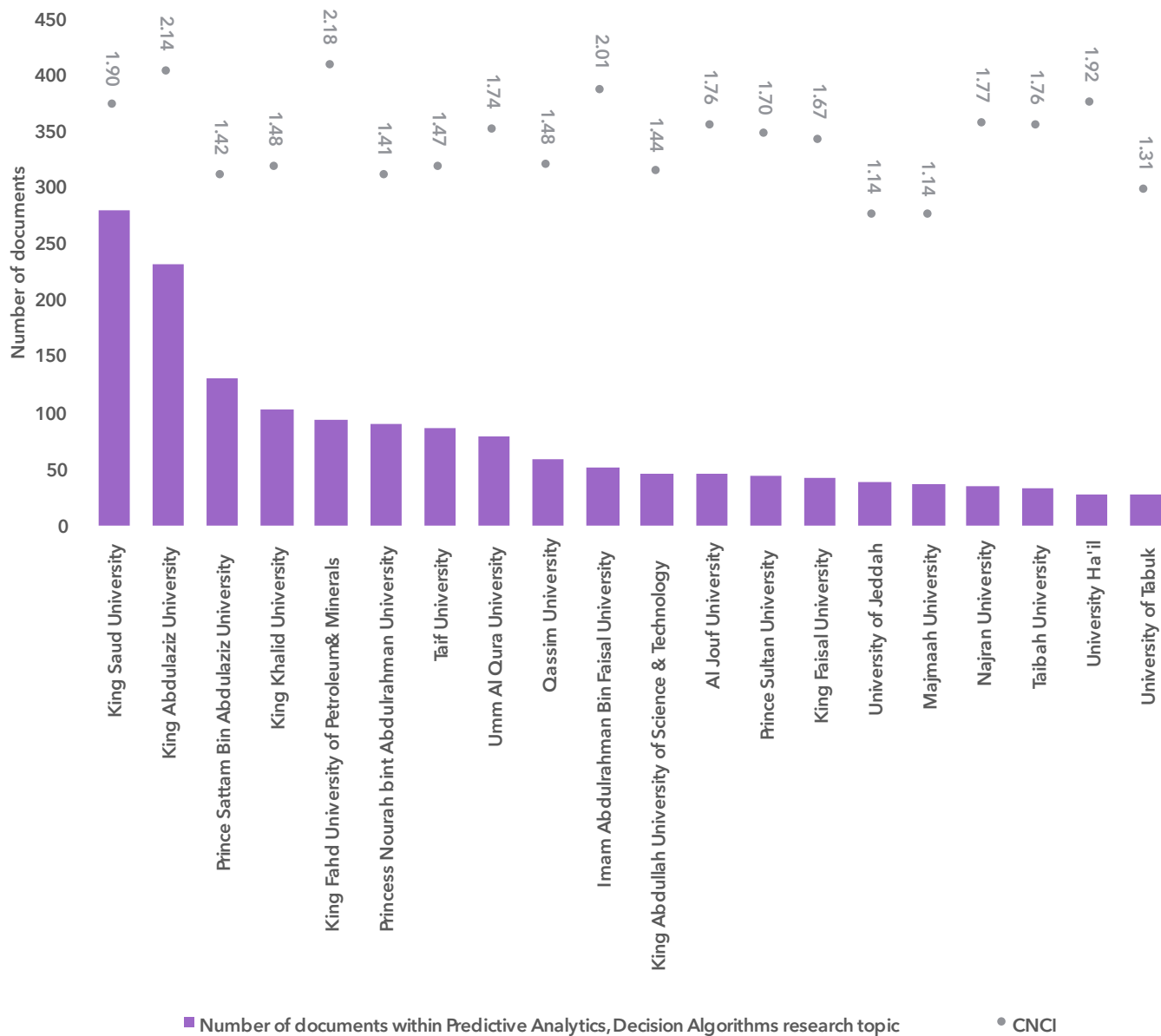


Figure 62: Top 20 Saudi organizations in terms of publications published in the research topic Predictive Analytics, Decision Algorithms in the period 2014-2023 and their corresponding CNCI

4.1.5.5 Top 20 researchers affiliated to Saudi organizations in terms of number of publications

The highest number of publications are published by Rashid Mehmood affiliated to King Abdulaziz University followed by M. Shamim Hossain affiliated to King Saud University and Iyad Katib affiliated to King Abdulaziz University with 24, 19 and 17 publications respectively as shown in Table 18.

The highest CNCI is achieved by publications published by Aiiad Albeshri affiliated to King Abdulaziz University with a CNCI of 4.28. M. Shamim Hossain affiliated to King Saud University has the highest number of Top 1% amounting to 4 publications while Rashid Mehmood affiliated to King Abdulaziz University has the highest number of publications in Top 10% amounting to 16 publications.

Table 18: Top 20 researchers affiliated to Saudi organizations in terms of number of publications published in the research topic Predictive Analytics, Decision Algorithms in the period 2014-2023

Name	Affiliation	Web of Science Publications	CNCI	Documents in top 1%	Documents in top 10%
Mehmood, Rashid	King Abdulaziz University	24	3.44	3	16
Hossain, M. Shamim	King Saud University	19	3.63	4	7
Katib, Iyad	King Abdulaziz University	17	3.78	2	13
Hassan, Mohammad Mehedi	King Saud University	15	3.47	2	5
Jamal, Arshad	King Fahd University of Petroleum & Minerals	13	2.73	1	7
Albeshri, Aiiad	King Abdulaziz University	12	4.28	2	8
Khalid, Muhammad	King Fahd University of Petroleum & Minerals	11	2.37	1	4
Hilal, Anwer Mustafa	Prince Sattam Bin Abdulaziz University	10	0.64	0	0
Imran, Muhammad	King Saud University	9	2.83	1	2
Aurangzeb, Khursheed	King Saud University	9	2.67	1	4
Hamza, Manar Ahmed	Prince Sattam Bin Abdulaziz University	8	0.88	0	0
Hoteit, Ibrahim	King Abdullah University of Science & Technology	8	0.84	0	0
Saba, Tanzila	Prince Sultan University	8	1.57	0	3
Aldhyani, Theyazn H. H.	King Faisal University	8	1.53	0	2
Tolba, Amr	King Saud University	8	3.60	1	3
Motwakel, Abdelwahed	Prince Sattam Bin Abdulaziz University	8	0.76	0	0
Muhammad, Ghulam	King Saud University	8	1.58	0	1
Ratrout, Nedal T.	King Fahd University of Petroleum & Minerals	7	0.56	0	0
Rahman, Syed Masiur	King Fahd University of Petroleum & Minerals	7	1.87	1	3
Mallick, Javed	King Khalid University	7	2.28	0	2

4.1.5.6 Top 10 countries in terms of publications

The highest number of publications published in this research topic are published by Mainland China (13,422 publications) followed by United States (12,466 publications) and India (4,239 publications) as shown in Figure 63.

The highest citation impact measured by the CNCI is achieved by publications published by Australia, United Kingdom, and Canada with a CNCI of 2.01, 1.97 and 1.85, respectively.

Five of the top 10 countries in terms of number of publications published in the research topic are also among the top 10 collaborators with Saudi Arabia. These are United States, India, United Kingdom, Canada, and Australia.

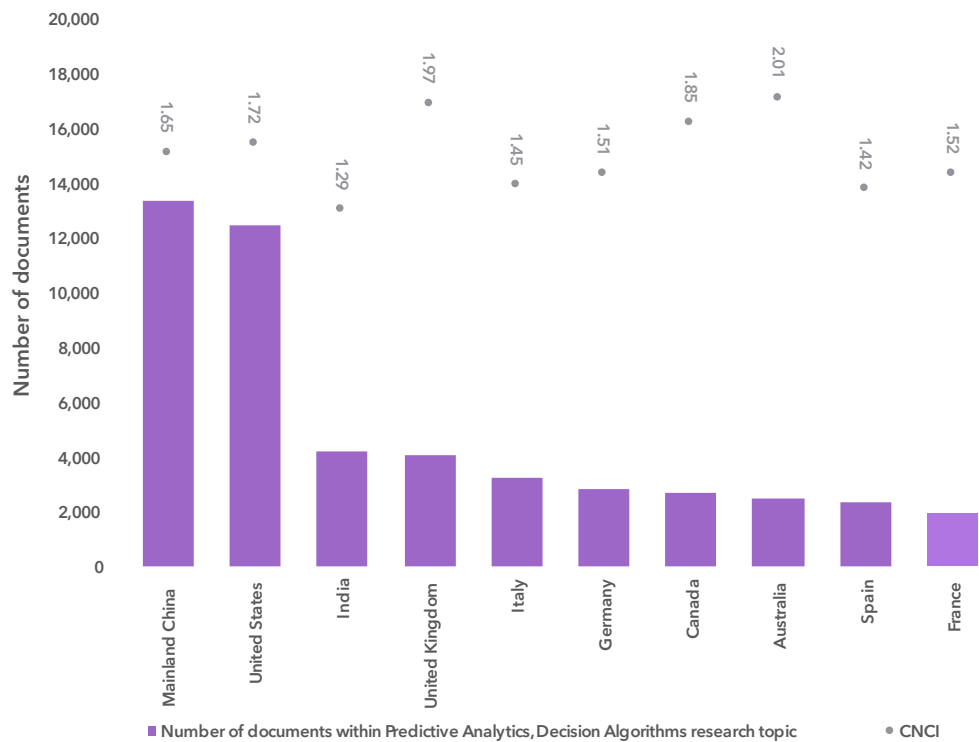


Figure 63: Top 10 countries in terms of number of publications in the research topic Predictive Analytics, Decision Algorithms in the period 2014-2023 and their corresponding CNCI

4.1.5.7 Top 20 organizations globally in terms of number of publications

The top 3 organizations in terms of number of publications published in this research topic in the period 2014-2023 are Chinese Academy of Sciences (1,169 publications) followed by University of California System (998 publications) and State University System of Florida (680 publications) respectively as shown in Figure 64.

In terms of citation impact measured by the CNCI, Swiss Federal Institutes of Technology Domain followed by Hong Kong Polytechnic University and University of London had the highest CNCI with 2.42, 2.36 and 2.31, respectively.

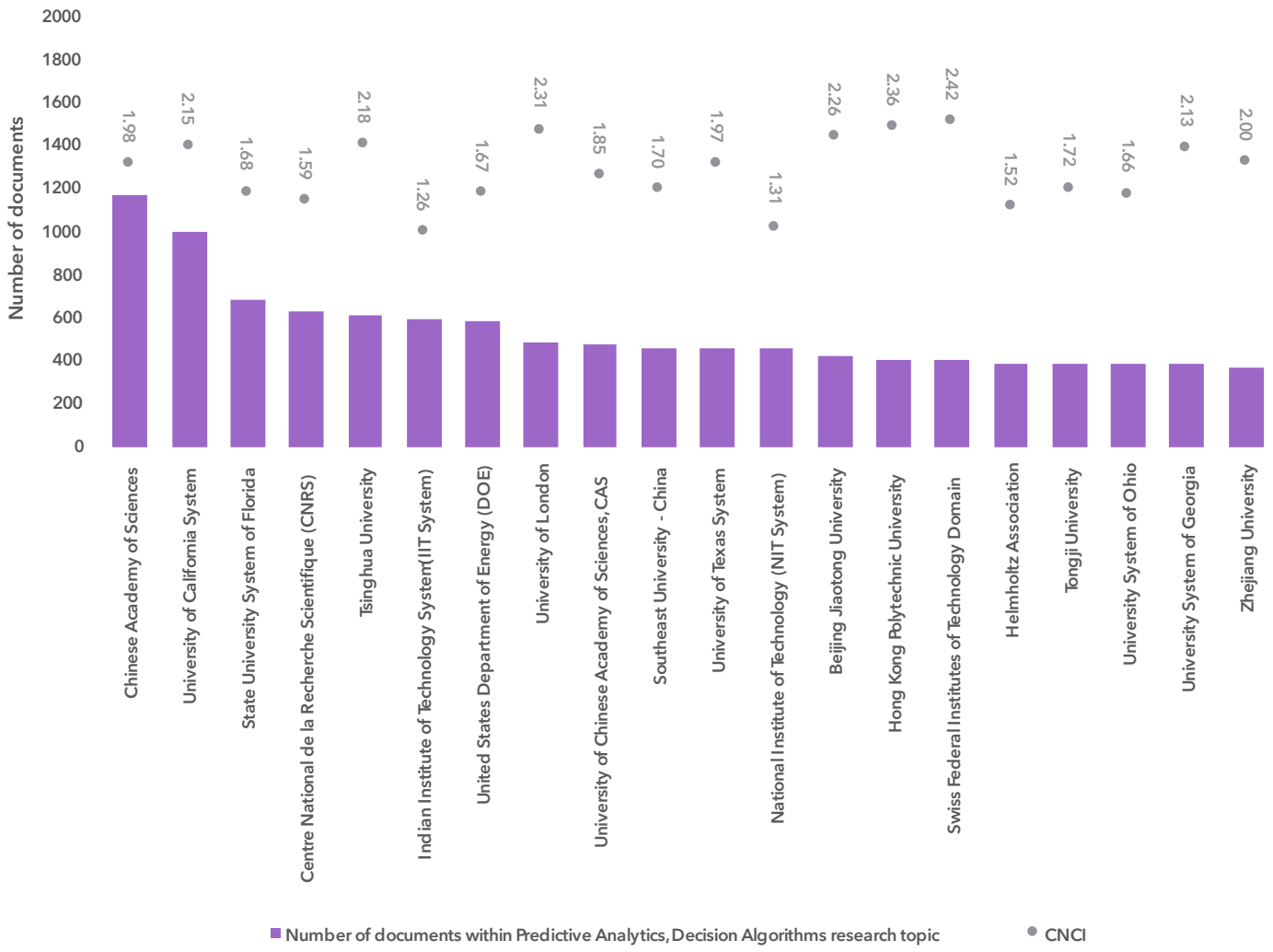


Figure 64: Top 20 organizations globally in terms of number of publications published in the research topic Predictive Analytics, Decision Algorithms in the period 2014-2023 and their corresponding CNCI

4.1.5.8 Top 20 researchers globally in terms of number of publications

The top 3 researchers globally in terms of the number of publications in this research topic are Zita Vale affiliated to Instituto Politecnico do Porto with 61 publications followed by Yinhai Wang affiliated to University of Washington Seattle with 41 publications and Nadeem Javaid affiliated to COMSATS University Islamabad (CUI) with 40 publications as shown in Table 19.

The highest CNCI among the top 20 researchers globally is achieved by Mohsen Guizani affiliated to Qatar University with a CNCI of 5.62. Mohsen Guizani affiliated to Qatar University, Dusit Niyato affiliated to Nanyang Technological University and Yinhai Wang affiliated to University of Washington Seattle have the highest Top 1% publications amounting to 6 publications while Mohsen Guizani affiliated to Qatar University has the highest Top 10% publications amounting to 20 publications.

Table 19: Top 20 researchers globally in terms of number of publications published in the research topic Predictive Analytics, Decision Algorithms in the period 2014-2023

Name	Affiliation	Web of Science Publications	CNCI	Documents in top 1%	Documents in top 10%	Country
Vale, Zita	Instituto Politecnico do Porto	61	0.63	0	2	Portugal
Wang, Yin Hai	University of Washington Seattle	41	2.77	6	12	United States
Javaid, Nadeem	COMSATS University Islamabad (CUI)	40	2.06	1	14	Pakistan
Xiong, Gang	Chinese Academy of Sciences	35	2.41	2	9	Mainland China
Boukerche, Azzedine	University of Ottawa	34	1.60	0	8	Canada
Kumar, Neeraj	Thapar Institute of Engineering & Technology	34	2.51	1	14	India
Pradhan, Biswajeet	University of Technology Sydney	31	3.03	2	15	Australia
Guizani, Mohsen	Qatar University	31	5.62	6	20	Qatar
Abdel-Aty, Mohamed	University of Central Florida	30	2.73	3	18	United States
Baik, Sung Wook	Sejong University	29	3.86	5	18	South Korea
Tanwar, Sudeep	Nirma University	29	3.05	2	13	India
Wang, Fei-Yue	Chinese Academy of Sciences	28	4.45	4	15	Mainland China
Del Ser, Javier	University of Basque Country	28	2.02	2	8	Spain
Srivastava, Gautam	Brandon University	27	3.06	2	13	Canada
Gou, Gaopeng	Chinese Academy of Sciences	26	0.71	0	3	Mainland China
Kantarci, Burak	University of Ottawa	26	2.13	0	7	Canada
Guerrero, Josep M.	Aalborg University	26	1.96	2	7	Denmark
Niyato, Dusit	Nanyang Technological University	25	5.02	6	13	Singapore
Mosavi, Amir	Obuda University	25	4.22	2	16	Hungary
Tzovaras, Dimitrios	Centre for Research & Technology Hellas	25	0.97	0	3	Greece

4.1.5.9 Top 20 global funders globally in terms of number of publications

The top 3 organizations in terms of funded publications in this research topic are National Natural Science Foundation of China (NSFC) with 6,587 publications followed by European Union (EU) with 2,116 publications and National Science Foundation (NSF) with 2,073 publications as shown in Figure 65.

The highest citation impact measured by the CNCI is observed in publications funded by National Science Foundation (NSF) followed by National Research Foundation of Korea and Engineering & Physical Sciences Research Council (EPSRC) with 2.17, 2.12 and 2.05, respectively. Among the top 20 global funding organizations, 11 are also among the top 20 funding organizations of Saudi publications in this research topic.

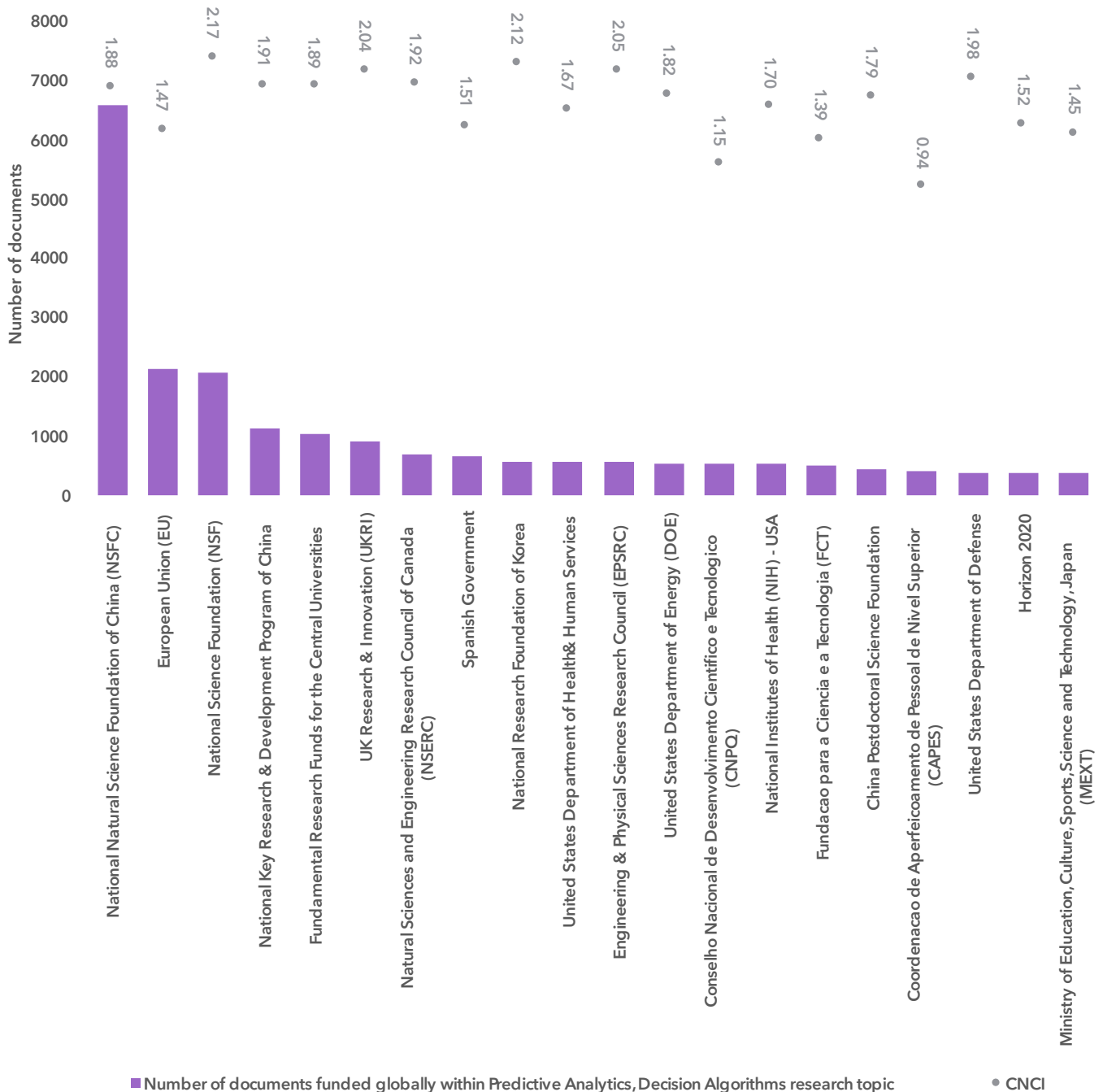


Figure 65: Top 20 funding organizations globally publications in the research topic Predictive Analytics, Decision Algorithms in terms of number of publications in the period 2014-2023

4.1.5.10 Emerging trends in the research topic globally and in Saudi Arabia

In this section we investigate the emerging trends globally and in Saudi Arabia in the research topic Cognitive Cities: Predictive Analytics, Decision Algorithms. For more information on the methodology used to identify emerging trends, please see the definition section Emerging Trends.

The top 3 emerging micro-topics globally in this research topic are Security Systems: Differential Privacy followed by Electrochemistry: Lithium-Ion Battery and Power Systems & Electric Vehicles: Non-Intrusive Load Monitoring as shown in Figure 66.

Table 20 shows the identified top 10 micro-topics in Saudi Arabia research output in this research topic.

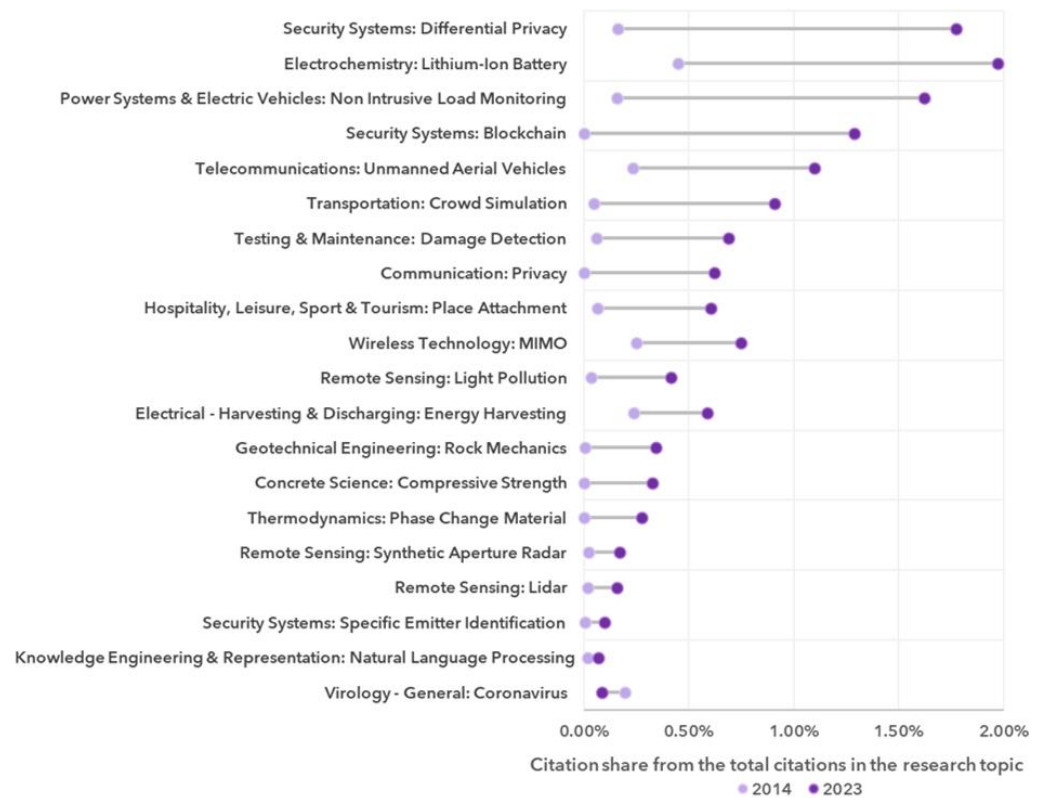


Figure 66: Top 20 emerging micro-topics globally in the research topic Predictive Analytics, Decision Algorithms in the period 2014-2023

Table 20: Top 10 Micro-topics identified in Saudi Arabia research output in the research topic Predictive Analytics, Decision Algorithms in the period 2014-2023

Topic	Number of Saudi Arabia publications in the period 2014-2023
Predictive Analytics, Decision Algorithms research topic	1501
Artificial Intelligence & Machine Learning: Intrusion Detection	213
Telecommunications: Internet Of Things	116
Power Systems & Electric Vehicles: Distributed Generation	85
Power Systems & Electric Vehicles: Unit Commitment	71
Transportation: Traffic Flow	68
Transportation: Road Safety	36
Security Systems: Blockchain	33
Telecommunications: Vehicular ad hoc Networks	32
Power Systems & Electric Vehicles: Non-Intrusive Load Monitoring	31
Computer Vision & Graphics: Deep Learning	25

4.1.6 Sustainable 6G Materials

4.1.6.1 Evolution of Saudi publication share of global publications in the research topic

The share of Saudi Arabia publications from global publications in the research topic increased almost continuously from 2014 till 2023 as shown in Figure 67. This shows that Saudi Arabia was not only able to increase the number of publications in this research topic but also having a growth higher than the global growth rate.

This is evident as the share of Saudi Arabia publications in the research topic is growing. The CNCI of Saudi Arabia publications in this research topic was in several years higher than 1, indicating a citation impact performance higher than the global average.

Overall, Saudi Arabia publications increased with a higher growth rate than the global average in this research topic and had a relatively good citation impact as measured by the CNCI. Nevertheless, after this high growth rate in terms of publications, one should focus on increasing/preserving the relatively good citation impact.

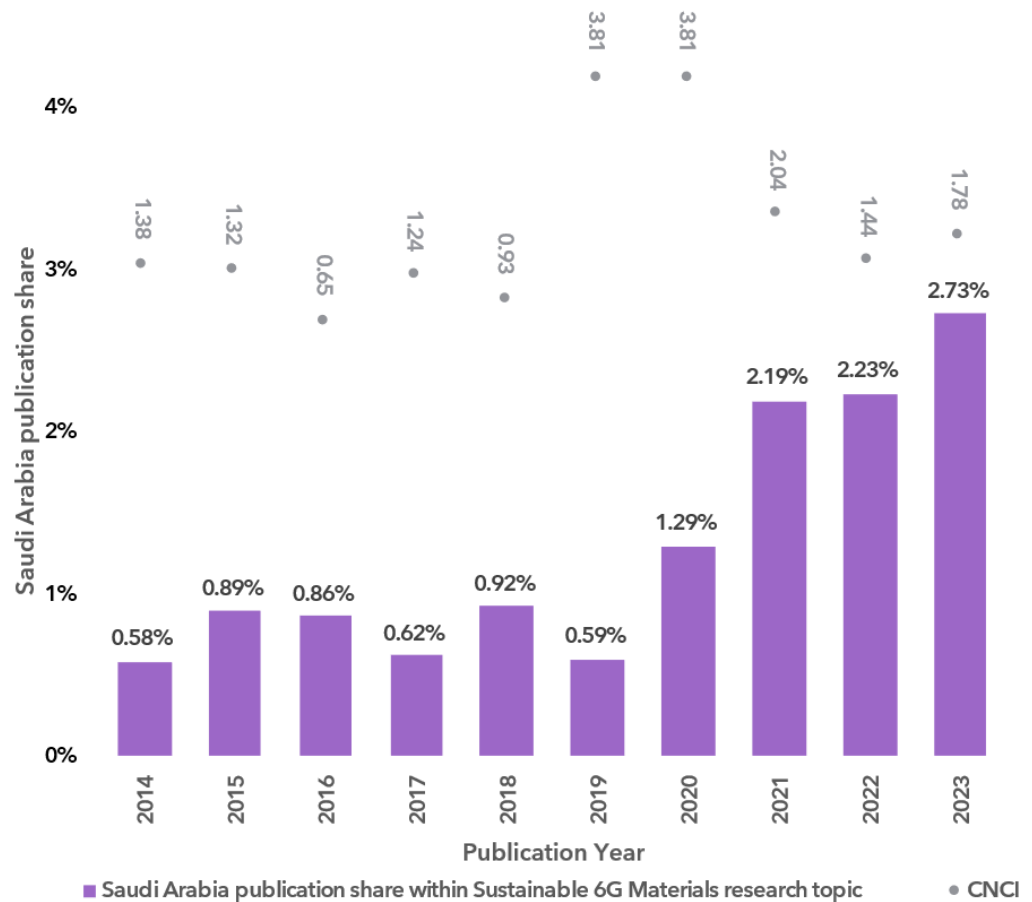


Figure 67: The share of Saudi Arabia from global publications in the research topic and the CNCI of Saudi Arabia publications in the research topic Sustainable 6G Materials in the period 2014-2023

4.1.6.2 Top 10 countries collaborating with Saudi Arabia

The top collaborating country with Saudi Arabia in this research topic in the period 2014-2023 are India followed by United States and Mainland China with 148, 138 and 123 publications respectively as shown in Figure 68.

In terms of citation impact measured by the CNCI publications published in collaboration with Turkiye followed by South Korea and Mainland China had the highest CNCI with 3.00, 2.75 and 2.39, respectively. Nevertheless, all publications with the top 10 collaborating countries had a CNCI higher than 1 reflecting a performance higher than the global average.

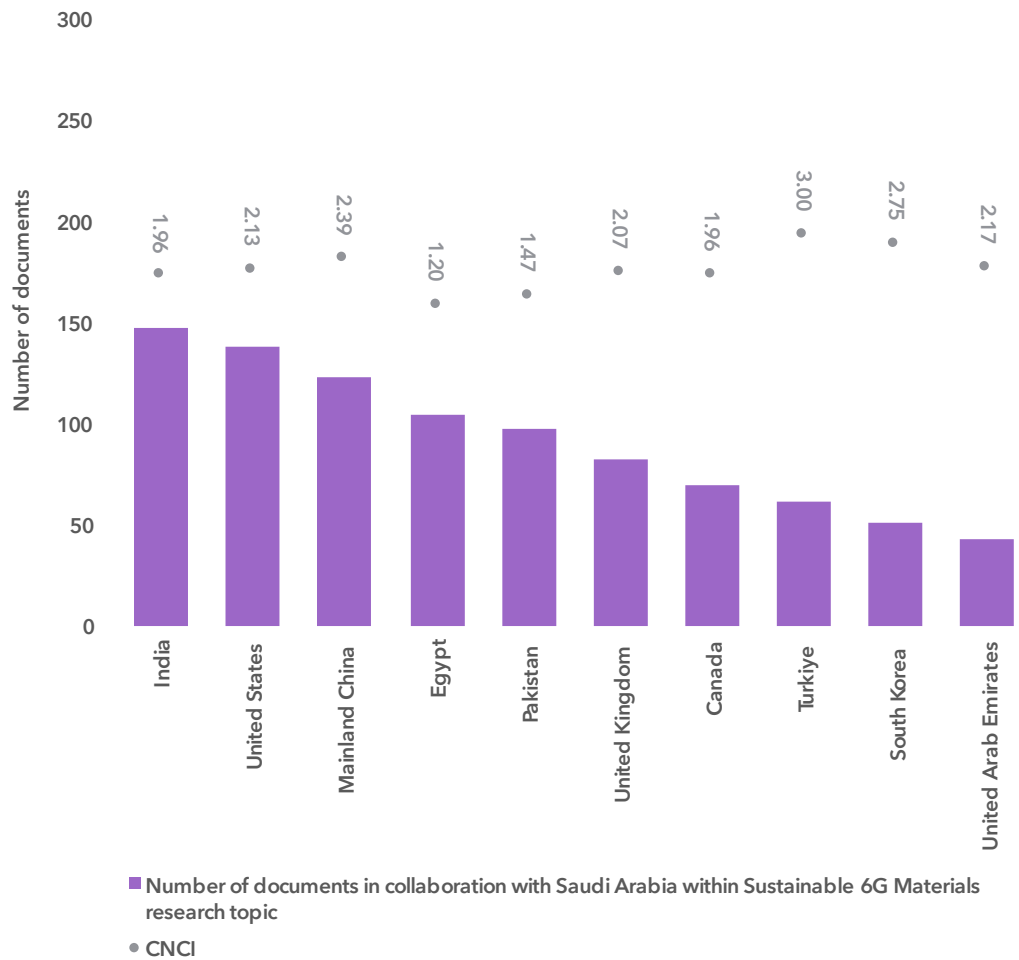


Figure 68: Top 10 collaborating countries with Saudi Arabia in terms of number of publications in the research topic Sustainable 6G Materials in the period 2014-2023

4.1.6.3 Top 20 funders of Saudi publications by number of publications

The top 3 funding organizations of Saudi Arabia publications in this research topic in terms of number of publications mentioning the organization in the funding text in the period 2014-2023 are National Natural Science Foundation of China (NSFC) followed by King Saud University and King Abdullah University of Science & Technology with 66, 52 and 44 publications respectively as shown in Figure 69.

Documents funded by Türkiye Bilimsel ve Teknolojik Arastırma Kurumu (TUBITAK) followed by European Union (EU) and National Research Foundation of Korea had the highest citation impact measured by the CNCI with 13.48, 7.58 and 4.52, respectively.

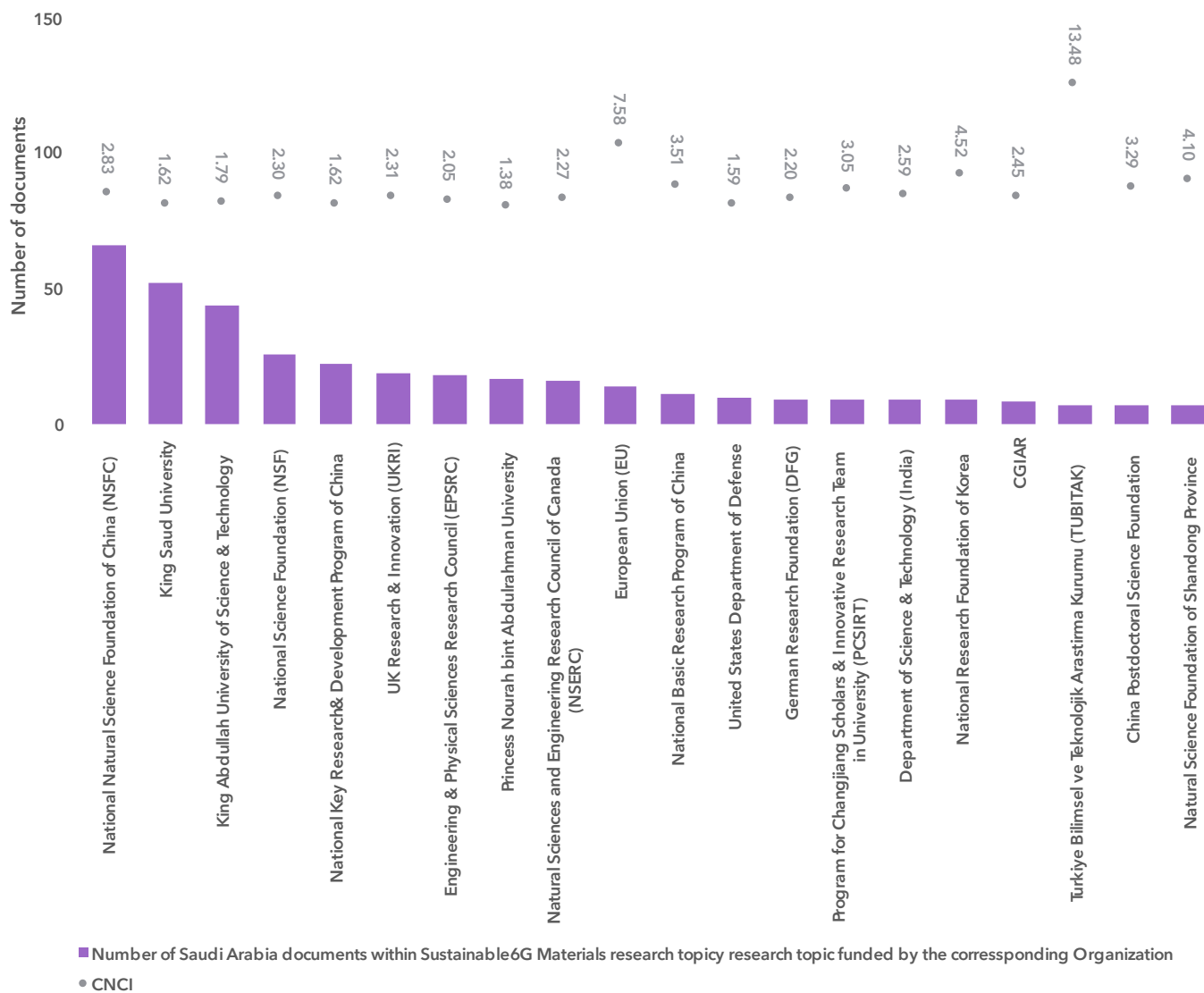


Figure 69: Top 20 funding organizations of Saudi Arabia publications in the research topic Sustainable 6G Materials in terms of number of publications in the period 2014-2023

4.1.6.4 Top 20 Saudi Arabia organizations in terms of number of publications

The top 3 organizations in terms of publications published in this research topic and in the period 2014-2023 are King Abdullah University of Science & Technology followed by King Abdulaziz University and King Saud University with 195, 149 and 132 publications respectively as shown in Figure 70.

In terms of citation impact as measured by the CNCI, King Abdullah University of Science & Technology followed by Prince Sultan University and University of Bisha had the highest CNCI with 3.26, 2.57 and 2.51, respectively. Nevertheless, 18 of top 20 organizations had a CNCI higher than 1, reflecting a citation impact performance higher than the global average.

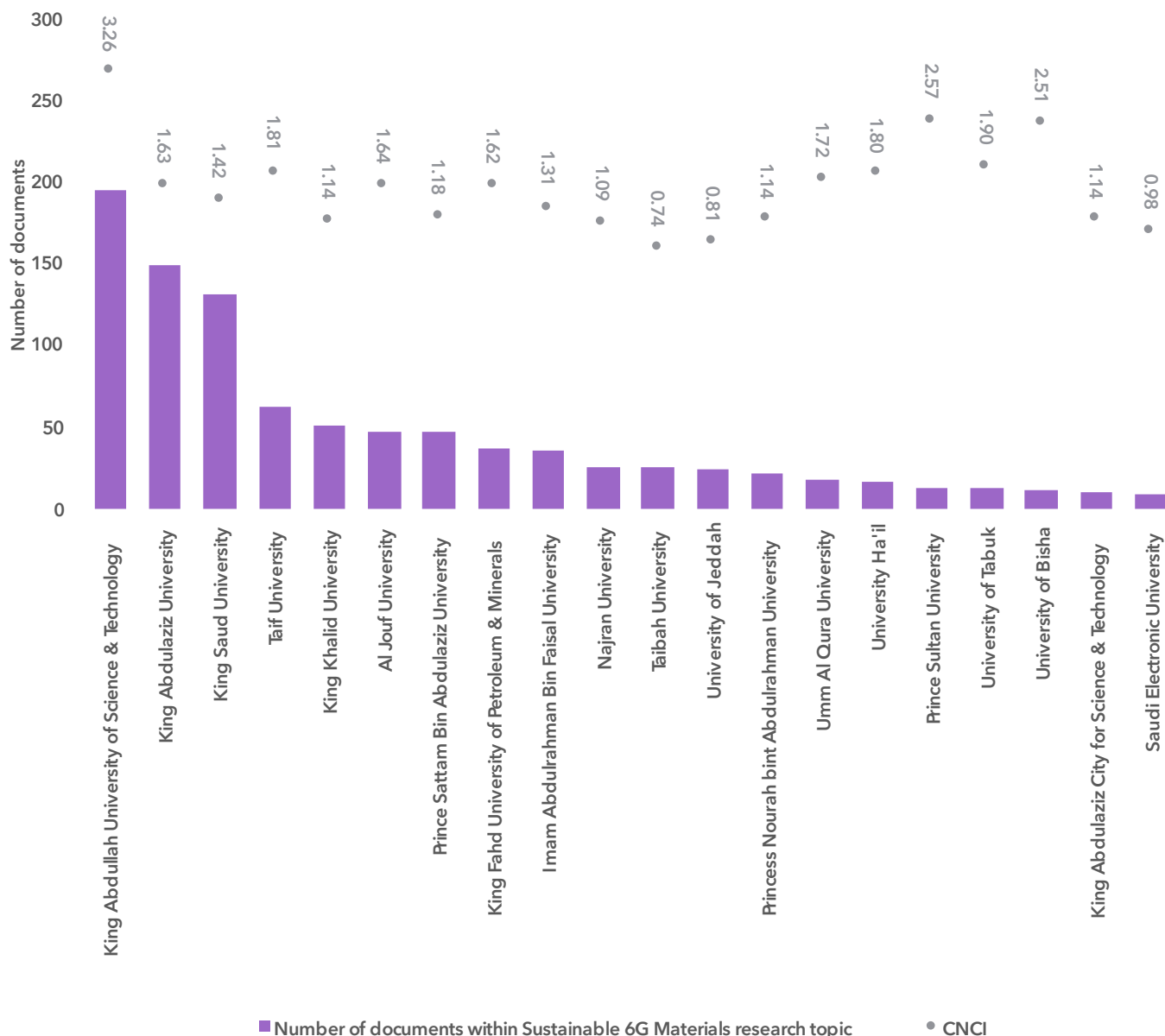


Figure 70: Top 20 Saudi organizations in terms of publications published in the research topic Sustainable 6G Materials in the period 2014-2023 and their corresponding CNCI

4.1.6.5 Top 20 researchers affiliated to Saudi organizations in terms of number of publications

The highest number of publications are published by Mohamed-Slim Alouini affiliated to King Abdullah University of Science & Technology followed by Xixiang Zhang affiliated to King Abdullah University of Science & Technology and Ibraheem Al-Naib affiliated to Imam Abdulrahman Bin Faisal University with 61, 26 and 22 publications respectively as shown in Table 21.

The highest CNCI is achieved by publications published by Mohamed-Slim Alouini affiliated to King Abdullah University of Science & Technology with a CNCI of 7.17.

The latter researcher has also the highest number of Top 1% amounting to 11 publications and Top 10% publications amounting to 32 publications.

Table 21: Top 20 researchers affiliated to Saudi organizations in terms of number of publications published in the research topic Sustainable 6G Materials in the period 2014-2023

Name	Affiliation	Web of Science Publications	CNCI	Documents in top 1%	Documents in top 10%
Alouini, Mohamed-Slim	King Abdullah University of Science & Technology	61	7.17	11	32
Zhang, Xixiang	King Abdullah University of Science & Technology	26	1.91	1	10
Al-Naib, Ibraheem	Imam Abdulrahman Bin Faisal University	22	1.68	1	6
Al-Naffouri, Tareq Y.	King Abdullah University of Science & Technology	20	3.34	3	8
Eid, Mahmoud M. A.	Taif University	17	0.89	0	0
Shihada, Basem	King Abdullah University of Science & Technology	15	5.57	2	4
Vettikalladi, Hamsakutty	King Saud University	14	0.82	0	1
Sarieddeen, Hadi	King Abdullah University of Science & Technology	14	5.70	4	8
Alkanhal, Majeed A. S.	King Saud University	12	0.33	0	0
Faragallah, Osama S.	Taif University	12	0.73	0	0
Rmili, Hatem	King Abdulaziz University	12	0.27	0	0
Kamruzzaman, M. M.	Al Jouf University	12	1.75	0	3
Almawgani, Abdulkarem H. M.	Najran University	10	1.76	0	2
Bagci, Hakan	King Abdullah University of Science & Technology	10	0.63	0	0
Armghan, Ammar	Al Jouf University	10	1.87	0	2
Aliqab, Khaled	Al Jouf University	10	1.87	0	2
Alhawari, Adam R. H.	Najran University	9	0.73	0	1
Alsharari, Meshari	Al Jouf University	9	1.26	0	1
Hossain, M. Shamim	King Saud University	9	2.62	1	2
Barnawi, Ahmed	King Abdulaziz University	8	2.01	0	4

4.1.6.6 Top 10 countries in terms of publications

The highest number of publications published in this research topic are published by Mainland China (21,324 publications) followed by United States (9,745 publications) and Germany (5,483 publications) as shown in Figure 71.

The highest citation impact measured by the CNCI is achieved by publications published by the United States, United Kingdom, and Italy with a CNCI of 1.45, 1.44 and 1.34, respectively. Four of the top 10 countries in terms of number of publications published in the research topic are also among the top 10 collaborators with Saudi Arabia. These are United States, United Kingdom, South Korea, and India.

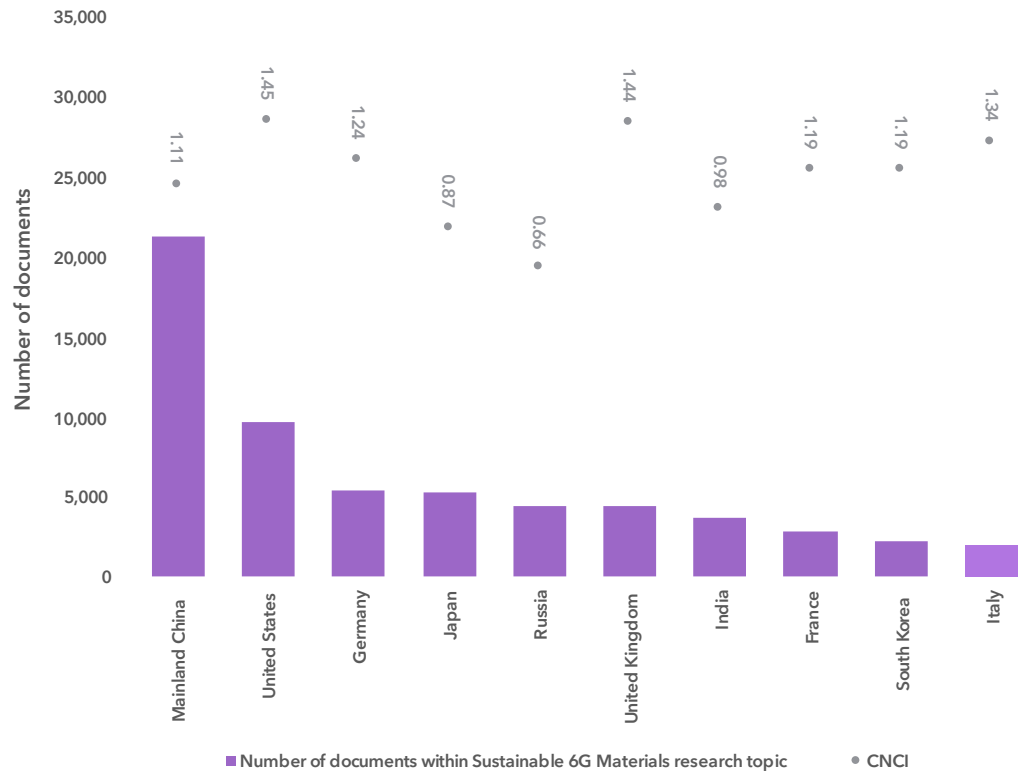


Figure 71: Top 10 countries in terms of number of publications in the research topic Sustainable 6G Materials in the period 2014-2023 and their corresponding CNCI

4.1.6.7 Top 20 organizations globally in terms of number of publications

The top 3 organizations in terms of number of publications published in this research topic in the period 2014-2023 are Chinese Academy of Sciences (3,253 publications) followed by Russian Academy of Sciences (2,916 publications) and Centre National de la Recherche Scientifique (CNRS) (1,888 publications) respectively as shown in Figure 72.

In terms of citation impact measured by the CNCI, Universite Paris Cite followed by Max Planck Society and University of London had the highest CNCI with 1.96, 1.90 and 1.87, respectively.

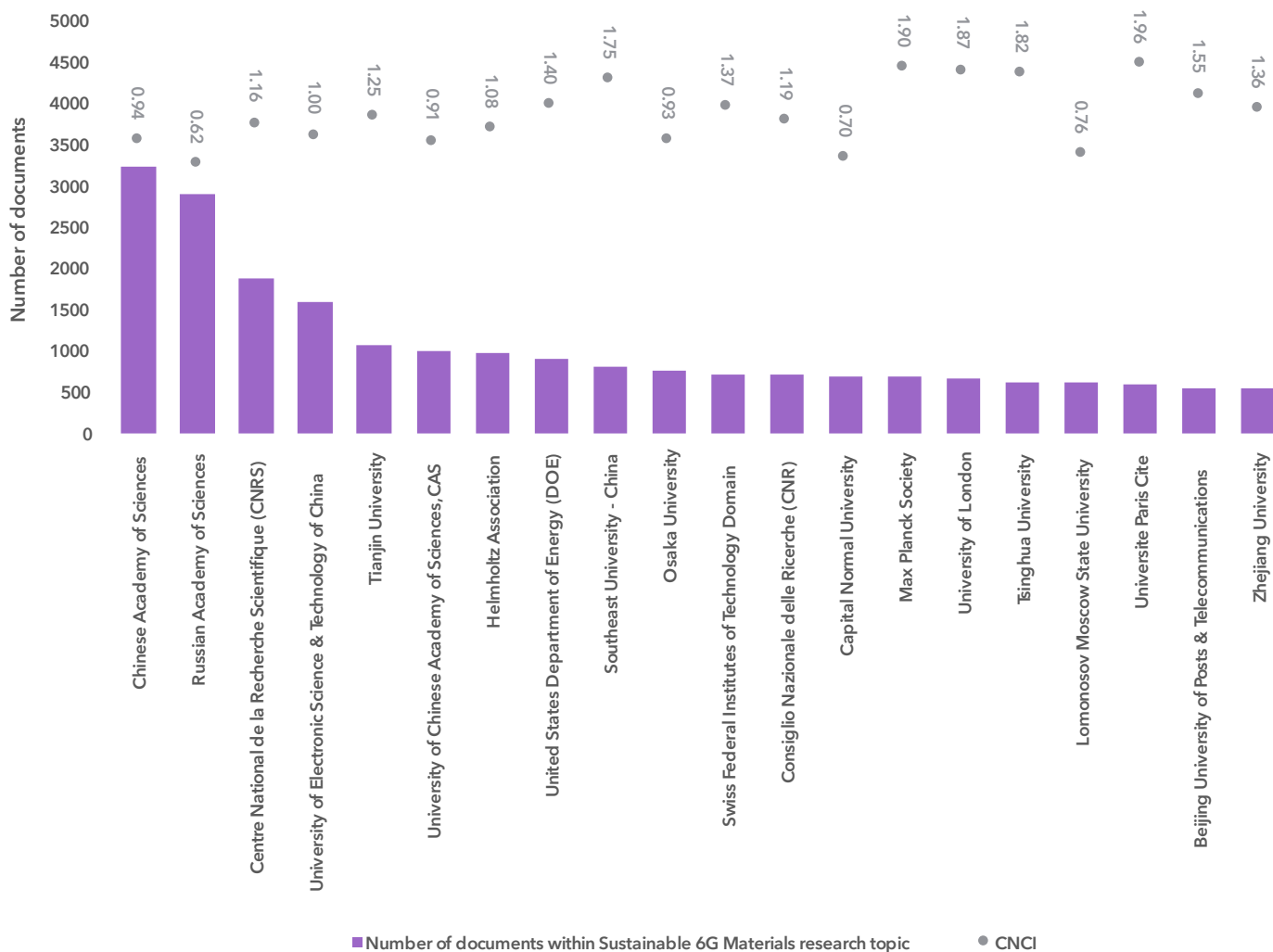


Figure 72: Top 20 organizations globally in terms of number of publications published in the research topic Sustainable 6G Materials in the period 2014-2023 and their corresponding CNCI

4.1.6.8 Top 20 researchers globally in terms of number of publications

The top 3 researchers globally in terms of number of publications in this research topic are Jianquan Yao affiliated to Tianjin University with 369 publications followed Jianguang Han affiliated to Tianjin University with 218 publications and Weili Zhang affiliated to Oklahoma State University - Stillwater with 196 publications as shown in Table 22.

The highest CNCI, Documents in top 1% and Documents in top 10% among the top 20 researchers globally is achieved by Ranjan Singh affiliated to Nanyang Technological University with a CNCI of 3.56, 15 publications in top 1% and 77 publications in top 10%.

Table 22: Top 20 researchers globally in terms of the number of publications published on the research topic Sustainable 6G Materials in the period 2014-2023

Name	Affiliation	Web of Science Publications	CNCI	Documents in the top 1%	Documents in the top 10%	Country
Yao, Jianquan	Tianjin University	369	1.37	14	62	Mainland China
Han, Jianguang	Tianjin University	218	1.91	9	66	United States
Zhang, Weili	Oklahoma State University - Stillwater	196	2.17	10	70	Japan
Nagatsuma, Tadao	Osaka University	173	2.15	5	49	Mainland China
Zhang, Cunlin	Capital Normal University	171	0.43	0	4	United States
Jarrahi, Mona	University of California Los Angeles	145	1.71	8	24	England
Zeitler, J. Axel	University of Cambridge	138	1.40	1	24	Mainland China
Fan, Fei	Nankai University	138	1.37	1	28	Singapore
Singh, Ranjan	Nanyang Technological University	138	3.56	15	77	Mainland China
Zhang, Yan	Capital Normal University	137	1.69	6	29	Australia
Withayachumnankul, Withawat	University of Adelaide	137	1.41	2	37	Mainland China
Xu, Degang	Tianjin University	136	0.69	1	9	Switzerland
Faist, Jerome	ETH Zurich	132	1.06	2	25	England
Linfield, Edmund H.	University of Leeds	129	0.84	0	12	Mainland China
Yang, Ziqiang	University of Electronic Science & Technology of China	129	0.77	2	12	Mainland China
Gong, Yubin	University of Electronic Science & Technology of China	127	0.47	1	3	Mainland China
Cui, Tie Jun	Southeast University - China	125	2.98	12	48	England
Li, Lianhe	University of Leeds	121	1.15	1	15	Mainland China
Zhang, Yaxin	University of Electronic Science & Technology of China	120	0.96	4	14	United States
Mittleman, Daniel M.	Brown University	116	1.55	6	23	United States

4.1.6.9 Top 20 global funders globally in terms of number of publications

The top 3 organizations in terms of funded publications in this research topic are the National Natural Science Foundation of China (NSFC) with 13,431 publications, followed by the European Union (EU) with 2,539 publications, Ministry of Education, Culture, Sports, Science and Technology, Japan (MEXT) with 2,351 publications as shown in Figure 73.

The highest citation impact measured by the CNCI is observed in publications funded by the European Research Council (ERC), followed by the National Science Foundation (NSF) and United States Department of Defense with 2.22, 2.01 and 1.84, respectively.

Among the top 20 global funding organizations, 11 are also among the top 20 funding organizations of Saudi publications in this research topic.

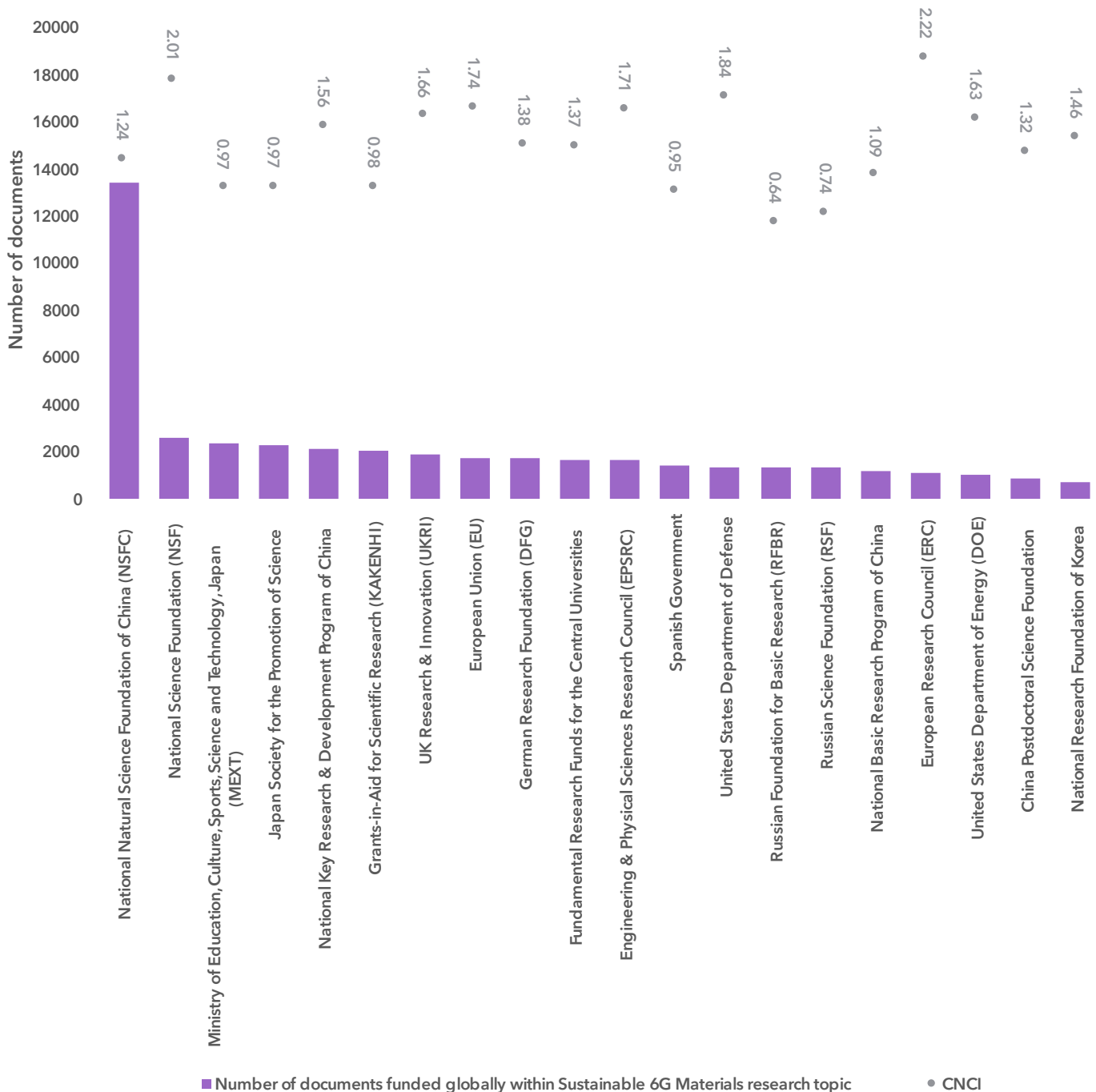


Figure 73: Top 20 funding organizations globally publications in the research topic Sustainable 6G Materials in terms of number of publications in the period 2014-2023

4.1.6.10 Emerging trends in the research topic globally and in Saudi Arabia

In this section, we investigate the emerging trends globally and in Saudi Arabia on the research topic of Sustainable 6G Materials. For more information on the methodology used to identify emerging trends, please see the definition section Emerging Trends.

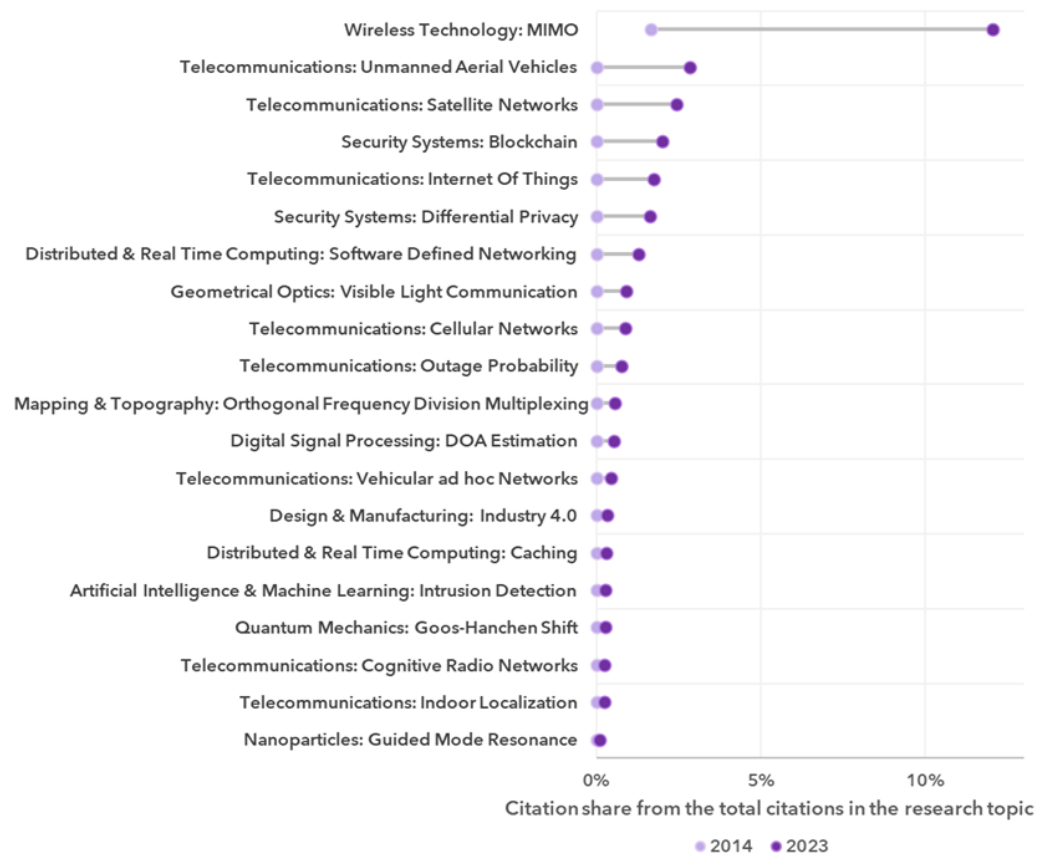


Figure 74: Top 20 emerging micro-topics globally in the research topic Sustainable 6G Materials in the period 2014-2023

The top 3 emerging micro-topics globally in this research topic are Wireless Technology: MIMO followed by Telecommunications: Unmanned Aerial Vehicles and Telecommunications: Satellite Networks as shown in Figure 74. Saudi Arabia has very few publications on this research topic, such that it was not meaningful to identify emerging micro-topics. Table 23 shows the identified top 10 micro-topics in Saudi Arabia's research output on this research topic.

Table 23: Top 10 Micro-topics identified in Saudi Arabia research output in the research topic Sustainable 6G Materials in the period 2014-2023

Topic	Number of Saudi Arabia publications in the period 2014-2023
Sustainable 6G Materials research topic	889
Wireless Technology: Metamaterials	102
Wireless Technology: MIMO	94
Wireless Technology: Terahertz	73
Nanoparticles: SERS	41
Telecommunications: Unmanned Aerial Vehicles	34
2D Materials: Graphene	32
Security Systems: Blockchain	23
2D Materials: MoS2	23
Telecommunications: Internet Of Things	21
Optical Electronics & Engineering: Photonic Crystal Fiber	20

4.1.7 Sustainable 6G Automatic Management

There were 550 publications in this area globally from 2014 to 2023. Of these, only four are affiliated with an organization in Saudi Arabia.

As this is a priority research topic, we analyze its global dynamics, identifying top countries, organizations, funding entities and researchers that Saudi-affiliated researchers could collaborate with to enhance the research output in this area.

4.1.7.1 Top 10 countries in terms of publications

The highest number of publications published in this research topic are published by Mainland China (206 publications) followed by United States (123 publications) and South Korea (63 publications) as shown in Figure 75. The highest citation impact measured by the CNCI is achieved by publications published by United Kingdom, Canada, and Australia with a CNCI of 2.82, 2.60 and 2.53, respectively.

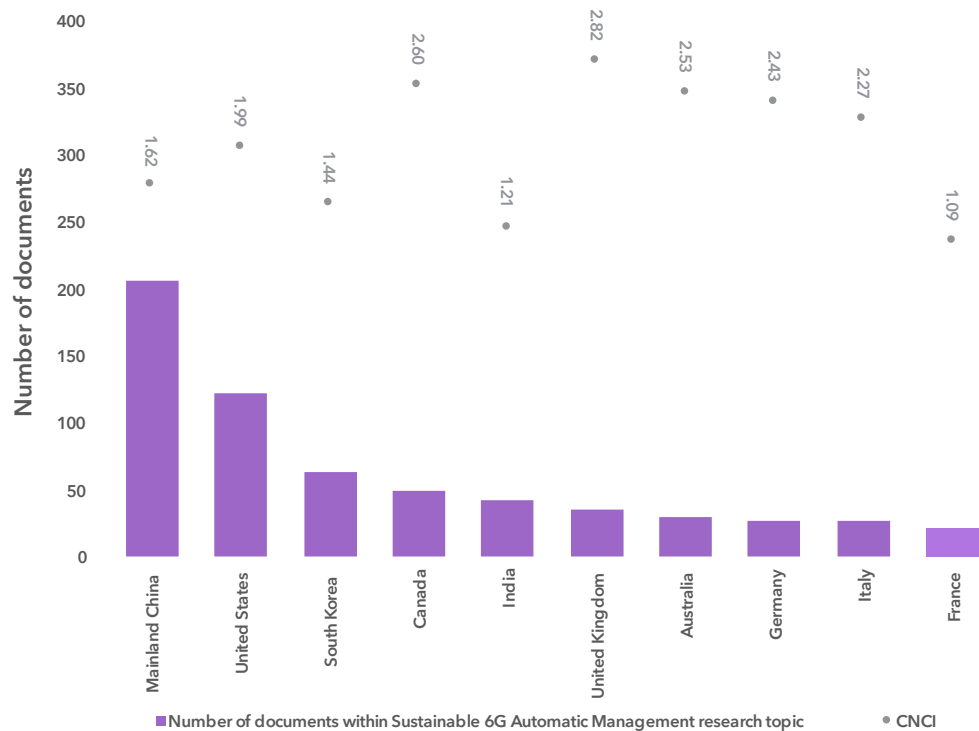


Figure 75: Top 10 countries in terms of the number of publications in the research topic Sustainable 6G Automatic Management in the period 2014-2023 and their corresponding CNCI

4.1.7.2 Top 20 organizations globally in terms of number of publications

The top 3 organizations in terms of a number of publications published in this research topic in the period 2014-2023 are Beijing University of Posts & Telecommunications (33 publications) followed by Carleton University (17 publications) and Xidian University (14 publications) respectively, as shown in Figure 76.

In terms of citation impact measured by the CNCI, Huazhong University of Science & Technology, followed by the University of Manitoba and Muroran Institute of Technology, had the highest CNCI with 4.64, 3.67 and 3.47, respectively.

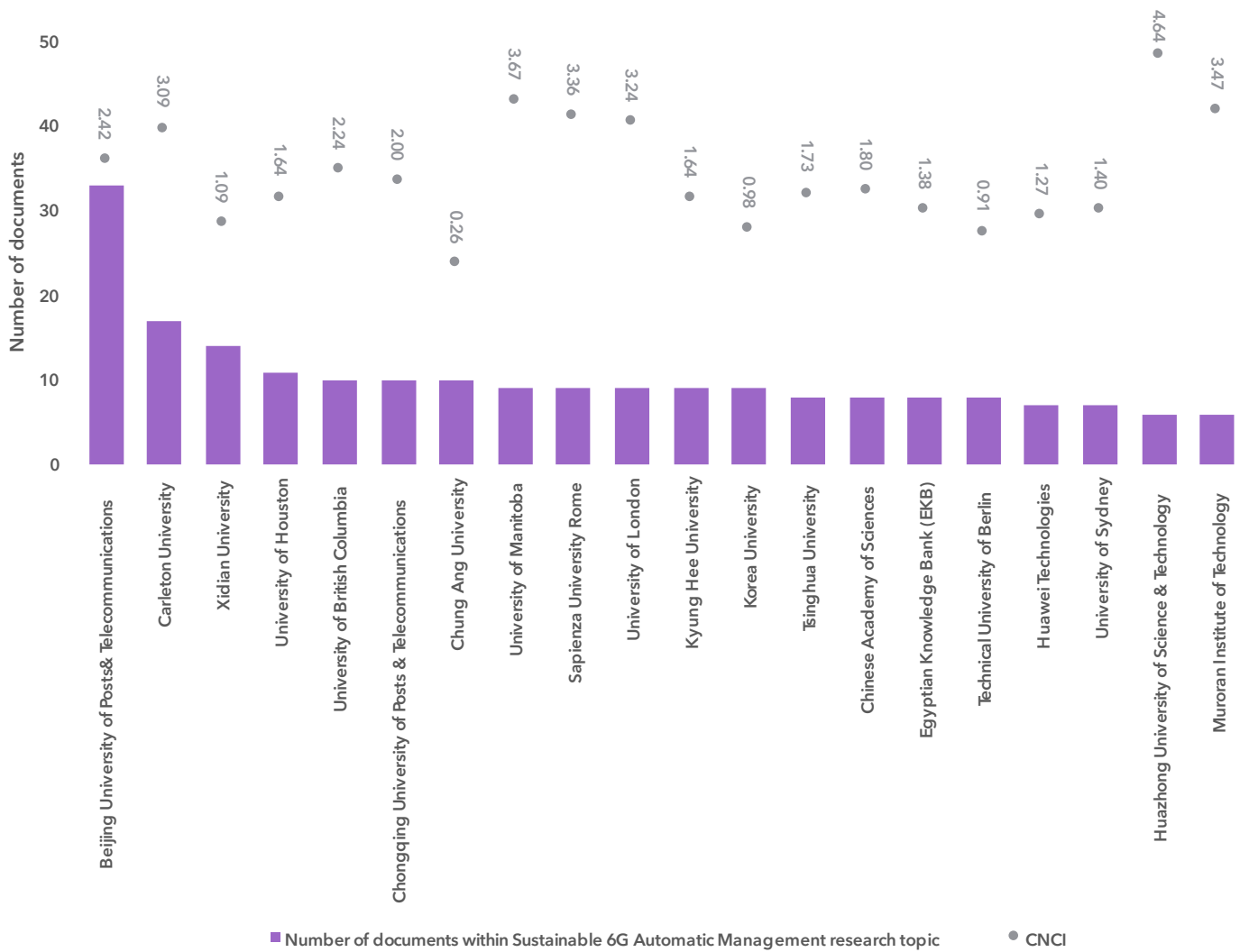


Figure 76: Top 20 organizations globally in terms of number of publications published in the research topic Sustainable 6G Automatic Management in the period 2014-2023 and their corresponding CNCI

4.1.7.3 Top 20 researchers globally in terms of number of publications

The top 3 researchers globally in terms of the number of publications on this research topic are F. Richard Yu who was affiliated with Carleton University with 13 publications, followed by Zhu Han, affiliated with the University of Houston with 11 publications, and Jung-Ryun Lee, affiliated with Chung Ang University with nine publications, as shown in Table 24.

The highest CNCI among the top 20 researchers globally is achieved by Kaoru Ota affiliated to Muroran Institute of Technology with a CNCI of 4.40.

F. Richard Yu, affiliated with Carleton University, has the highest Top 1% publications, amounting to 2 publications, and Top 10% publications, amounting to 7 publications.

Table 24: Top 20 researchers globally in terms of the number of publications published in the research topic Sustainable 6G Automatic Management in the period 2014-2023

Name	Affiliation	Web of Science Publications	CNCI	Documents in the top 1%	Documents in the top 10%	Country
Yu, F. Richard	Carleton University	13	3.74	2	7	Canada
Han, Zhu	University of Houston	11	1.64	0	3	United States
Lee, Jung-Ryun	Chung Ang University	9	0.23	0	0	South Korea
Hossain, Ekram	University of Manitoba	8	3.81	1	5	Canada
Leung, Victor C. M.	University of British Columbia	8	2.66	1	4	Canada
Ji, Hong	Beijing University of Posts & Telecommunications	8	2.14	0	4	Mainland China
Baccarelli, Enzo	Sapienza University Rome	5	2.79	0	3	Italy
Chang, Zheng	University of Jyvaskyla	5	0.84	0	0	Finland
Cordeschi, Nicola	Sapienza University Rome	5	2.79	0	3	Italy
Choi, Hyun-Ho	Hankyong National University	5	0.35	0	0	South Korea
Jorswieck, Eduard	Technische Universitat Dresden	4	3.74	1	1	Germany
Niyato, Dusit	Nanyang Technological University	4	2.21	0	1	Singapore
Li, Jiandong	Xidian University	4	1.36	0	1	Mainland China
Ota, Kaoru	Muroran Institute of Technology	4	4.40	1	2	Japan
Anpalagan, Alagan	Toronto Metropolitan University	4	0.91	0	0	Canada
Dong, Mianxiong	Muroran Institute of Technology	4	3.37	1	1	Japan
Yanikomeroğlu, Halim	Carleton University	4	1.01	0	0	Canada
Papavassiliou, Symeon	National Technical University of Athens	4	1.11	0	1	Greece
Zhou, Zhenyu	North China Electric Power University	4	4.40	1	2	Mainland China
Liu, Gang	Beijing University of Posts & Telecommunications	4	1.53	0	2	Mainland China

4.1.7.4 Top 20 global funders globally in terms of number of publications

The top 3 organizations in terms of funded publications in this research topic are the National Natural Science Foundation of China (NSFC) with 119 publications, followed by the National Science Foundation (NSF) with 36 publications, and the National Research Foundation of Korea with 26 publications, as shown in Figure 77.

The highest citation impact measured by the CNCI is observed in publications funded by UK Research & Innovation (UKRI) and Engineering & Physical Sciences Research Council (EPSRC) sharing the same CNCI followed by China Scholarship Council and NSF - Division of Electrical, Communications & Cyber Systems (ECCS) with 5.83, 4.36 and 3.96, respectively.

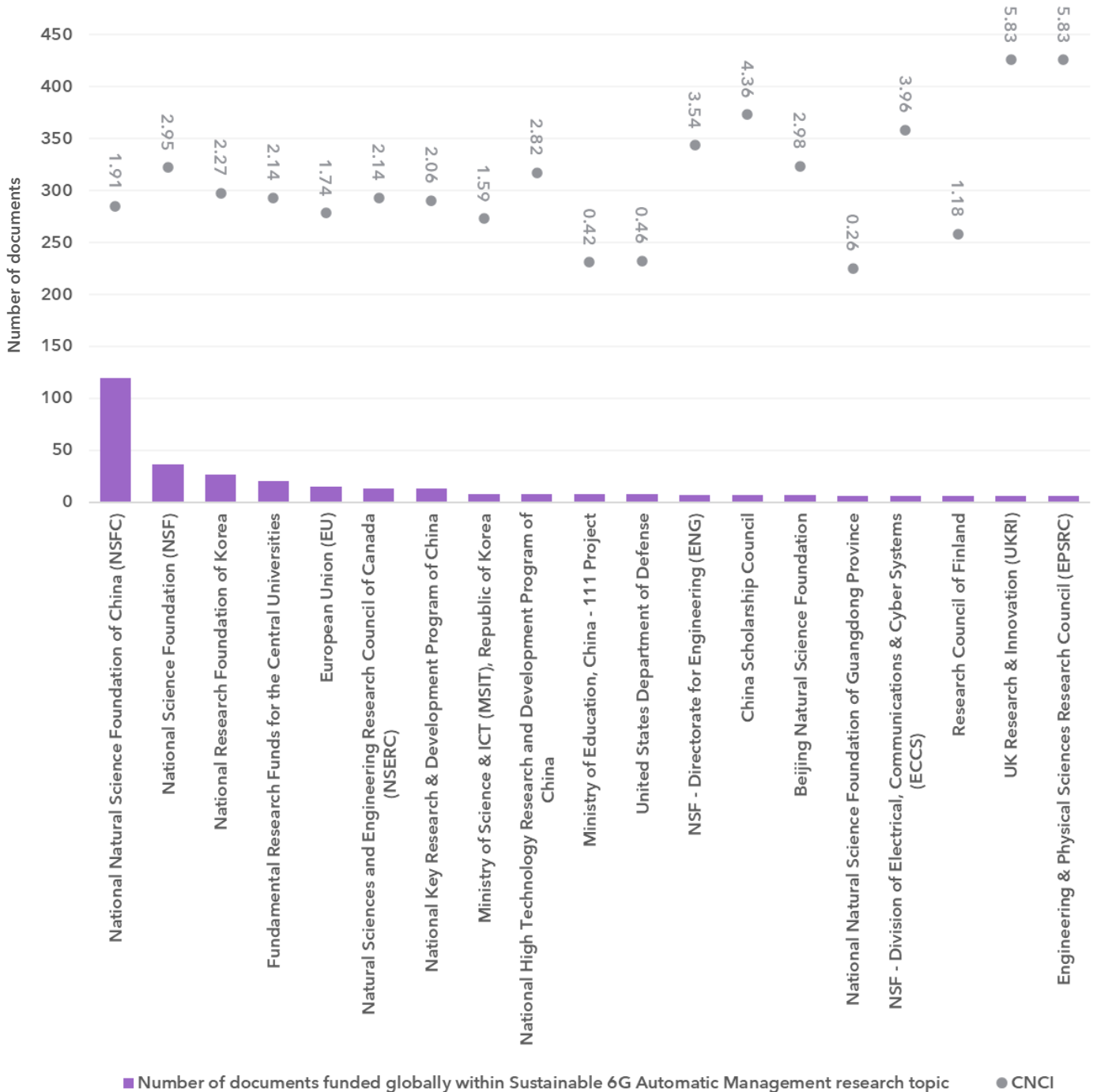


Figure 77: Top 20 funding organizations globally publications in the research topic Sustainable 6G Automatic Management in terms of number of publications in the period 2014-2023

4.1.7.5 Top micro-topics in the research topic globally

As there are few documents in this the research topic Sustainable 6G Automatic Management globally, it was not meaningful to derive emerging trends.

Nevertheless, Table 25 highlights the top micro-topics in this research topic globally.

Table 25: Top 10 micro-topics globally in the research topic Sustainable 6G - Automatic Management in the period 2014-2023

Topic	Number of Global publications in the period 2014-2023
Sustainable 6G Automatic Management research topic	550
Telecommunications: Cellular Networks	171
Telecommunications: Internet Of Things	86
Telecommunications: Outage Probability	53
Distributed & Real Time Computing: Software Defined Networking	22
Telecommunications: Vehicular ad hoc Networks	22
Telecommunications: Cognitive Radio Networks	16
Power Systems & Electric Vehicles: Distributed Generation	15
Wireless Technology: MIMO	14
Telecommunications: Wireless Sensor Networks	11
Security Systems: Blockchain	11

4.1.8 Sustainable 6G Energy Efficient Edge Infrastructure

Globally there are only 322 publications in this area in the period 2014-2023. Within the identified 322 publications, only 8 of them have an affiliation associated with an organization in Saudi Arabia.

As this is a priority research topic, in the following we analyze the global dynamics in this research topic, identifying top countries, organizations, funding entities and researchers that Saudi affiliated researchers could collaborate with to enhance the research output in this area

4.1.8.1 Top 10 countries in terms of publications

The highest number of publications published in this research topic are published by Mainland China (125 publications) followed by United States (54 publications) and India (46 publications) as shown in Figure 78.

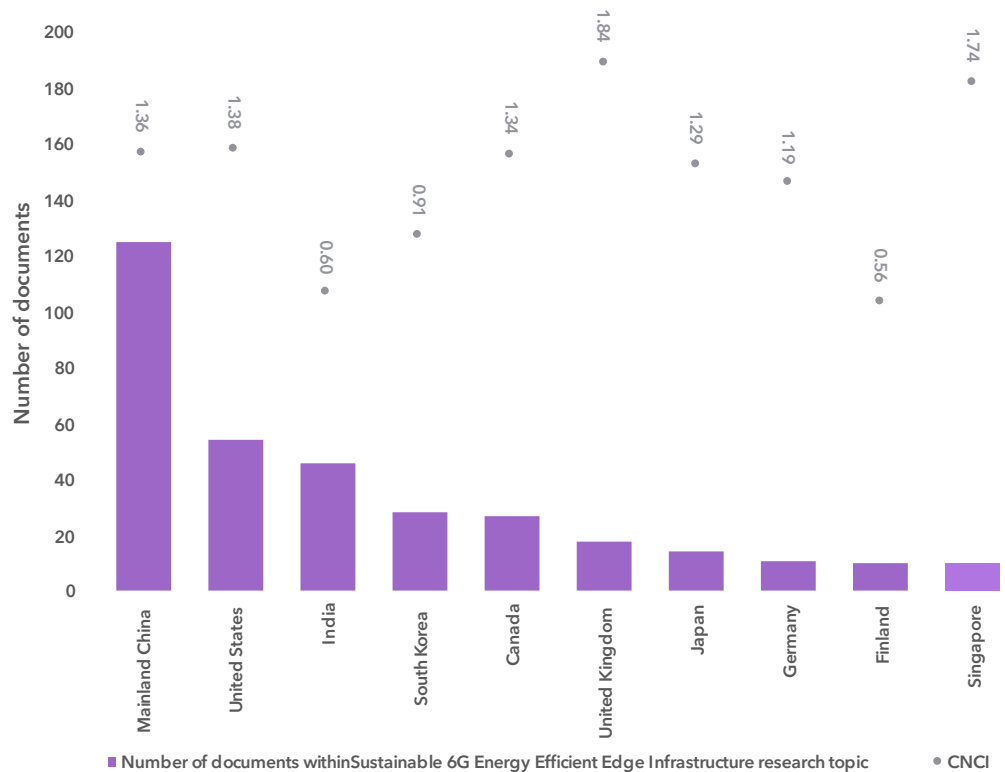


Figure 78: Top 10 countries in terms of number of publications in the research topic Sustainable 6G Energy Efficient Edge Infrastructure in the period 2014-2023 and their corresponding CNCI

The highest citation impact measured by the CNCI is achieved by publications published by United Kingdom, Singapore, and United States with a CNCI of 1.84, 1.74 and 1.38, respectively.

4.1.8.2 Top 20 organizations globally in terms of number of publications

The top 3 organizations in terms of number of publications published in this research topic in the period 2014-2023 are Beijing University of Posts & Telecommunications (14 publications) followed by Southeast University - China (11 publications) followed by Egyptian Knowledge Bank (EKB) and Shenzhen Research Institute, City University of Hong Kong sharing the same number of publications (8 publications) as shown in Figure 79.

In terms of citation impact measured by the CNCI, Huawei Technologies followed by University of Waterloo and Zhejiang University of Technology sharing the same CNCI followed by Southeast University - China had the highest CNCI with 2.07, 1.8 and 1.74, respectively.

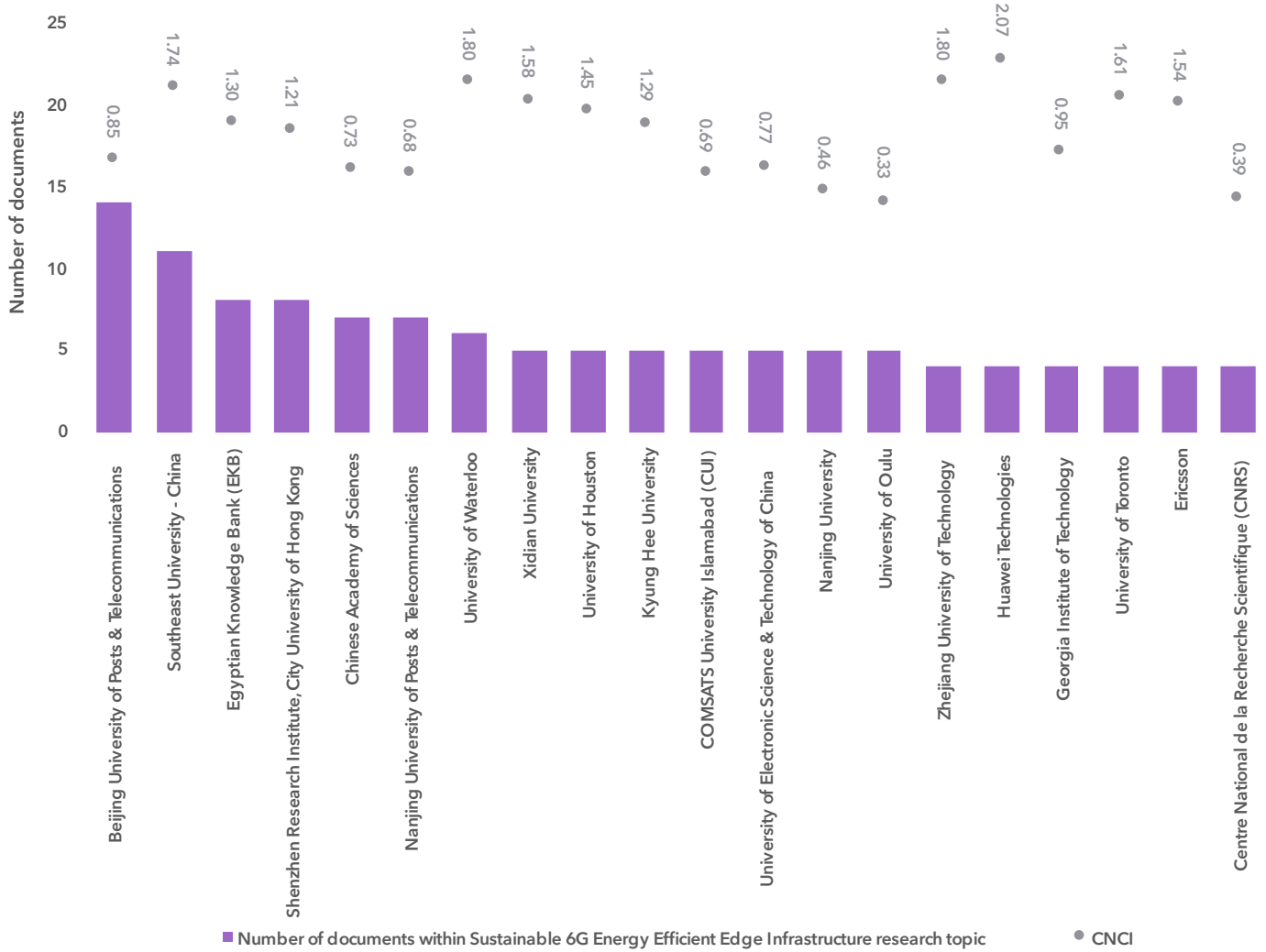


Figure 79: Top 20 organizations globally in terms of the number of publications published in the research topic Sustainable 6G Energy Efficient Edge Infrastructure in the period 2014-2023 and their corresponding CNCI

4.1.8.3 Top 20 researchers globally in terms of number of publications

The top researcher globally in terms of the number of publications on this research topic is Zhu Han, affiliated with the University of Houston, with five publications, as shown in Table 26.

The highest CNCI among the top 20 researchers globally is achieved by Kazi Huq Mohammed Saidul, affiliated to Universidade de Aveiro, with a CNCI of 4.57.

There are no publications in top 1% among the top researchers, while for publications in top 10%, they can be grouped into 3 groups with 2,1 or 0 publications.

Table 26: Top 20 researchers globally in terms of the number of publications published in the research topic Sustainable 6G Energy Efficient Edge Infrastructure in the period 2014-2023

Name	Affiliation	Web of Science Publications	CNCI	Documents in the top 1%	Documents in the top 10%	Country
Han, Zhu	University of Houston	5	1.45	0	1	United States
Shen, Xuemin	University of Waterloo	4	1.99	0	2	Canada
Wu, Yuan	Zhejiang University of Technology	4	1.80	0	2	Mainland China
Boudreau, Gary	Ericsson	4	1.54	0	1	Sweden
Lin, Stanley	MediaTek Incorporated	4	0.73	0	0	Taiwan
Hsu, Ian	Mediatek Incorporated	4	0.73	0	0	Taiwan
Yu, Kai	Nanjing University	4	0.47	0	0	Mainland China
Zhou, Haibo	Nanjing University	4	0.47	0	0	Mainland China
Heng, Wei	Southeast University - China	3	3.93	0	1	Mainland China
Nazemi, Mostafa	George Washington University	3	2.91	0	2	United States
Dehghanian, Payman	George Washington University	3	2.91	0	2	United States
Wang, Jiaheng	Southeast University - China	3	2.05	0	1	Mainland China
Chen, Chi-Yuan	Mediatek Incorporated	3	0.90	0	0	Taiwan
Liang, Ben	University of Toronto	3	0.88	0	0	Canada
Hazra, Ranjay	National Institute of Technology Silchar	3	0.61	0	0	India
Godfrey, W. Wilfred	ABV-Indian Institute of Information Technology & Management, Gwalior	3	0.57	0	0	India
Trivedi, Aditya	ABV-Indian Institute of Information Technology & Management, Gwalior	3	0.57	0	0	India
Khan, Zaheer	University of Oulu	3	0.40	0	0	Finland
Zhao, Jiwei	Nanjing University	3	0.26	0	0	Mainland China
Huq, Kazi Mohammed Saidul	Universidade de Aveiro	2	4.57	0	1	Portugal

4.1.8.4 Top 20 global funders globally in terms of number of publications

The top 3 organizations in terms of funded publications in this research topic are National Natural Science Foundation of China (NSFC) with 81 publications followed by Fundamental Research Funds for the Central Universities with 19 publications and National Science Foundation (NSF) with 17 publications as shown in Figure 80.

The highest citation impact measured by the CNCI is observed in publications funded by Ministry of Education, China - 111 Project followed by the China Scholarship Council, Ministry of Education, Culture, Sports, Science and Technology, Japan (MEXT) and Japan Society for the Promotion of Science sharing the same CNCI followed by Natural Sciences and Engineering Research Council of Canada (NSERC) with CNCI of 8.23, 3.12 and 2.19 respectively.

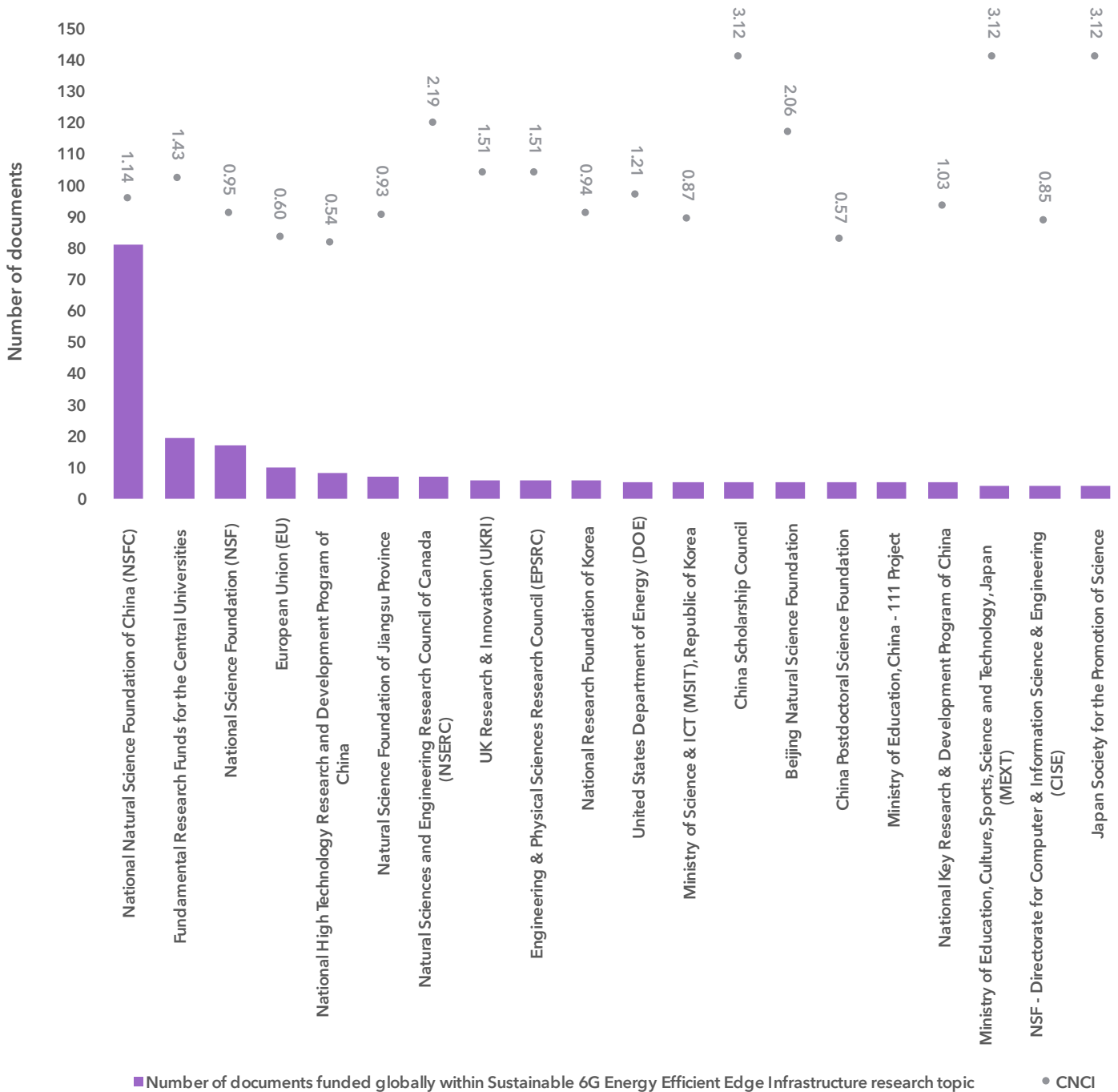


Figure 80: Top 20 funding organizations globally publications in the research topic Sustainable 6G Energy Efficient Edge Infrastructure in terms of number of publications in the period 2014-2023

4.1.8.5 Top micro-topics in the research topic globally

As there are few documents globally published on the research topic Sustainable 6G Energy Efficient Edge Infrastructure, it is not meaningful to derive emerging trends. Nevertheless, Table 27 highlights the top micro-topics in this research topic globally.

Table 27: Top 20 emerging micro-topics globally in the research topic Sustainable 6G Energy Efficient Edge Infrastructure in the period 2014-2023

Topic	Number of Global publications in the period 2014-2023
Sustainable 6G Energy Efficient Edge Infrastructure research topic	322
Telecommunications: Cellular Networks	114
Telecommunications: Outage Probability	27
Telecommunications: Internet Of Things	17
Wireless Technology: MIMO	16
Distributed & Real-Time Computing: Software-Defined Networking	11
Wireless Technology: Wireless Power Transfer	9
Telecommunications: Unmanned Aerial Vehicles	8
Telecommunications: Wireless Sensor Networks	8
Distributed & Real-Time Computing: Caching	8
Telecommunications: Cognitive Radio Networks	6

4.1.9 Autonomous Vehicles

4.1.9.1 Evolution of Saudi publication share of global publications in the research topic

The share of Saudi Arabian publications from global publications on the research topic increased almost continuously from 2014 till 2023, as shown in Figure 81. This shows that Saudi Arabia was not only able to increase the number of publications on this research topic but also had a growth higher than the global growth rate.

This is evident as the share of Saudi Arabia publications in the research topic is growing. The CNCI of Saudi Arabia publications in this research topic were in all years higher than 1, indicating a citation impact performance higher than the global average.

Overall, Saudi Arabia publications increased with a higher growth rate than the global average in this research topic and had a relatively good citation impact as measured by the CNCI.

Nevertheless, after this high growth rate in terms of publications, one should focus on increasing/preserving the relatively good citation impact.

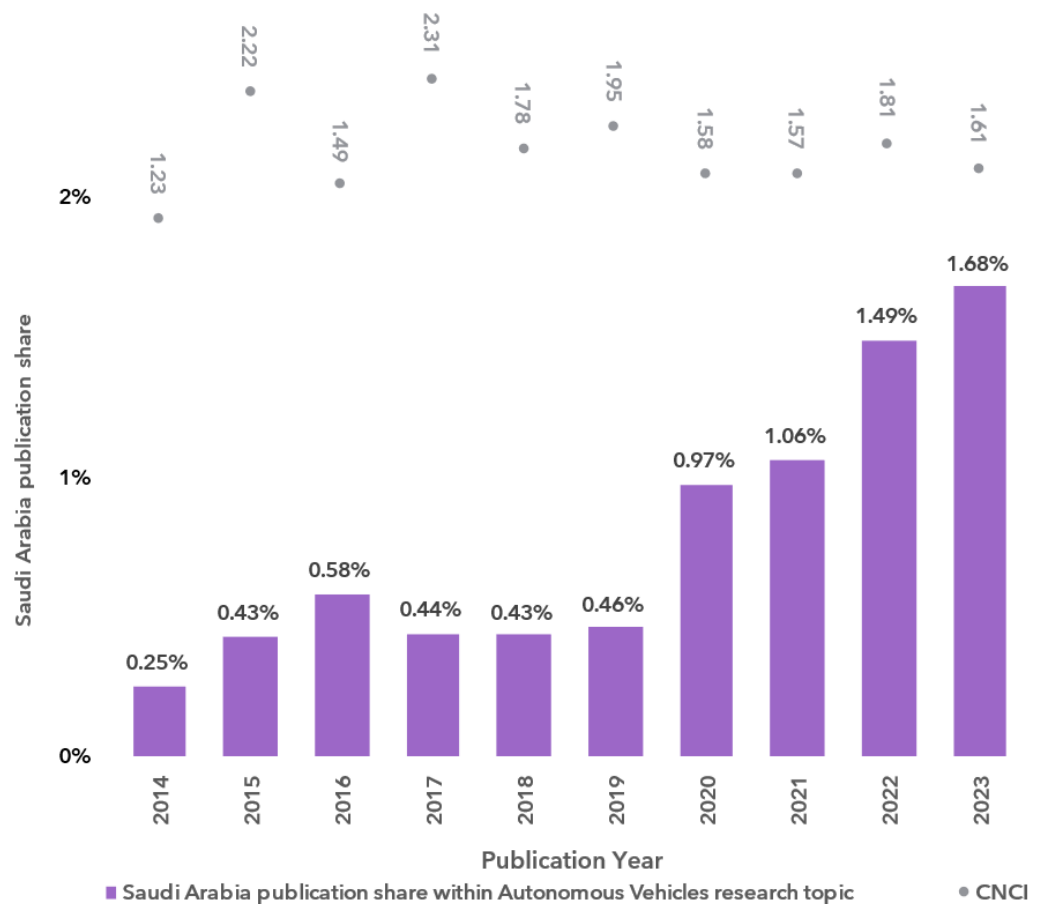


Figure 81: The share of Saudi Arabia from global publications in the research topic and the CNCI of Saudi Arabia publications in the research topic Autonomous Vehicles in the period 2014-2023

4.1.9.2 Top 10 countries collaborating with Saudi Arabia

The top collaborating country with Saudi Arabia in this research topic in the period 2014-2023 are Pakistan followed by India and United States with 81, 78 and 72 publications respectively as shown in Figure 82.

In terms of citation impact measured by the CNCI publications published in collaboration with United Kingdom followed by Malaysia and South Korea had the highest CNCI with 3.00, 2.66 and 2.47, respectively.

Nevertheless, all publications with the top 10 collaborating countries had a CNCI higher than 1, reflecting a performance higher than the global average.

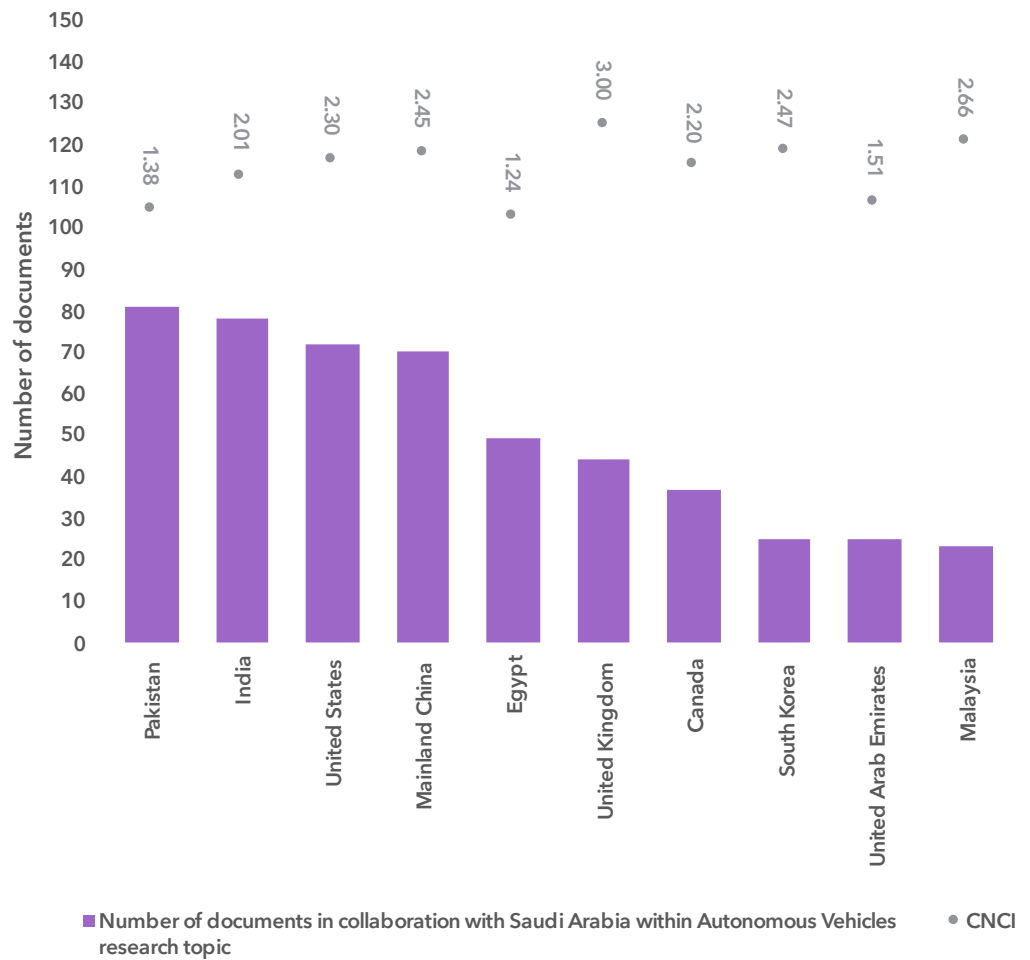


Figure 82: Top 10 collaborating countries with Saudi Arabia in terms of the number of publications on the research topic of Autonomous Vehicles in the period 2014-2023

4.1.9.3 Top 20 funders of Saudi publications by number of publications

The top 3 funding organizations of Saudi Arabia publications in this research topic in terms of number of publications mentioning the organization in the funding text in the period 2014-2023 are King Saud University followed by Princess Nourah bint Abdulrahman University and National Natural Science Foundation of China (NSFC) with 40, 22 and 20 publications respectively as shown in Figure 83.

Documents funded by the Federal Ministry of Education & Research (BMBF) followed by European Union (EU) and Qatar National Research Fund (QNRF) had the highest citation impact measured by the CNCI with 17.47, 11.10 and 4.64, respectively.

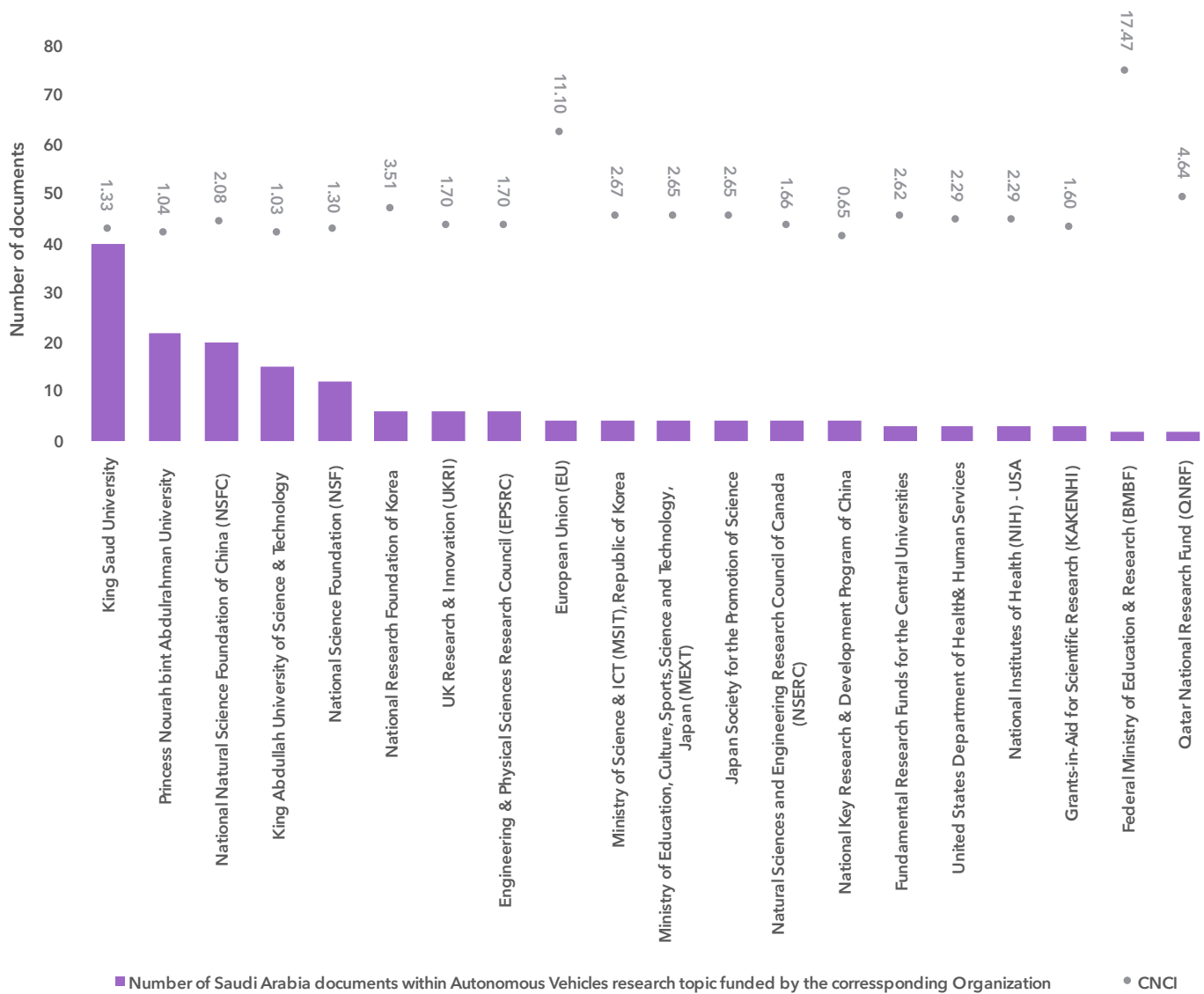


Figure 83: Top 20 funding organizations of Saudi Arabia publications in the research topic Autonomous Vehicles in terms of number of publications in the period 2014-2023

4.1.9.4 Top 20 Saudi Arabia organizations in terms of number of publications

The top 3 organizations in terms of publications published on this research topic in the period 2014-2023 are King Saud University, followed by King Abdulaziz University and King Abdullah University of Science & Technology, with 80, 77 and 60 publications, respectively, as shown in Figure 84.

Regarding citation impact as measured by the CNCI, Northern Border University, followed by King Faisal University and the University of Tabuk, had the highest CNCI with 2.76, 2.67 and 2.56, respectively.

Nevertheless, 15 of the top 20 organizations had a CNCI higher than 1, reflecting a citation impact performance higher than the global average.

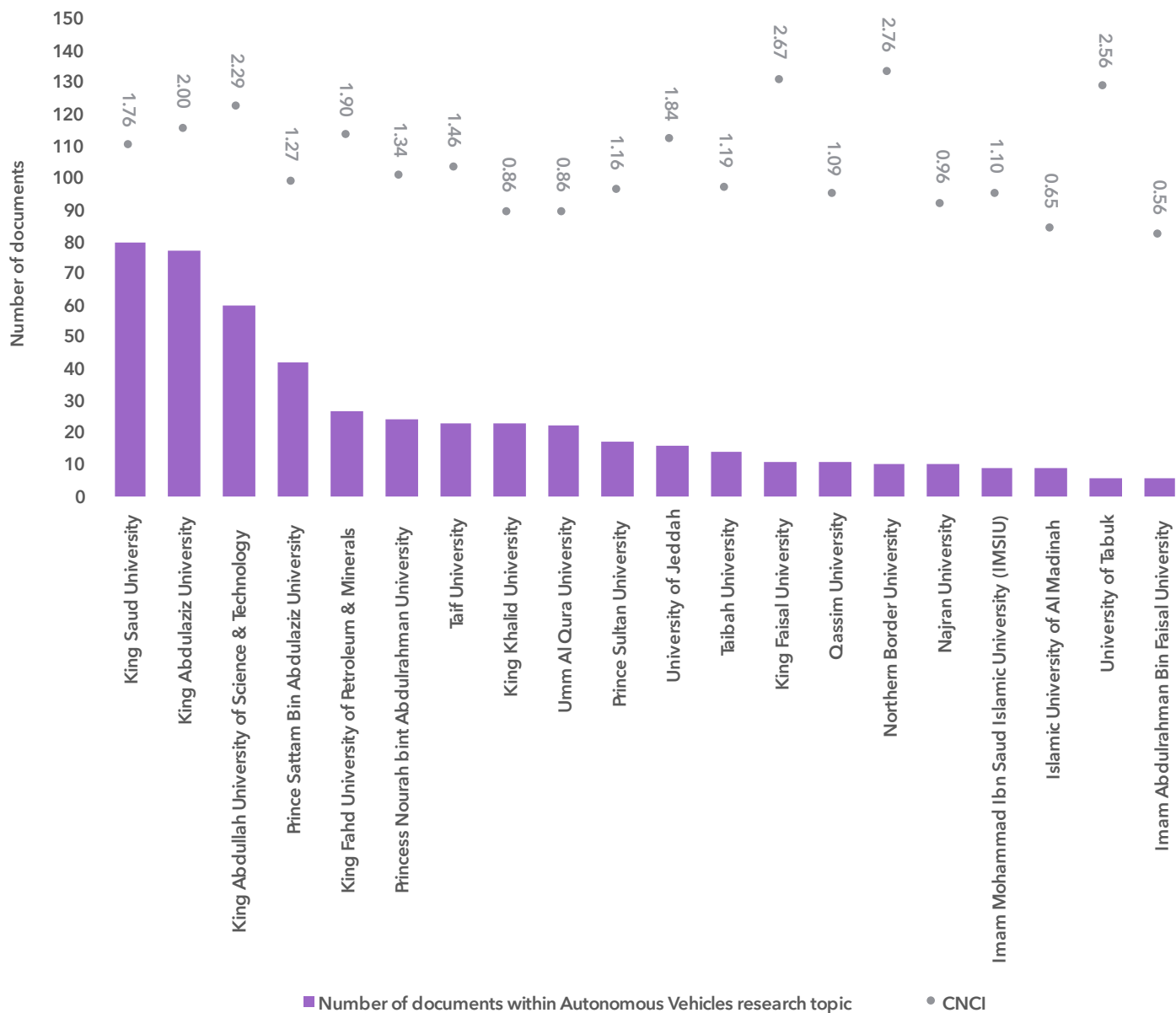


Figure 84: Top 20 Saudi organizations in terms of publications published in the research topic Autonomous Vehicles in the period 2014-2023 and their corresponding CNCI

4.1.9.5 Top 20 researchers affiliated with Saudi organizations in terms of number of publications.

The highest number of publications are published by Mohamed-Slim Alouini, affiliated with King Abdullah University of Science & Technology, with 16 publications, as shown in Table 28.

The highest CNCI is achieved by publications published by Iyad Katib affiliated to King Abdulaziz University with a CNCI of 5.00. Mohamed-Slim Alouini affiliated to King Abdullah University of Science & Technology also has the highest number of Top 10% amounting to 5 publications.

Table 28: Top 20 researchers affiliated with Saudi organizations in terms of the number of publications published in the research topic Autonomous Vehicles in the period 2014-2023

Name	Affiliation	Web of Science Publications	CNCI	Documents in the top 1%	Documents in the top 10%
Alouini, Mohamed-Slim	King Abdullah University of Science & Technology	16	1.97	0	5
Hassan, Mohammad Mehedi	King Saud University	7	2.95	1	3
Imran, Muhammad	King Saud University	7	2.10	1	1
Ghanem, Bernard	King Abdullah University of Science & Technology	7	1.89	0	2
Mehmood, Rashid	King Abdulaziz University	6	4.23	1	3
Ansari, Uzair	King Abdulaziz University	6	1.88	0	2
Bajodah, Abdulrahman H.	King Abdulaziz University	6	1.88	0	2
Hossain, M. Shamim	King Saud University	5	4.45	1	1
Muhammad, Ghulam	King Saud University	5	4.12	1	1
Khan, Muhammad Khurram	King Saud University	5	1.85	0	1
Hoteit, Ibrahim	King Abdullah University of Science & Technology	5	0.79	0	0
Thayananthan, Vijey	King Abdulaziz University	5	0.71	0	0
Katib, Iyad	King Abdulaziz University	4	5.00	1	2
Almogren, Ahmad	King Saud University	4	1.92	0	1
Saudagar, Abdul Khader Jilani	Imam Mohammad Ibn Saud Islamic University (IMSIU)	4	1.57	0	1
Ooi, Boon S.	King Abdullah University of Science & Technology	4	1.22	0	1
Ng, Tien Khee	King Abdullah University of Science & Technology	4	1.22	0	1
Alkhazragi, Omar	King Abdullah University of Science & Technology	4	1.22	0	1
Tariq, Usman	Prince Sattam Bin Abdulaziz University	4	1.15	0	1
Lima, Ricardo M.	King Abdullah University of Science & Technology	4	0.53	0	0

4.1.9.6 Top 10 countries in terms of publications

As shown in Figure 85, Mainland China published the most publications on this research topic (13,260), followed by the United States (10,869) and Germany (4,205).

The highest citation impact measured by the CNCI is achieved by publications published by United States followed by Canada and United Kingdom followed by Germany with a CNCI of 2.32, 2.29 and 1.93, respectively.

Six of the top 10 countries in terms of number of publications published in the research topic are also among the top 10 collaborators with Saudi Arabia. These are United States, Canada, United Kingdom, Mainland China, South Korea, and India.

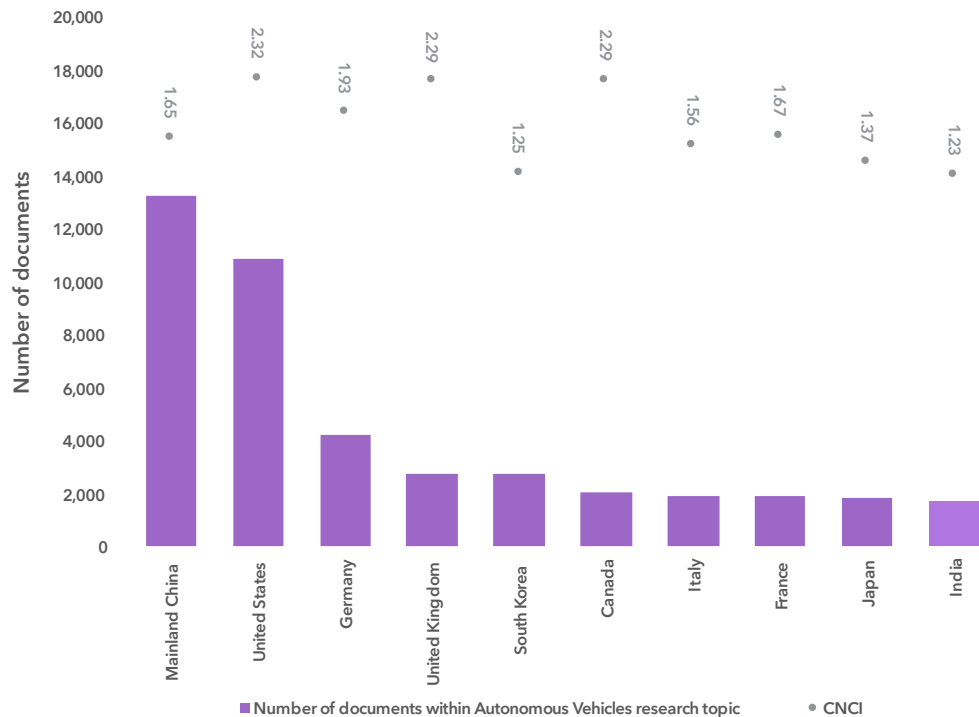


Figure 85: Top 10 countries in terms of the number of publications in the research topic Autonomous Vehicles in the period 2014-2023 and their corresponding CNCI

4.1.9.7 Top 20 organizations globally in terms of number of publications

The top 3 organizations in terms of number of publications published in this research topic in the period 2014-2023 are Tsinghua University (971 publications) followed by Chinese Academy of Sciences (970 publications) and Centre National de la Recherche Scientifique (CNRS) (950 publications) respectively as shown in Figure 86.

Regarding citation impact measured by the CNCI, the University of California Berkeley, followed by Carnegie Mellon University and Swiss Federal Institutes of Technology Domain, had the highest CNCI with 4.18, 4.13 and 3.73, respectively.

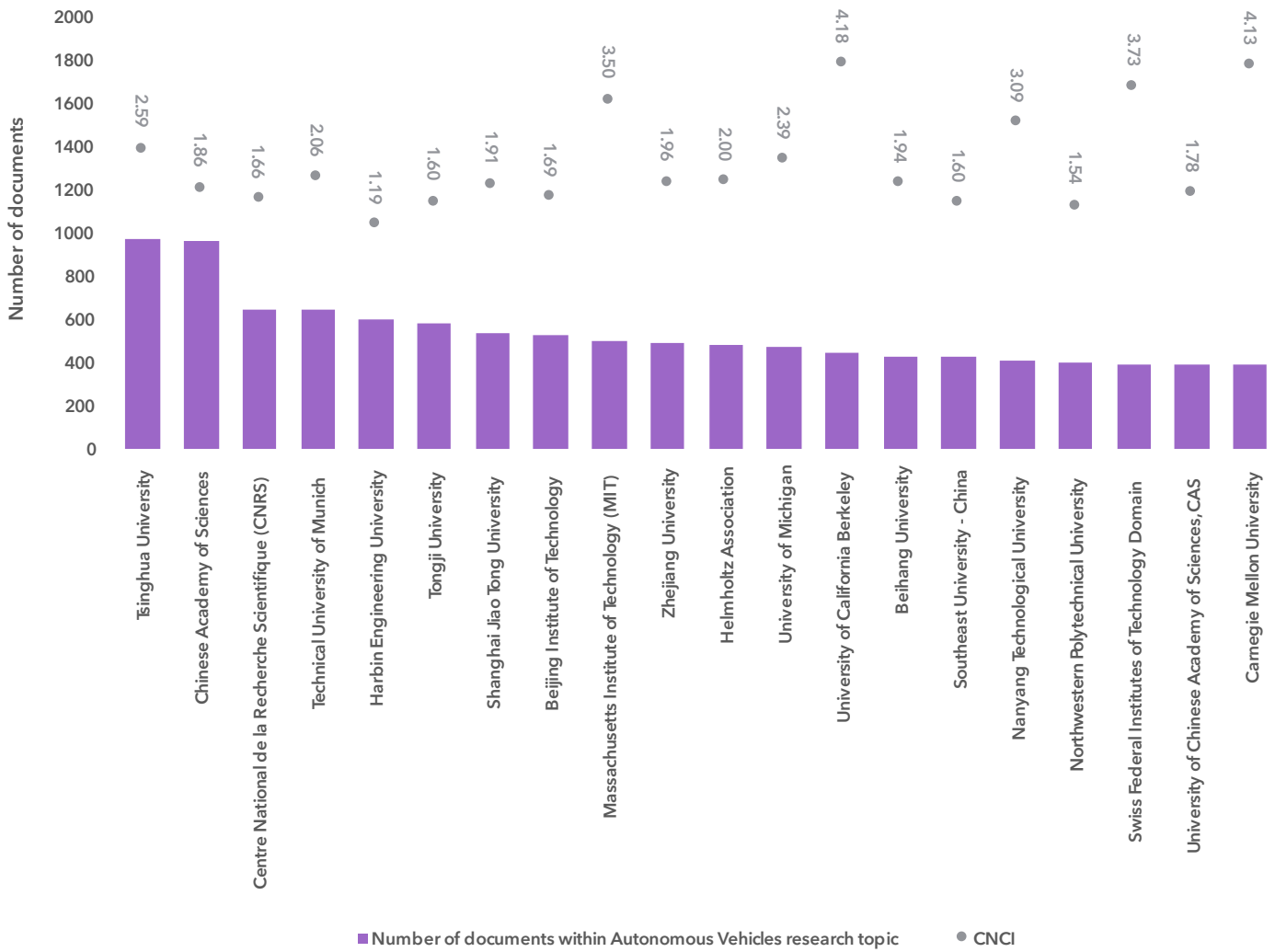


Figure 86: Top 20 organizations globally in terms of the number of publications published in the research topic Autonomous Vehicles in the period 2014-2023 and their corresponding CNCI

4.1.9.8 Top 20 researchers globally in terms of number of publications

The top three researchers globally in terms of the number of publications in this research topic are Bo He, affiliated to Ocean University of China, with 108 publications, followed by Alois Knoll, affiliated to Technical University of Munich, with 107 publications, and Masayoshi Tomizuka, affiliated to the University of California Berkeley, with 88 publications, as shown in Table 29.

The highest CNCI among the top 20 researchers globally is achieved by Chen Lv, affiliated with Nanyang Technological University, with a CNCI of 5.24.

Zhouhua Peng affiliated to Dalian Maritime University has the highest Top 1% publications amounting to 15 publications while Masayoshi Tomizuka affiliated to University of California Berkeley has the highest Top 10% publications amounting to 48 publications.

Table 29: Top 20 researchers globally in terms of the number of publications published on the research topic Autonomous Vehicles in the period 2014-2023

Name	Affiliation	Web of Science Publications	CNCI	Documents in the top 1%	Documents in the top 10%	Country
He, Bo	Ocean University of China	108	1.46	2	19	Mainland China
Knoll, Alois	Technical University of Munich	107	1.71	3	25	Germany
Tomizuka, Masayoshi	University of California Berkeley	88	3.90	12	48	United States
Rus, Daniela	Massachusetts Institute of Technology (MIT)	84	3.81	12	36	United States
Lv, Chen	Nanyang Technological University	74	5.24	13	41	Singapore
Peng, Zhouhua	Dalian Maritime University	69	3.59	15	31	Mainland China
Cao, Dongpu	University of Waterloo	69	3.08	8	33	Canada
Li, Keqiang	Tsinghua University	68	3.50	7	33	Mainland China
Zheng, Nanning	Xi'an Jiaotong University	68	2.69	2	24	Mainland China
Liu, Ming	Hong Kong University of Science & Technology	67	2.40	3	25	Hong Kong
Gaspar, Peter	Hungarian Research Network	65	0.79	0	3	Hungary
Zhu, Daqi	Shanghai Maritime University	62	1.72	1	19	Mainland China
Yang, Diange	Tsinghua University	61	1.81	2	16	Mainland China
Ridolfi, Alessandro	University of Florence	61	1.74	1	15	Italy
Wang, Fei-Yue	Chinese Academy of Sciences	60	4.74	10	30	Mainland China
Dietmayer, Klaus	Ulm University	60	3.88	5	29	Germany
Wang, Dan	Dalian Maritime University	60	3.15	10	25	Mainland China
Xiang, Xianbo	Huazhong University of Science & Technology	59	2.36	4	27	Mainland China
Althoff, Matthias	Technical University of Munich	58	4.69	9	40	Germany
Xiong, Lu	Tongji University	58	1.75	2	13	Mainland China

4.1.9.9 Top 20 global funders globally in terms of number of publications

The top 3 organizations in terms of funded publications in this research topic are the National Natural Science Foundation of China (NSFC), with 7,547 publications, followed by the National Science Foundation (NSF), with 2,131 publications, and the European Union (EU) with 1,598 publications, as shown in Figure 87.

The highest citation impact measured by the CNCI is observed in publications funded by the NSF–Directorate for Computer & Information Science & Engineering (CISE), followed by the Engineering & Physical Sciences Research Council (EPSRC) and the German Research Foundation (DFG), with 3.72, 2.95 and 2.87, respectively.

Among the top 20 global funding organizations, 13 are also among the top 20 funding organizations of Saudi publications in this research topic.

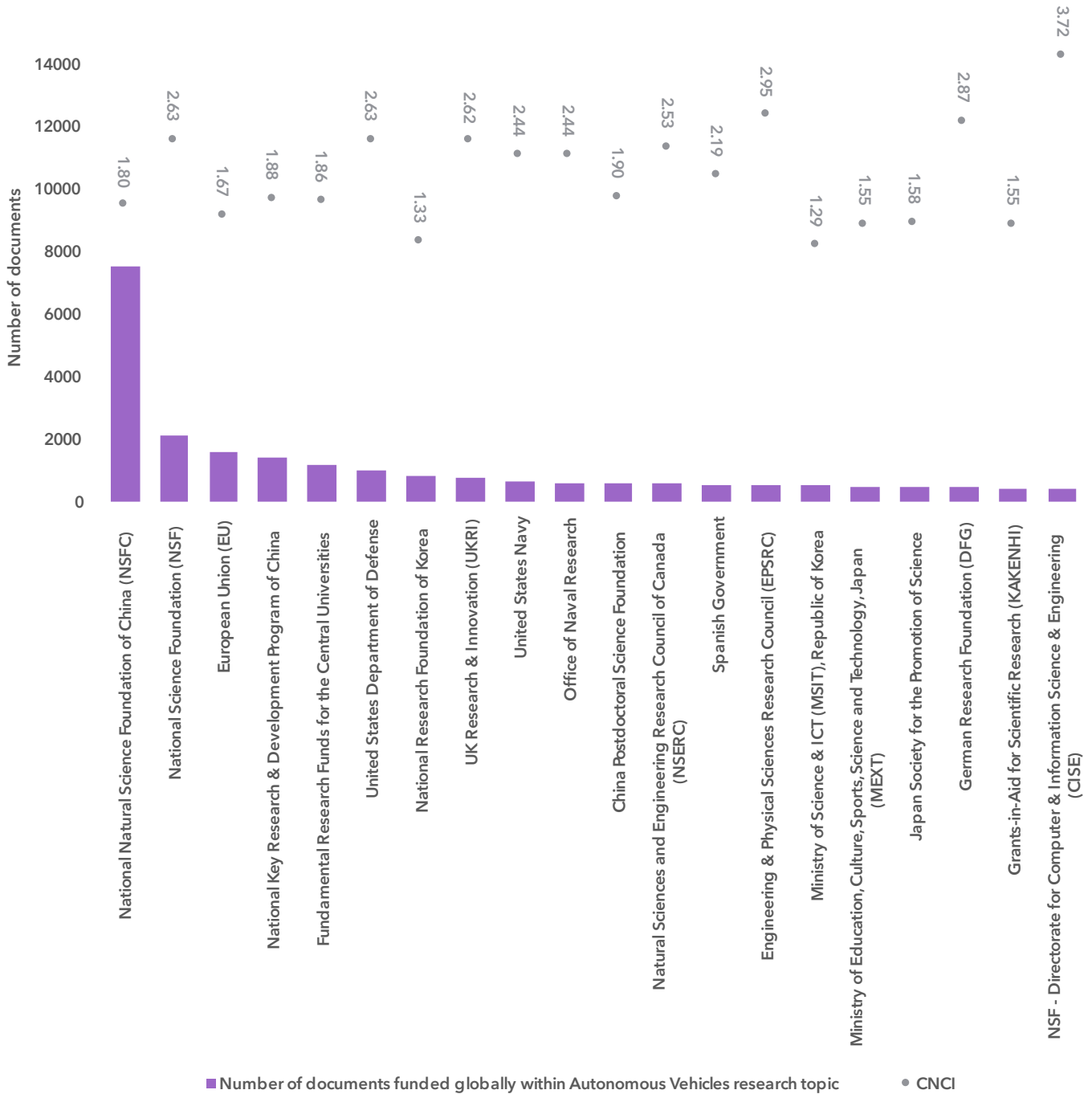


Figure 87: Top 20 funding organizations globally publications in the research topic Autonomous Vehicles in terms of number of publications in the period 2014-2023

4.1.9.10 Emerging trends in the research topic globally and in Saudi Arabia

In this section we investigate the emerging trends globally and in Saudi Arabia in the research topic Autonomous Vehicles. For more information on the methodology used to identify emerging trends, please see the definition section Emerging Trends.

The top 3 emerging micro-topics globally in this research topic are Computer Vision & Graphics Deep Learning, followed by Telecommunications, Unmanned Aerial Vehicles, and Transportation Crowd Simulation, as shown in Figure 88.

Table 30 shows the identified top 10 micro-topics in Saudi Arabia research output in this research topic.

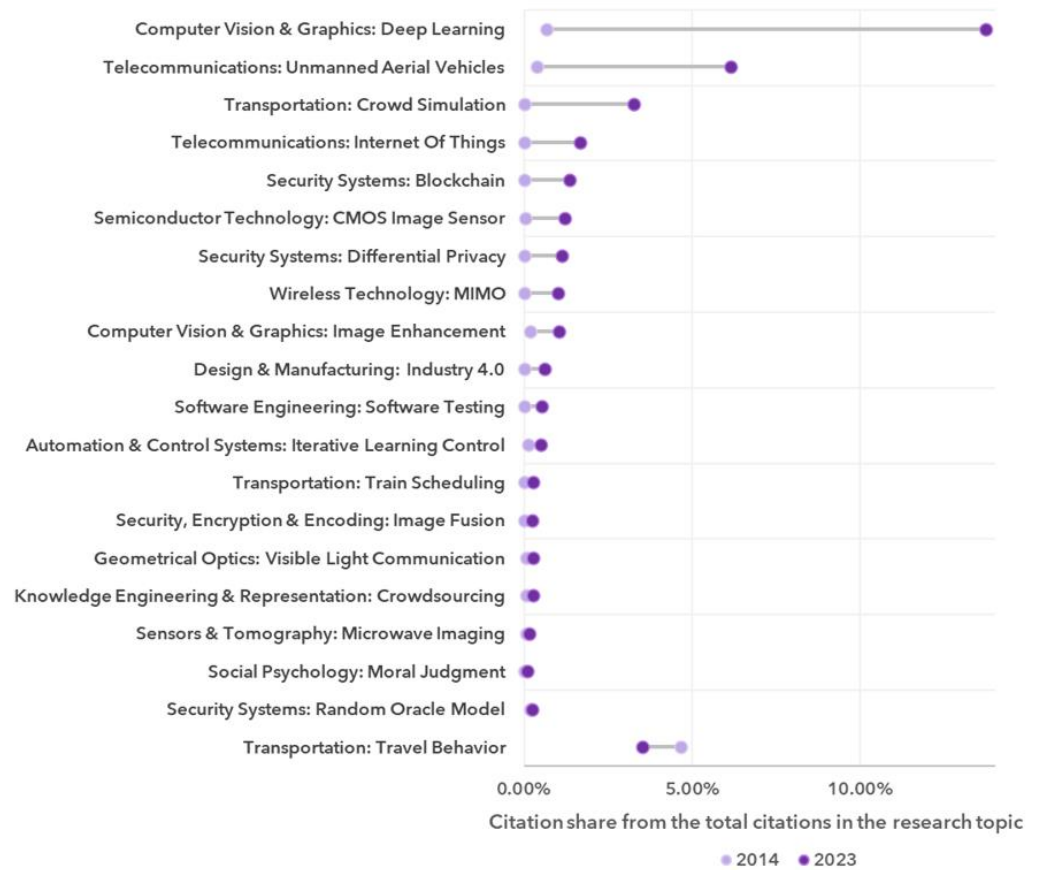


Figure 88: Top 20 emerging micro-topics globally in the research topic Autonomous Vehicles in the period 2014-2023

Table 30: Top 10 Micro-topics identified in Saudi Arabia research output in the research topic Autonomous Vehicles in the period 2014-2023

Topic	Number of Saudi Arabia publications in the period 2014-2023
Autonomous Vehicles research topic	481
Computer Vision & Graphics: Deep Learning	47
Telecommunications: Vehicular ad hoc Networks	43
Automation & Control Systems: Multi Agent Systems	28
Transportation: Traffic Flow	27
Telecommunications: Unmanned Aerial Vehicles	27
Telecommunications: Internet Of Things	22
Automation & Control Systems: Adaptive Control	21
Sensors & Tomography: Underwater Acoustic Communication	20
Robotics: Simultaneous Localization and Mapping	17
Security Systems: Blockchain	16

4.1.10 Semiconductors

4.1.10.1 Evolution of Saudi publication share of global publications in the research topic

The share of Saudi Arabia publications from global publications on the research topic increased almost continuously from 2014 till 2023, as shown in Figure 89. This shows that Saudi Arabia was not only able to increase the number of publications on this research topic but also had a growth higher than the global growth rate.

This is evident as the share of Saudi Arabia publications in the research topic is growing. The CNCI of Saudi Arabia publications in this research topic were in all years higher than 1, indicating a citation impact performance higher than the global average.

Overall, Saudi Arabia publications increased with a higher growth rate than the global average in this research topic and had a relatively good citation impact as measured by the CNCI.

Nevertheless, after this high growth rate in terms of publications, one should focus on increasing/preserving the relatively good citation impact.

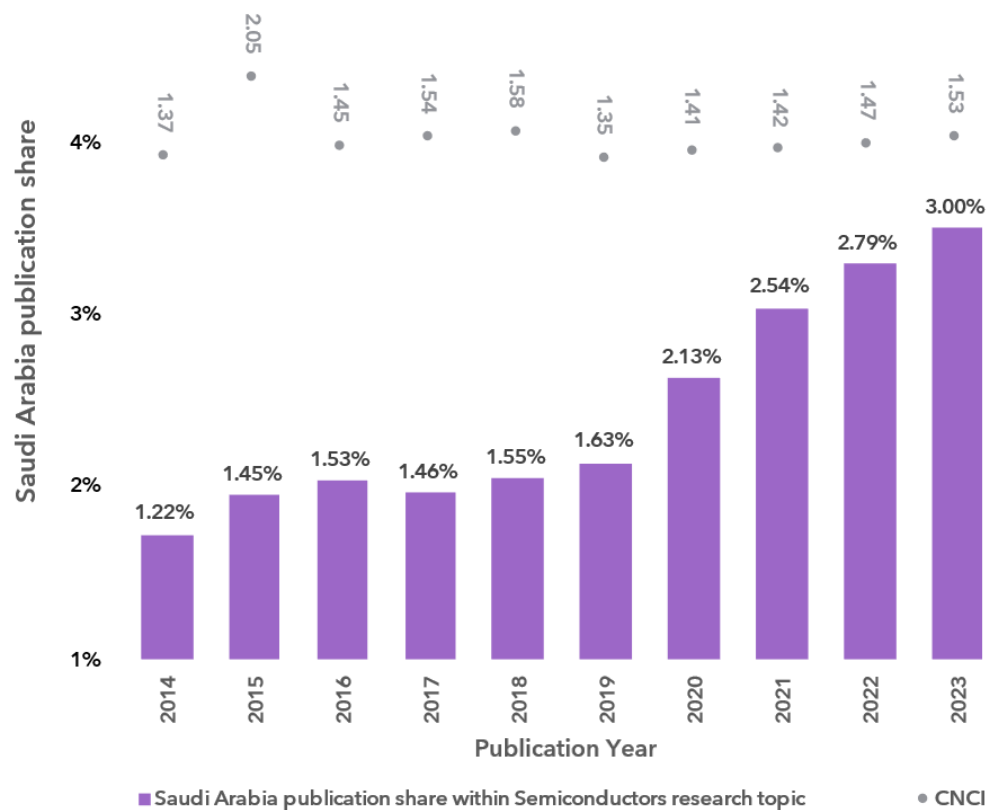


Figure 89: The share of Saudi Arabia from global publications in the research topic and the CNCI of Saudi Arabia publications in the research topic Semiconductors in the period 2014-2023

4.1.10.2 Top 10 countries collaborating with Saudi Arabia

The top collaborating country with Saudi Arabia in this research topic in the period 2014-2023 is Egypt, followed by Mainland China and China with 2,085, 1,645 and 1,587 publications, respectively as shown in Figure 90.

In terms of citation impact measured by the CNCI publications published in collaboration with Mainland China followed by United States and United Kingdom had the highest CNCI with 2.51, 2.44 and 1.98, respectively.

Nevertheless, all publications with the top 10 collaborating countries except for Tunisia had a CNCI higher than 1, reflecting a performance higher than the global average.

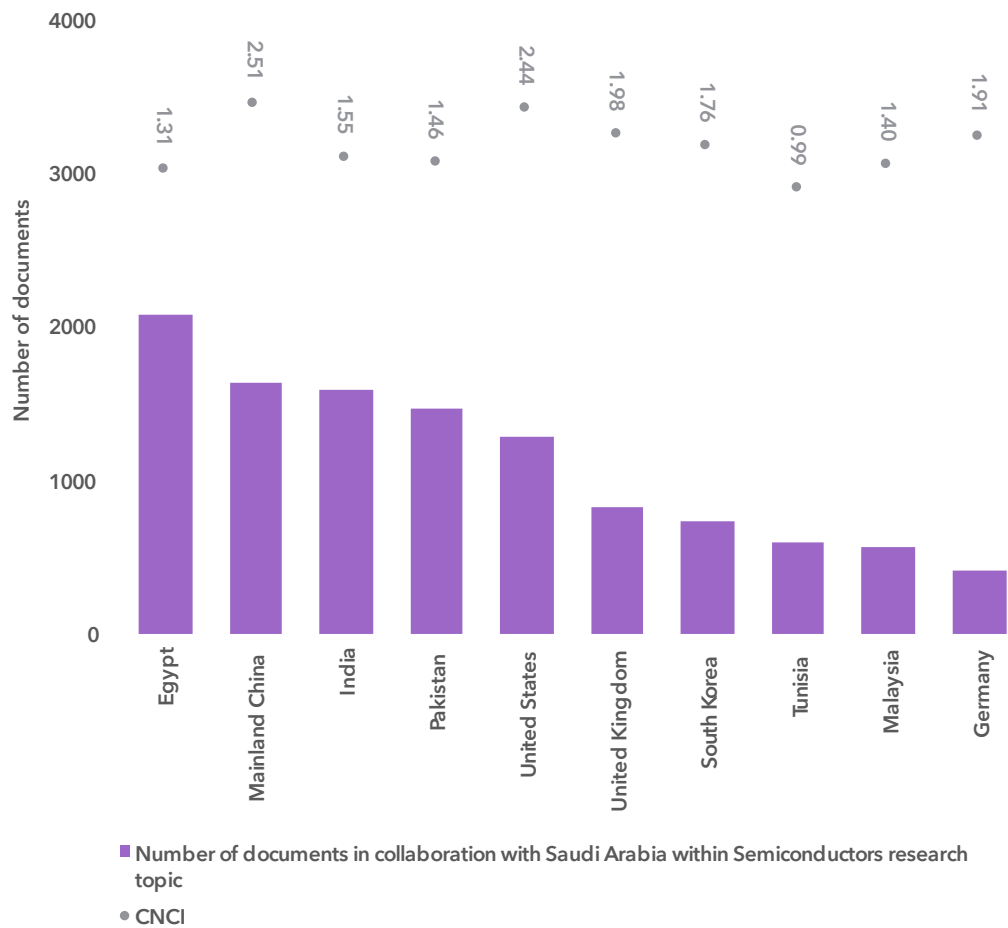


Figure 90: Top 10 collaborating countries with Saudi Arabia in terms of number of publications in the research topic Semiconductors in the period 2014-2023

4.1.10.3 Top 20 funders of Saudi publications by number of publications

The top 3 funding organizations of Saudi Arabia publications in this research topic in terms of number of publications mentioning the organization in the funding text in the period 2014-2023 are King Saud University followed by King Abdullah University of Science & Technology and National Natural Science Foundation of China (NSFC) with 1138, 808 and 771 publications respectively as shown in Figure 91.

Documents funded by National Basic Research Program of China followed by Fundamental Research Funds for the Central Universities and United States Department of Defense had the highest citation impact measured by the CNCI with 4.45, 3.84 and 3.59, respectively.

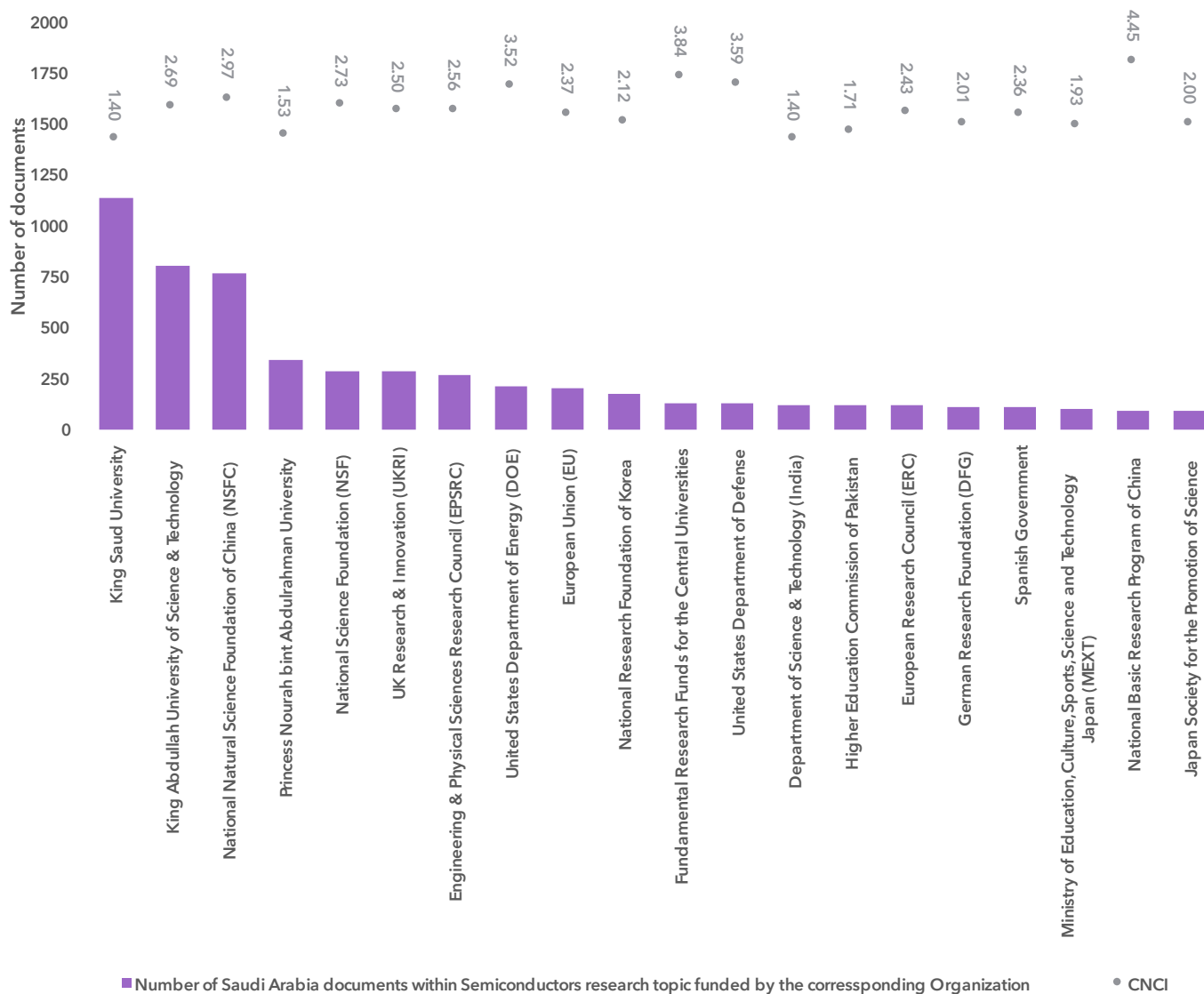


Figure 91: Top 20 funding organizations of Saudi Arabia publications in the research topic Semiconductors in terms of number of publications in the period 2014-2023

4.1.10.4 Top 20 Saudi Arabia organizations in terms of number of publications

The top 3 organizations in terms of publications published on this research topic in the period 2014-2023 are King Saud University, followed by King Abdullah University of Science & Technology and King Abdulaziz University, with 2,078, 2,051 and 1,848 publications, respectively, as shown in Figure 92.

In terms of citation impact as measured by the CNCI, King Abdullah University of Science & Technology, followed by King Abdulaziz University and University Ha'il, had the highest CNCI with 2.31, 1.70 and 1.54, respectively.

Nevertheless, all top 20 organizations except Taibah University and Imam Mohammad Ibn Saud Islamic University (IMSIU) had a CNCI higher than 1, reflecting a citation impact performance higher than the global average.

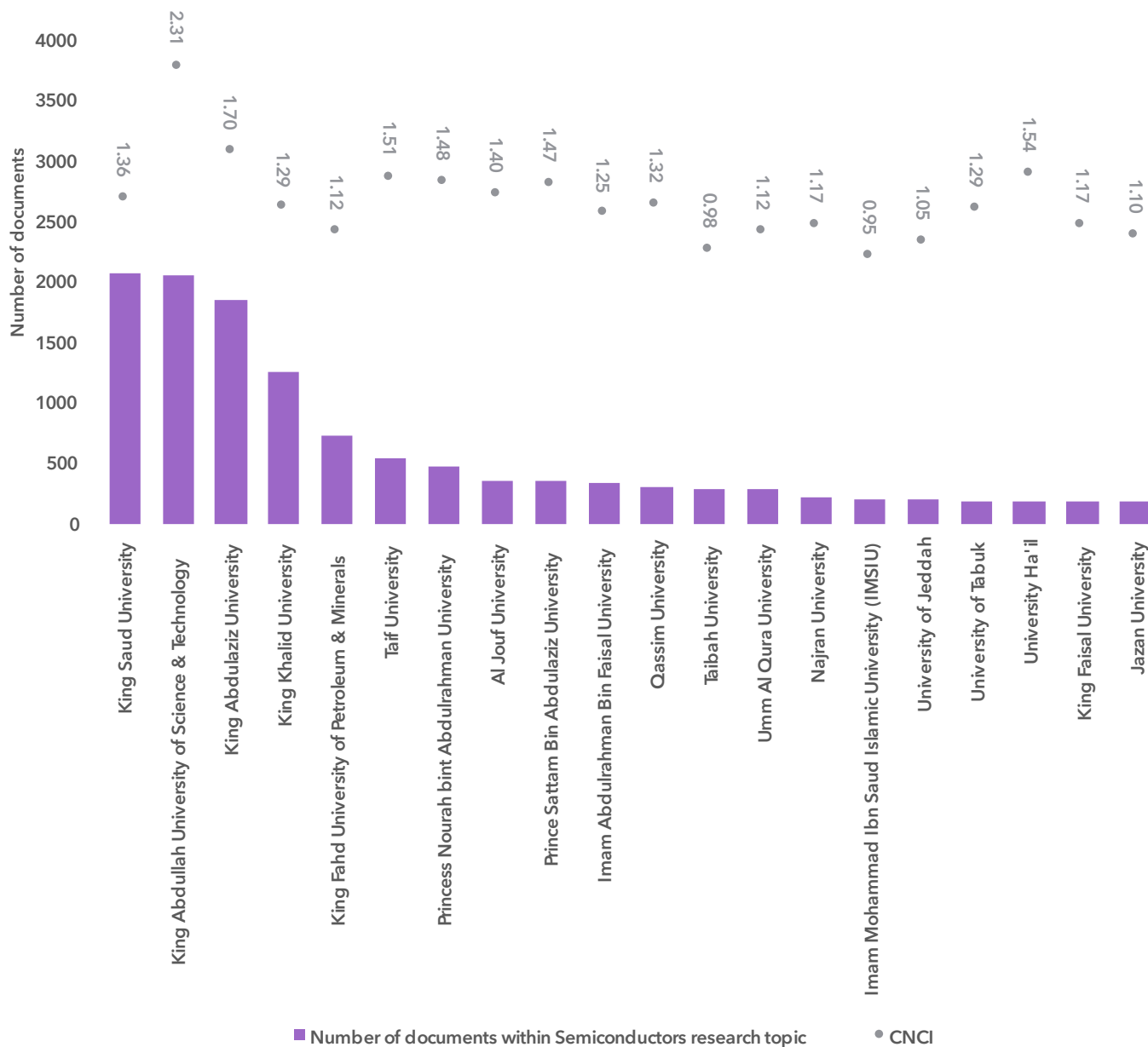


Figure 92: Top 20 Saudi organizations in terms of publications published in the research topic Semiconductors in the period 2014-2023 and their corresponding CNCI

4.1.10.5 Top 20 researchers affiliated with Saudi organizations in terms of number of publications.

The highest number of publications are published by Iain McCulloch, affiliated with King Abdullah University of Science & Technology, followed by Boon S. Ooi, affiliated to King Abdullah University of Science & Technology and Abdullah G. Al-Sehemi, affiliated to King Khalid University, with 87, 43 and 15 publications respectively as shown in Table 31.

The highest CNCI and Documents in top 1% is achieved by publications published by Osman M. Bakr affiliated to King Abdullah University of Science & Technology with a CNCI of 6.19. The highest number of publications in top 10% is achieved by Iain McCulloch affiliated to King Abdullah University of Science & Technology.

Table 31: Top 20 researchers affiliated with Saudi organizations in terms of the number of publications published on the research topic Semiconductors in the period 2014-2023

Name	Affiliation	Web of Science Publications	CNCI	Documents in the top 1%	Documents in the top 10%
McCulloch, Iain	King Abdullah University of Science & Technology	157	3.42	15	87
Ooi, Boon S.	King Abdullah University of Science & Technology	142	1.84	7	43
Al-Sehemi, Abdullah G.	King Khalid University	138	1.05	2	15
Asiri, Abdullah M.	King Abdulaziz University	137	1.56	4	29
Anthopoulos, Thomas D.	King Abdullah University of Science & Technology	133	2.06	8	38
Al-Ghamdi, Ahmed A.	King Abdulaziz University	114	1.91	6	19
Yahia, I. S.	King Khalid University	112	0.98	0	12
Ng, Tien Khee	King Abdullah University of Science & Technology	110	1.84	6	31
Bakr, Osman M.	King Abdullah University of Science & Technology	109	6.19	28	67
Mohammed, Omar F.	King Abdullah University of Science & Technology	97	5.31	20	46
Laref, A.	King Saud University	97	0.96	1	12
Shkir, Mohd	King Khalid University	80	1.19	0	13
Li, Lain-Jong	King Abdullah University of Science & Technology	78	4.05	10	41
Alshareef, Husam N.	King Abdullah University of Science & Technology	77	3.05	8	28
AlFaify, S.	King Khalid University	77	1.20	0	14
Irfan, Ahmad	King Khalid University	70	0.83	0	7
Inal, Sahika	King Abdullah University of Science & Technology	68	3.34	6	38
Umar, Ahmad	Najran University	67	0.99	0	10
Mahmood, Asif	King Saud University	65	0.93	0	9
Amassian, Aram	King Abdullah University of Science & Technology	64	3.51	7	30

4.1.10.6 Top 10 countries in terms of publications

Mainland China has published the most on this research topic (182,922 publications), followed by the United States (88,413 publications) and India (47,458 publications), as shown in Figure 93.

The highest citation impact measured by the CNCI is achieved by publications published in the United Kingdom, the United States and Mainland China, with CNCIs of 1.47, 1.45 and 1.25, respectively.

Six of the top 10 countries, in terms of the number of publications published on the research topic are also among the top 10 collaborators with Saudi Arabia. These are the United States, Mainland China, the United Kingdom, India, Germany, and South Korea.

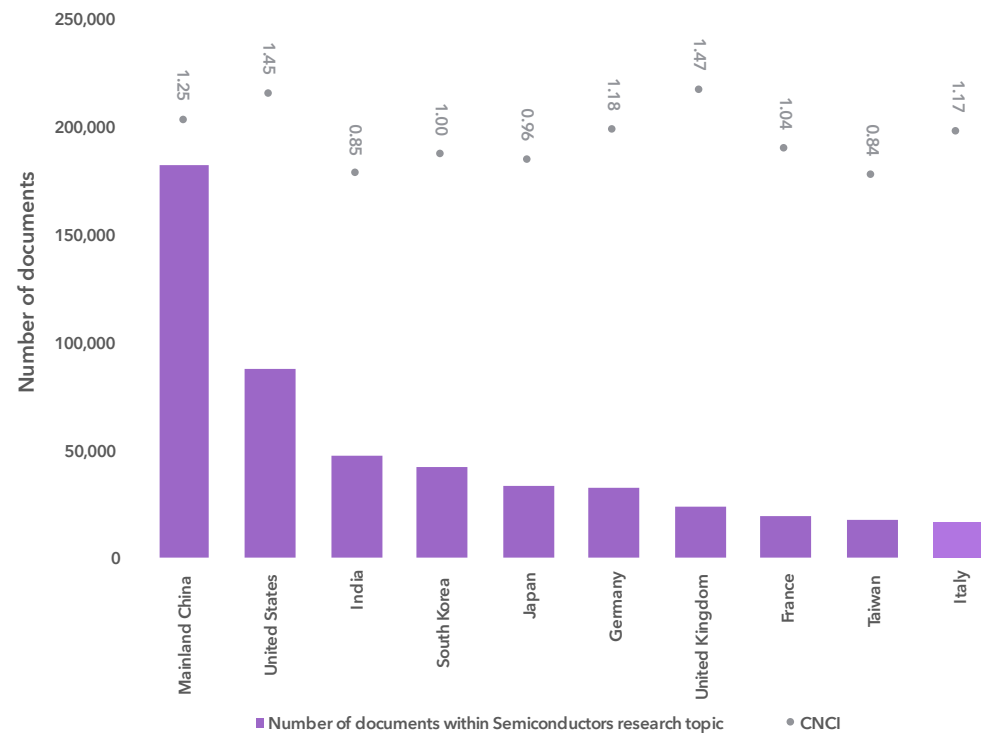


Figure 93: Top 10 countries in terms of number of publications in the research topic Semiconductors in the period 2014-2023 and their corresponding CNCI

4.1.10.7 Top 20 organizations globally in terms of number of publications

The top 3 organizations in terms of the number of publications published on this research topic in the period 2014-2023 are the Chinese Academy of Sciences (35,338 publications), followed by the Centre National de la Recherche Scientifique (CNRS) (12,970 publications) and University of Chinese Academy of Sciences, CAS (12,383 publications) respectively as shown in Figure 94.

In terms of citation impact measured by the CNCI, Nanyang Technological University, followed by the Swiss Federal Institutes of Technology Domain and United States Department of Energy (DOE), had the highest CNCI with 2.00, 1.87 and 1.82, respectively.

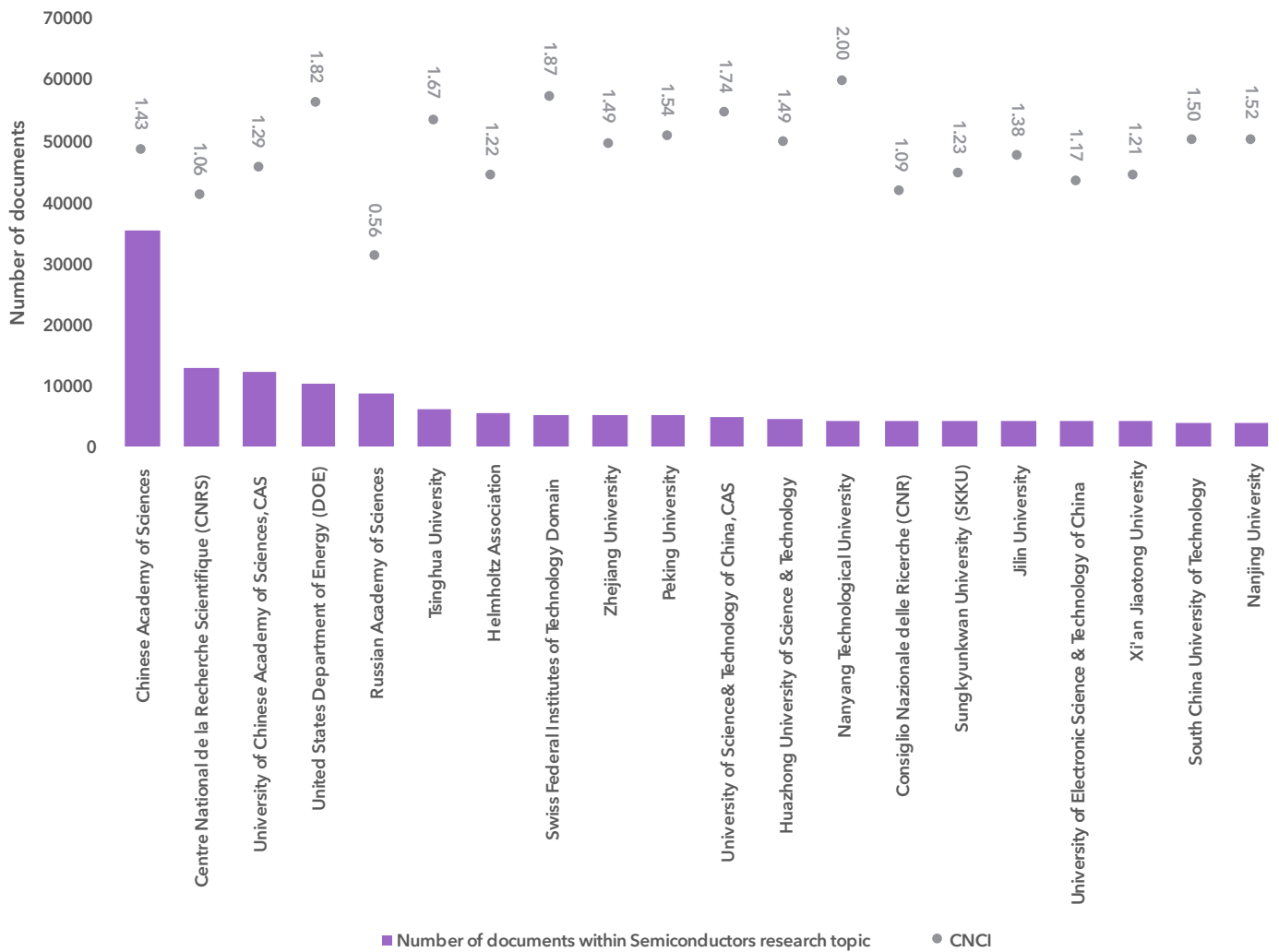


Figure 94: Top 20 organizations globally in terms of number of publications published in the research topic Semiconductors in the period 2014-2023 and their corresponding CNCI

4.1.10.8 Top 20 researchers globally in terms of number of publications

The top 3 researchers globally in terms of the number of publications in this research topic are Yue Hao, affiliated with Xidian University, with 767 publications, followed by Takashi Taniguchi, affiliated with the National Institute for Materials Science, with 582 publications, and Kenji Watanabe, affiliated to the National Institute for Materials Science with 574 publications as shown in Table 32.

The highest CNCI among the top 20 researchers globally is achieved by Mercouri G. Kanatzidis affiliated to Northwestern University with a CNCI of 3.76.

Kenji Watanabe affiliated with the National Institute for Materials Science, has the highest Top 1% publications, amounting to 47 publications, while both Kenji Watanabe and Takashi Taniguchi, who are affiliated with the National Institute for Materials Science, have the top 10% publications, amounting to 209 publications.

Table 32: Top 20 researchers globally in terms of the number of publications published on the research topic Semiconductors in the period 2014-2023

Name	Affiliation	Web of Science Publications	CNCI	Documents in the top 1%	Documents in the top 10%	Country
Hao, Yue	Xidian University	767	0.96	5	76	Mainland China
Taniguchi, Takashi	National Institute for Materials Science	582	3.08	46	209	Japan
Watanabe, Kenji	National Institute for Materials Science	574	3.12	47	209	Japan
Huang, Wei	Nanjing Tech University	508	2.24	24	137	Mainland China
Blaabjerg, Frede	Aalborg University	405	2.84	26	150	Denmark
Lee, Jun Yeob	Sungkyunkwan University (SKKU)	375	1.26	5	60	South Korea
Zhang, Jincheng	Xidian University	362	1.14	3	44	Mainland China
Wang, Zhong Lin	Georgia Institute of Technology	337	3.26	32	183	United States
Adachi, Chihaya	Kyushu University	337	2.92	21	116	Japan
Hu, Wenping	Tianjin University	327	1.57	5	72	Mainland China
Zhang, Bo	University of Electronic Science & Technology of China	325	0.67	1	14	Mainland China
Cao, Yong	South China University of Technology	304	2.44	11	75	Mainland China
Yang, Yintang	Xidian University	292	0.52	0	7	Mainland China
Zhang, David Wei	Fudan University	288	1.39	8	53	Mainland China
Peng, Junbiao	South China University of Technology	285	0.84	1	23	Mainland China
Liao, Liang-Sheng	Soochow University - China	258	2.08	13	71	Mainland China
Park, Byung-Gook	Seoul National University (SNU)	252	0.81	1	23	South Korea
Guo, Tailiang	Fuzhou University	239	1.38	2	47	Mainland China
Ma, Dongge	South China University of Technology	238	1.70	6	61	Mainland China
Kanatzidis, Mercouri G.	Northwestern University	238	3.76	28	100	United States

4.1.10.9 Top 20 global funders globally in terms of number of publications

The top 3 organizations in terms of funded publications in this research topic are the National Natural Science Foundation of China (NSFC) with 129,127 publications, followed by the National Science Foundation (NSF) with 25,263 publications, and Fundamental Research Funds for the Central Universities with 17,533 publications, as shown in Figure 95.

The highest citation impact measured by the CNCI is observed in publications funded by United States Department of Defense followed by United States Department of Energy (DOE) and Chinese Academy of Sciences with 2.03, 1.88 and 1.74, respectively.

Among the top 20 global funding organizations, 15 are also among the top 20 funding organizations of Saudi publications in this research topic.

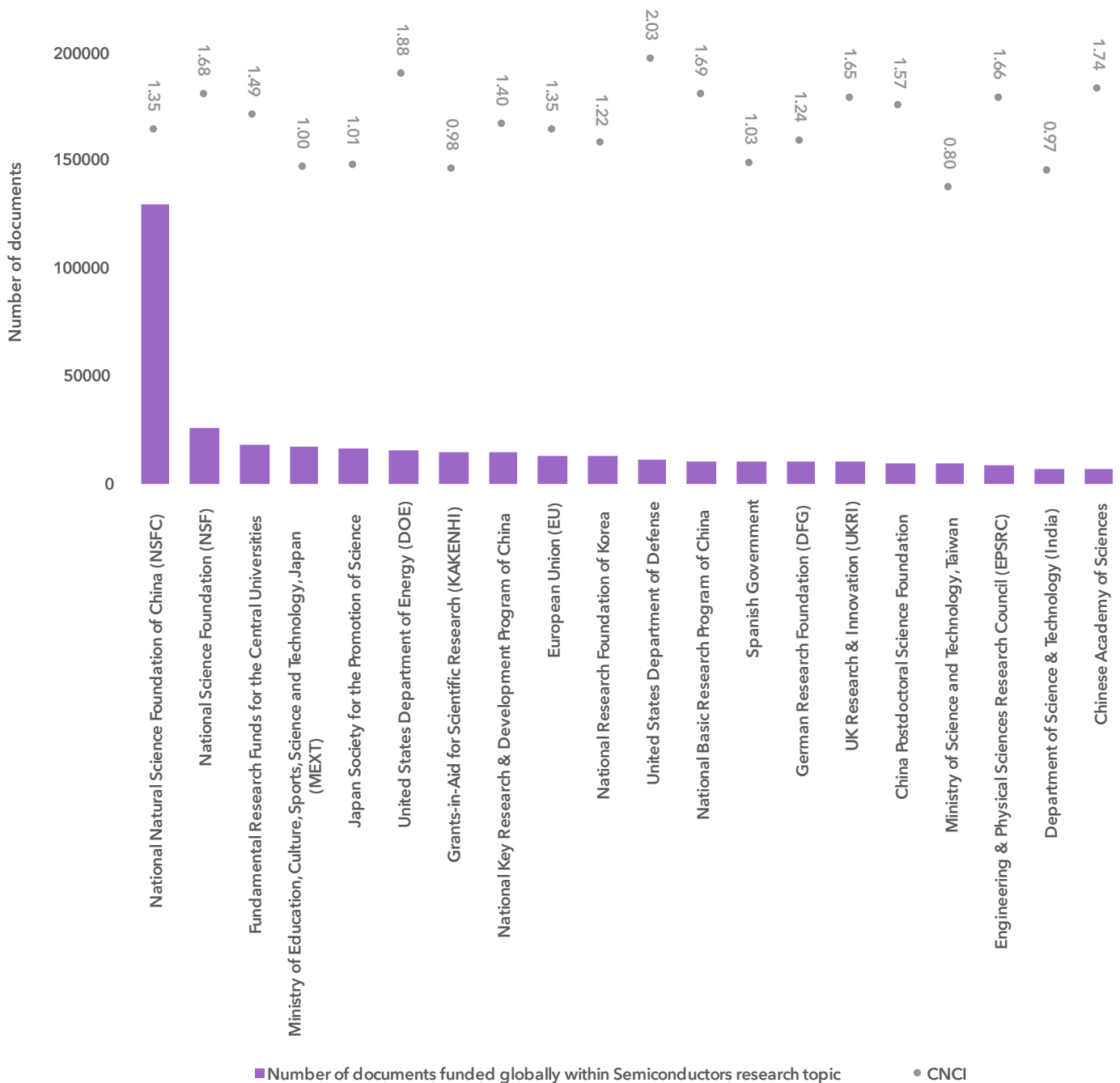


Figure 95: Top 20 funding organizations globally publications in the research topic Semiconductors in terms of number of publications in the period 2014-2023

4.1.10.10 Emerging trends in the research topic globally and in Saudi Arabia

In this section, we investigate the emerging trends globally and in Saudi Arabia in the research topic of Semiconductors. For more information on the methodology used to identify emerging trends, please see the definition section Emerging Trends.



Figure 96: Top 20 emerging micro-topics globally in the research topic Semiconductors in the period 2014-2023

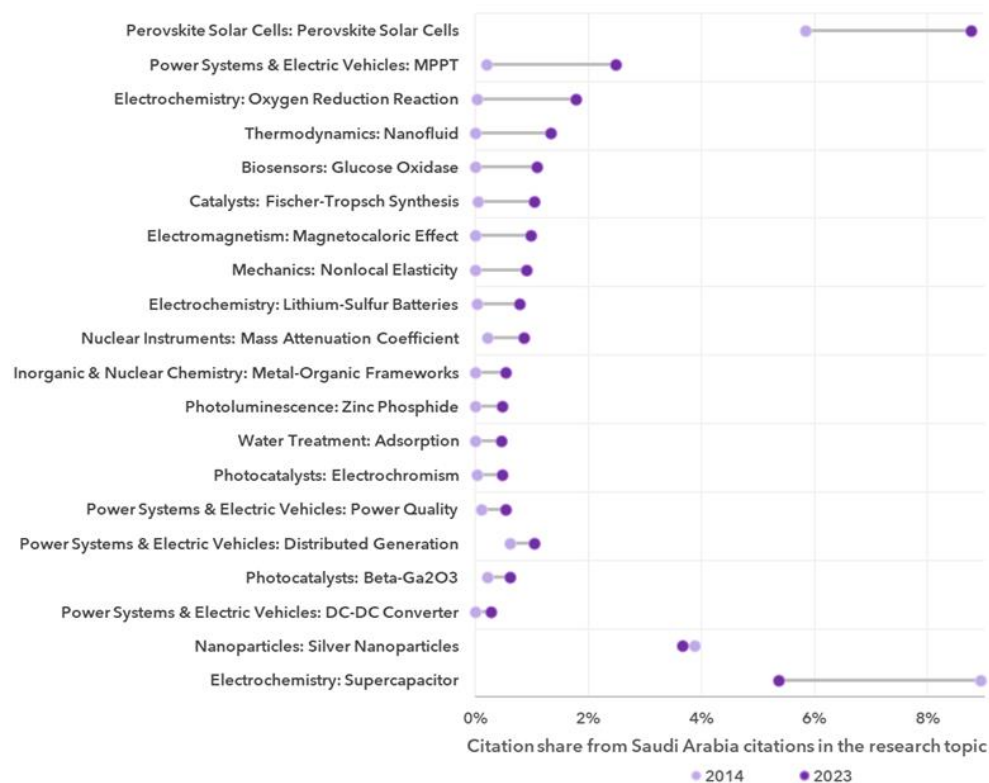


Figure 97: Top 20 emerging micro-topics identified in Saudi Arabia research output in the research topic Semiconductors in the period 2014-2023

The top 3 emerging micro-topics globally in this research topic are Electrochemistry: CO2 Reduction followed by Thermodynamics: Solar Still and Metallurgical Engineering: High-Entropy Alloys as shown in Figure 96. Figure 97 shows the identified top 20 emerging micro-topics in Saudi Arabia research output in this research topic.

The Photoluminescence: Zinc Phosphide micro-topic is a common emerging micro-topic among the top 20 identified micro-topics both globally and in Saudi Arabia.

4.1.11 OpenRAN

Globally, there were only 158 publications in this area in the period 2014-2023. Within the identified 158 publications, none of them has an affiliation associated with an organization in Saudi Arabia.

As this is a priority research topic, we will analyze the global dynamics of this research topic, identifying the top countries, organizations, funding entities and researchers that Saudi-affiliated researchers could collaborate with to enhance the research output in this area.

4.1.11.1 Top 10 countries in terms of publications

The highest number of publications published on this research topic are published by the United States (35 publications), followed by Spain (19 publications) and Mainland China (18 publications), as shown in Figure 98. The highest citation impact measured by the CNCI is achieved by publications published by Germany, the United States and Sweden with a CNCI of 5.68, 3.60 and 2.71, respectively.

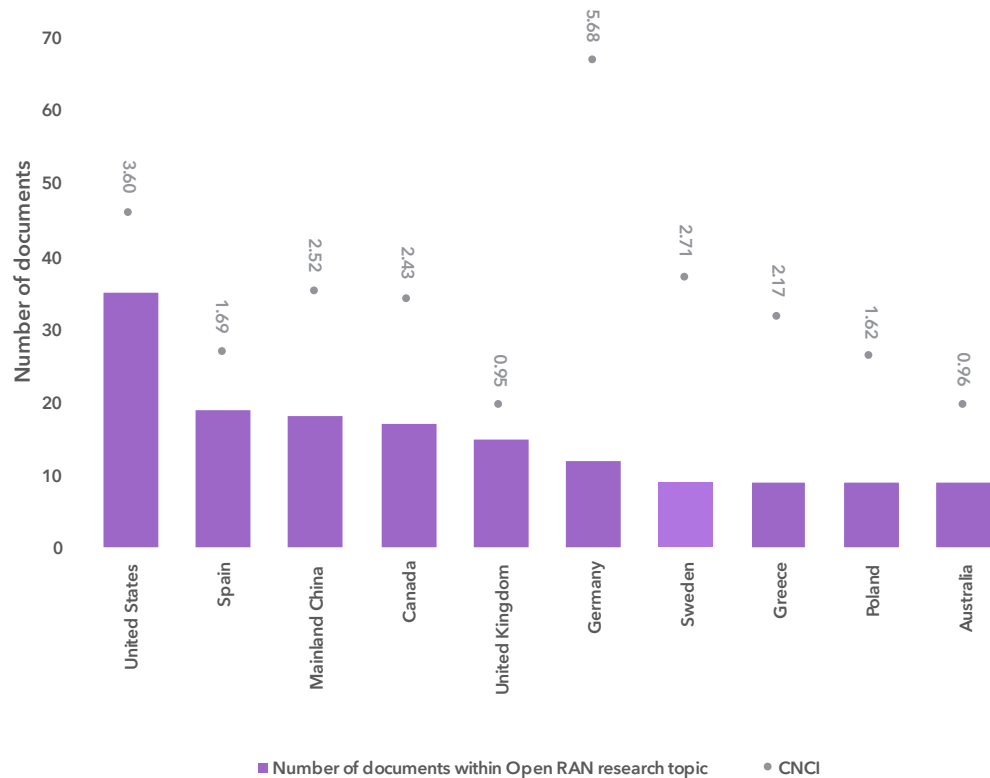


Figure 98: Top 10 countries in terms of the number of publications in the research topic OpenRAN in the period 2014-2023 and their corresponding CNCI

4.1.11.2 Top 20 organizations globally in terms of number of publications

As mentioned earlier the global research output in this research topic amounts to few publications. Accordingly, top organizations have few publications as well. The top organization in terms of number of publications published in this research topic in the period 2014-2023 is Northeastern University (6 publications) followed by three organizations with 5 publications and six organizations with four publications as shown in Figure 99.

In terms of citation impact measured by the CNCI, Northeastern University, followed by the University of Oulu and the University of Electronic Science & Technology of China, had the highest CNCI with 11.06, 5.73 and 4.57, respectively.

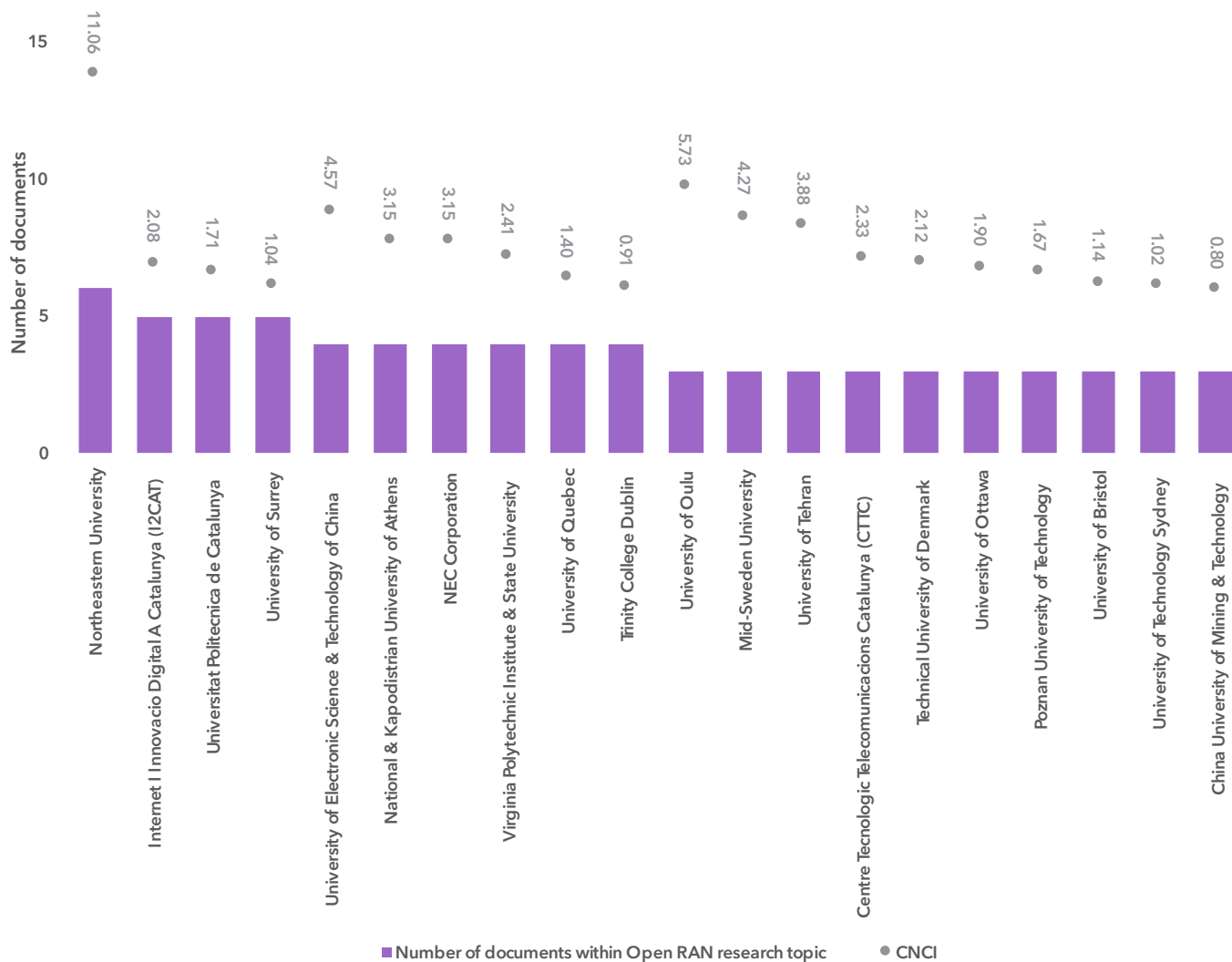


Figure 99: Top 20 organizations globally in terms of the number of publications published in the research topic OpenRAN in the period 2014-2023 and their corresponding CNCI

4.1.11.3 Top 20 researchers globally in terms of number of publications

The top 3 researchers globally in terms of the number of publications in this research topic are Michele Polese, with the same publications as Leonardo Bonati, and Tommaso Melodia, all affiliated to Northeastern University with six publications, as shown in Table 33.

Two other researchers from the same organization have five publications, and several other researchers from different organizations have 4, 3 and 2 publications. The highest CNCI among the top 20 researchers globally is achieved by Stefano Basagni, affiliated with Northeastern University, with a CNCI of 13.02.

The latter also has the highest Top 1% publications, amounting to 3 publications, and Top 10% publications, amounting to 5 publications.

Several other researchers from the same organization have also 3 Top 1% publications and 5 Top 10% publications. This indicates that those researchers are co-authors of those publications.

Table 33: Top 20 researchers globally in terms of the number of publications published in the research topic OpenRAN in the period 2014-2023

Name	Affiliation	Web of Science Publications	CNCI	Documents in the top 1%	Documents in the top 10%	Country
Polese, Michele	Northeastern University	6	11.06	3	5	United States
Bonati, Leonardo	Northeastern University	6	11.06	3	5	United States
Melodia, Tommaso	Northeastern University	6	11.06	3	5	United States
Basagni, Stefano	Northeastern University	5	13.02	3	5	United States
D'Oro, Salvatore	Northeastern University	5	10.97	2	4	United States
Cheriet, Mohamed	University of Quebec	4	1.40	0	1	Canada
Tafazolli, Rahim	University of Surrey	4	1.07	0	0	England
Ruffini, Marco	Trinity College Dublin	4	0.91	0	0	Ireland
Gidlund, Mikael	Mid-Sweden University	3	4.27	1	2	Sweden
Mahmood, Aamir	Mid-Sweden University	3	4.27	1	2	Sweden
Shah-Mansouri, Vahid	University of Tehran	3	3.88	0	2	Iran
Erol-Kantarci, Melike	University of Ottawa	3	1.90	0	0	Canada
Nguyen, Kim Khoa	University of Quebec	3	1.87	0	1	Canada
Perez-Romero, Jordi	Universitat Politecnica de Catalunya	3	1.11	0	0	Spain
Reed, Jeffrey H.	Virginia Polytechnic Institute & State University	3	1.11	0	1	USA
Abolhasan, Mehran	University of Technology Sydney	3	1.02	0	0	Australia
Lipman, Justin	University of Technology Sydney	3	1.02	0	0	Australia
Ndikumana, Anselme	Ecole de Technologie Superieure - Canada	3	0.76	0	0	Canada
Chatzinotas, Symeon	University of Luxembourg	2	10.78	1	2	Luxembourg
Pollin, Sofie	KU Leuven	2	8.48	1	1	Belgium

4.1.11.4 Top 20 global funders globally in terms of number of publications

The top 3 organizations in terms of funded publications in this research topic are the European Union (EU) with 23 publications, followed by the National Science Foundation (NSF) with 14 publications, and the National Natural Science Foundation of China (NSFC) with 12 publications, as shown in Figure 100. The highest citation impact measured by the CNCI is observed in publications funded by the United States Navy with the same CNCI as the Office of Naval Research, followed by the European Commission Joint Research Centre and Luxembourg National Research Fund with 11.75, 10.81 and 10.78, respectively.

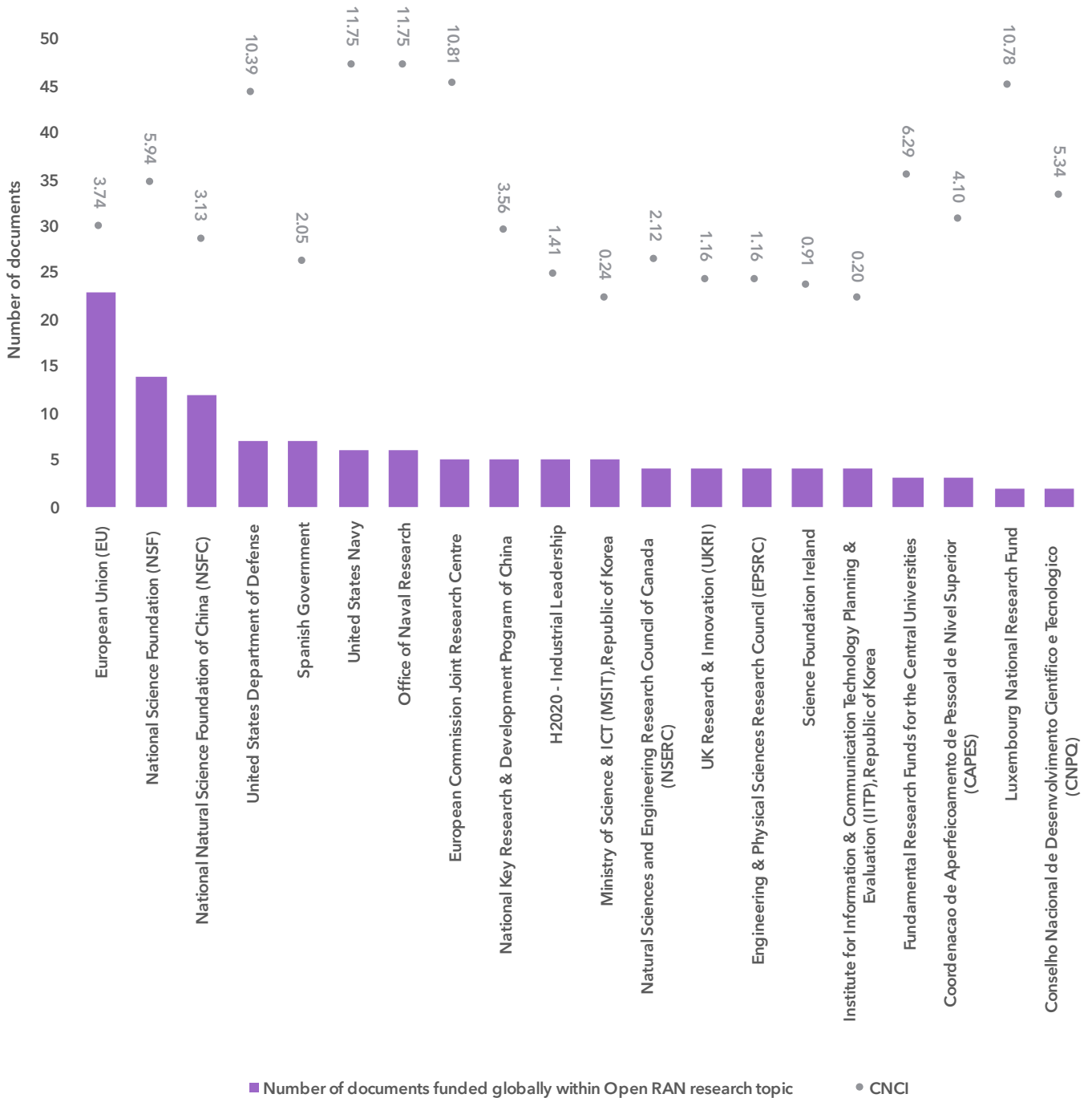


Figure 100: Top 20 funding organizations globally publications in the research topic OpenRAN in terms of number of publications in the period 2014-2023

4.1.11.5 Emerging trends in the research topic globally

As the number of global publications published on the research topic is few, it was not meaningful to identify emerging trends.

Nevertheless, Table 34 shows the top 10 micro-topics in terms of number of publications identified from the global research output.

Table 34: Top 20 emerging micro-topics globally in the research topic OpenRAN in the period 2014-2023

Topic	Number of Global publications in the period 2014-2023
OpenRAN research topic	158
Distributed & Real Time Computing: Software Defined Networking	40
Telecommunications: Cellular Networks	34
Wireless Technology: MIMO	13
Optical Electronics & Engineering: Microwave Photonics	7
Telecommunications: Unmanned Aerial Vehicles	6
Security Systems: Blockchain	5
Security Systems: Differential Privacy	3
Design & Manufacturing: Industry 4.0	3
Distributed & Real Time Computing: Caching	3
Robotics: Reinforcement Learning	2

4.1.12 Urban Air Mobility

4.1.12.1 Evolution of Saudi publication share of global publications in the research topic

The share of Saudi Arabia publications from global publications on the research topic increased almost continuously from 2014 till 2023, as shown in Figure 101. This shows that Saudi Arabia was not only able to increase the number of publications on this research topic but also had a growth higher than the global growth rate.

This is evident as the share of Saudi Arabia publications in the research topic is growing. The CNCI of Saudi Arabia publications in this research topic were in all years higher than 1, indicating a citation impact performance higher than the global average.

Overall, Saudi Arabia publications increased with a higher growth rate than the global average in this research topic and had a relatively good citation impact as measured by the CNCI.

Nevertheless, after this high growth rate in terms of publications, one should focus on increasing/preserving the relatively good citation impact.

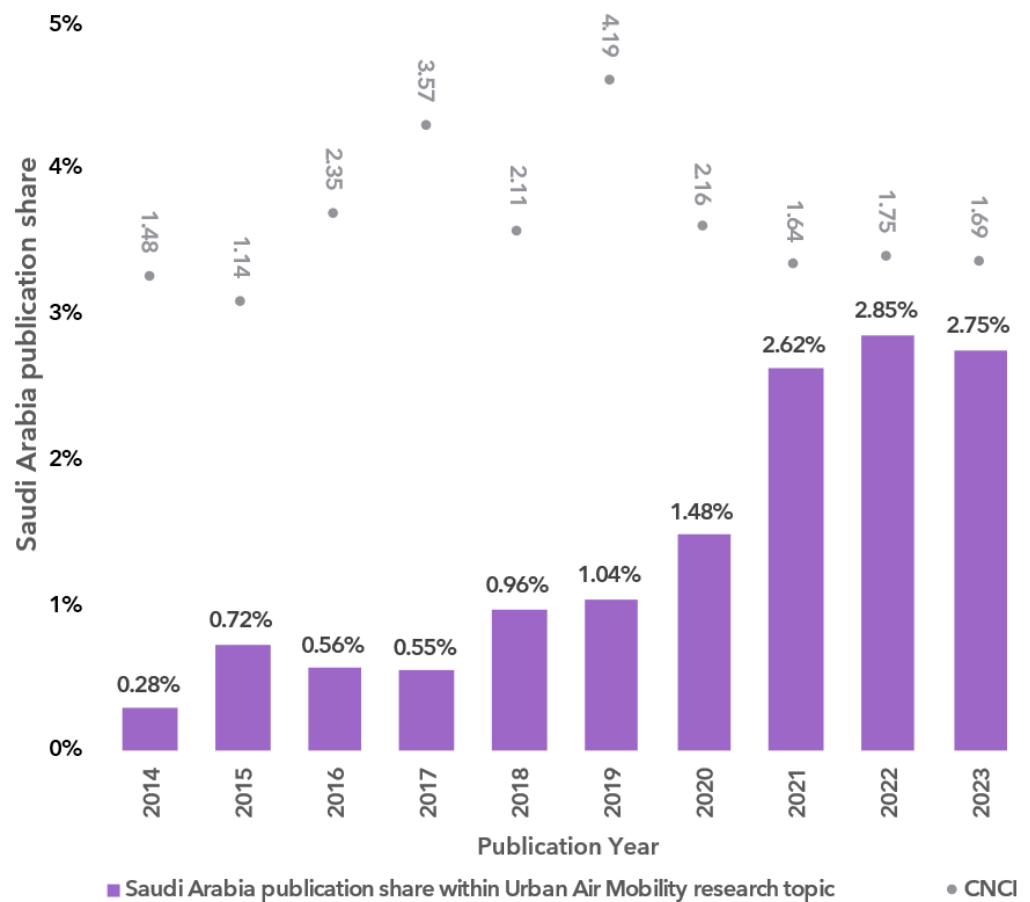


Figure 101: The share of Saudi Arabia from global publications in the research topic and the CNCI of Saudi Arabia publications in the research topic Urban Air Mobility in the period 2014-2023

4.1.12.2 Top 10 countries collaborating with Saudi Arabia

The top collaborating country with Saudi Arabia in this research topic in the period 2014-2023 are Mainland China followed by Pakistan and India with 150, 129 and 125 publications respectively as shown in Figure 102.

In terms of citation impact measured by the CNCI publications published in collaboration with Tunisia, followed by United States and Mainland China had the highest CNCI with 3.36, 3.28 and 2.82, respectively.

Nevertheless, all publications with the top 10 collaborating countries had a CNCI higher than 1 reflecting a performance higher than the global average.

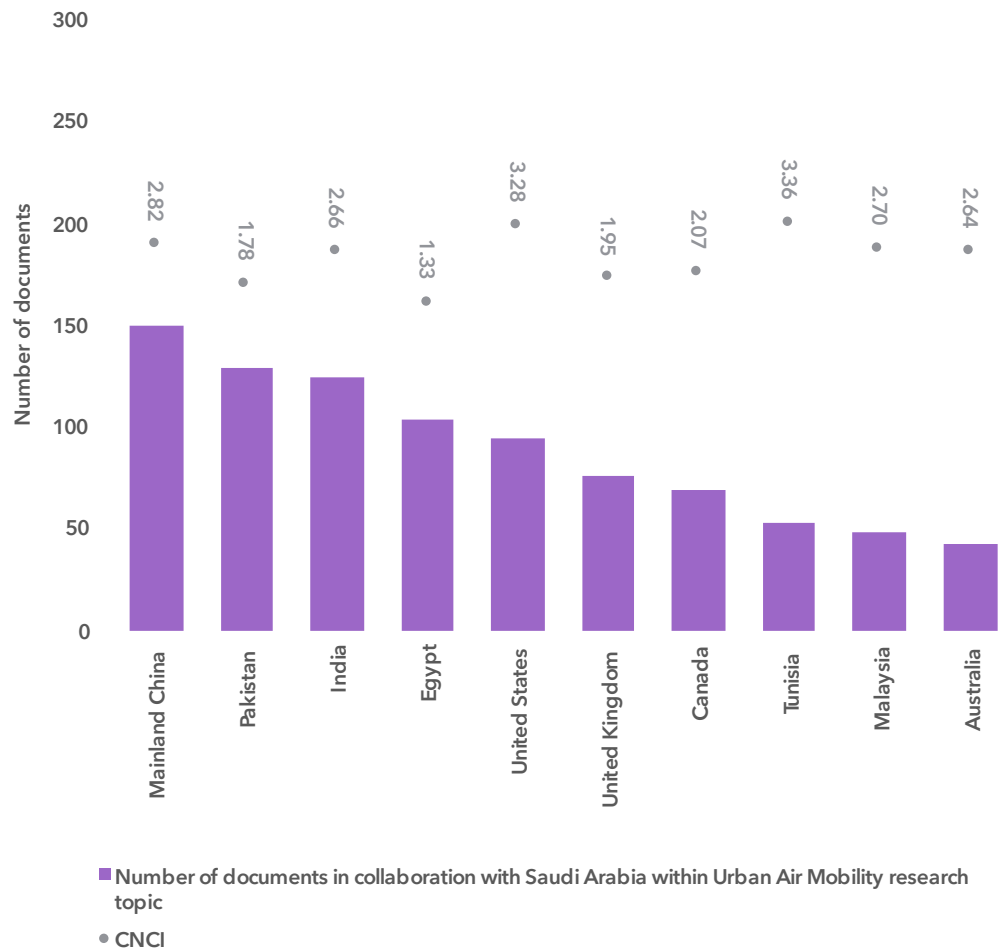


Figure 102: Top 10 collaborating countries with Saudi Arabia in terms of the number of publications in the research topic Urban Air Mobility in the period 2014-2023

4.1.12.3 Top 20 funders of Saudi publications by number of publications

The top 3 funding organizations of Saudi Arabia publications in this research topic in terms of number of publications mentioning the organization in the funding text in the period 2014-2023 are King Saud University followed by Princess Nourah bint Abdulrahman University and National Natural Science Foundation of China (NSFC) with 69, 49 and 38 publications respectively as shown in Figure 103.

Documents funded by Science Foundation Ireland followed by National Science Foundation (NSF) and Fundamental Research Funds for the Central Universities had the highest citation impact measured by the CNCI with 6.03, 4.48 and 3.52 respectively.

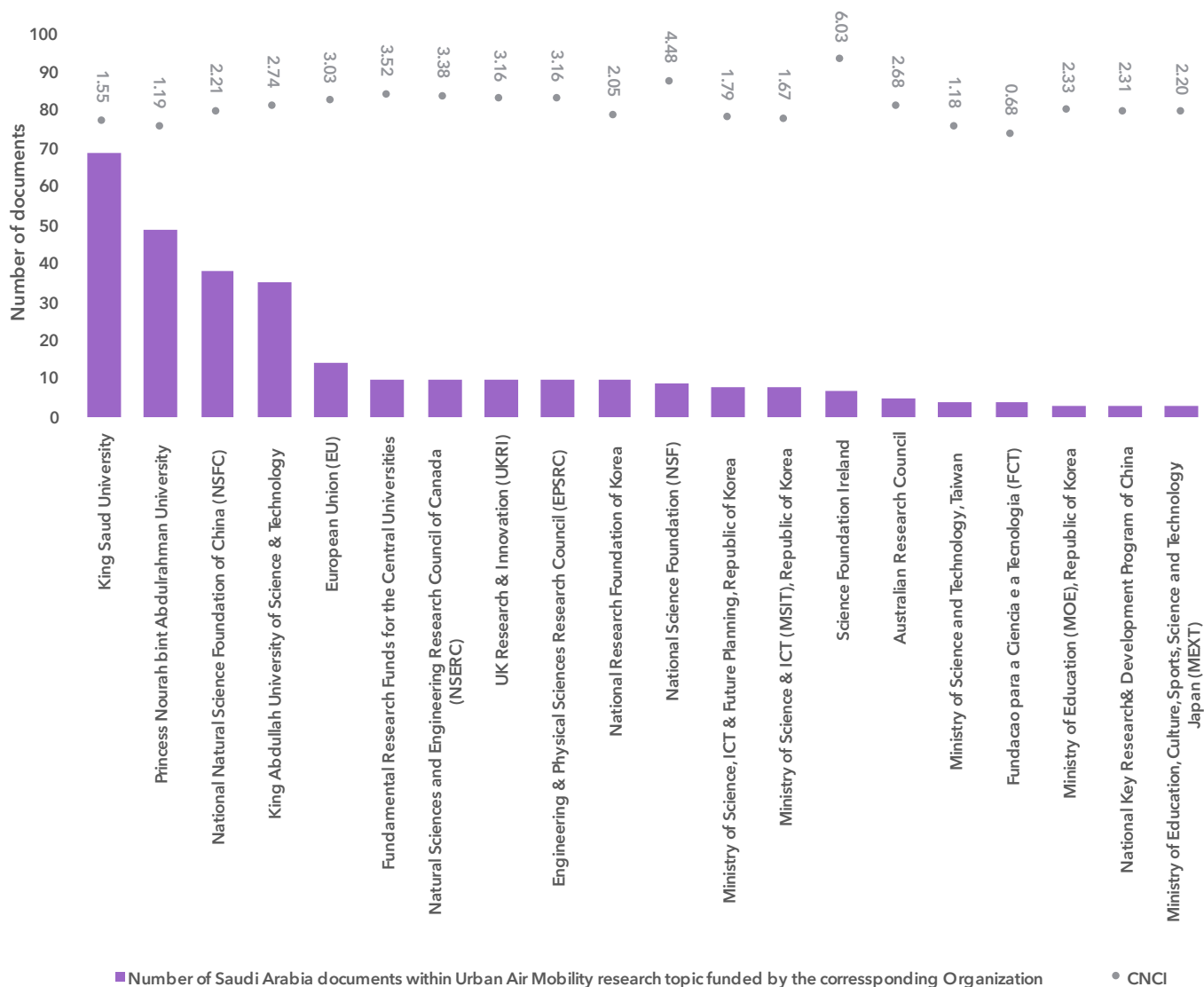


Figure 103: Top 20 funding organizations of Saudi Arabia publications in the research topic Urban Air Mobility in terms of number of publications in the period 2014-2023

4.1.12.4 Top 20 Saudi Arabia organizations in terms of number of publications

The top 3 organizations in terms of publications published on this research topic in the period 2014-2023 are King Abdullah University of Science & Technology, followed by King Saud University and King Abdulaziz University with 157, 127 and 113 publications, respectively, as shown in Figure 104.

In terms of citation impact as measured by the CNCI, Northern Border University followed by University of Tabuk and Qassim University had the highest CNCI with 4.60, 3.63 and 3.14, respectively.

Nevertheless, all top 20 organizations except Alfaisal University and Umm Al Qura University had a CNCI higher than 1, reflecting a citation impact performance higher than the global average.

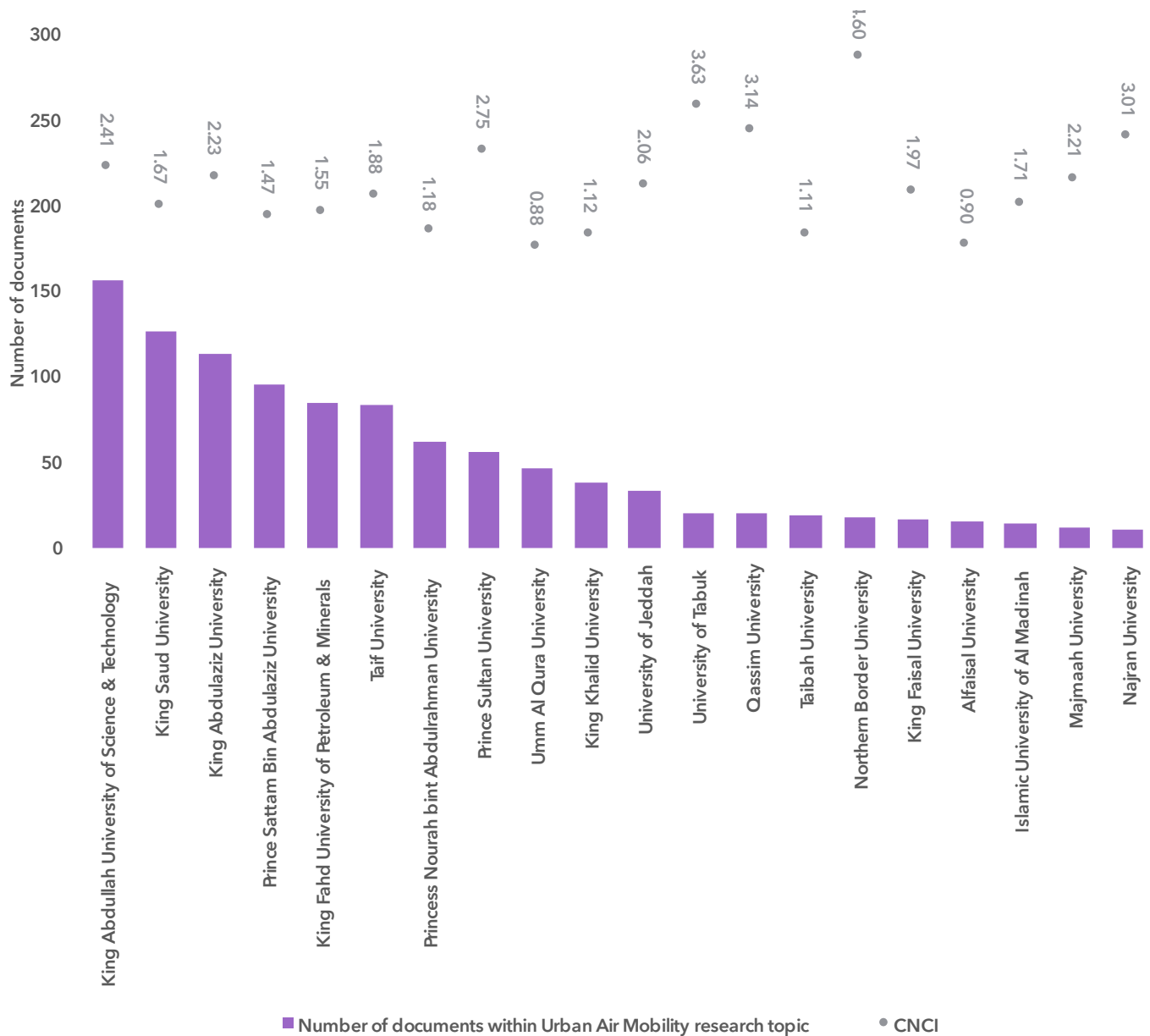


Figure 104: Top 20 Saudi organizations in terms of publications published in the research topic Urban Air Mobility in the period 2014-2023 and their corresponding CNCI

4.1.12.5 Top 20 researchers affiliated with Saudi organizations in terms of number of publications

The highest number of publications are published by Mohamed-Slim Alouini, affiliated to King Abdullah University of Science & Technology, followed by Anis Koubaa, affiliated to Prince Sultan University and Matthew F. McCabe, affiliated to King Abdullah University of Science & Technology, with 78, 26 and 20 publications respectively as shown in Table 35.

The highest CNCI is achieved by publications published by Anis Koubaa, affiliated with, affiliated to Prince Sultan University, with a CNCI of 3.79.

Mohamed-Slim Alouini, affiliated with King Abdullah University of Science & Technology, has the highest number of Top 1%, amounting to 4 publications, and the Top 10% publications, amounting to 31 publications.

Table 35: Top 20 researchers affiliated with Saudi organizations in terms of the number of publications published on the research topic Urban Air Mobility in the period 2014-2023

Name	Affiliation	Web of Science Publications	CNCI	Documents in the top 1%	Documents in the top 10%
Alouini, Mohamed-Slim	King Abdullah University of Science & Technology	78	2.62	4	31
Koubaa, Anis	Prince Sultan University	26	3.79	3	13
McCabe, Matthew F.	King Abdullah University of Science & Technology	20	3.19	3	11
Barnawi, Ahmed	King Abdulaziz University	17	1.92	1	5
Johansen, Kasper	King Abdullah University of Science & Technology	16	2.17	0	7
Almalki, Faris A.	Taif University	15	2.70	2	5
Alzahrani, Bander	King Abdulaziz University	14	2.00	1	3
Mohamed, Ehab Mahmoud	Prince Sattam Bin Abdulaziz University	14	1.75	0	4
Bazi, Yakoub	King Saud University	13	1.95	1	4
Imran, Muhammad	King Saud University	12	1.67	0	4
Kishk, Mustafa A.	King Abdullah University of Science & Technology	11	3.11	0	8
Park, Ki-Hong	King Abdullah University of Science & Technology	11	1.66	0	3
Hassan, Mohammad Mehedi	King Saud University	10	3.00	0	5
Al-Naffouri, Tareq Y.	King Abdullah University of Science & Technology	10	2.27	0	3
Hossain, M. Shamim	King Saud University	9	2.35	1	2
Motwakel, Abdelwahed	Prince Sattam Bin Abdulaziz University	9	0.46	0	0
Noor, Fazal	Islamic University of Al Madinah	8	2.29	1	2
Nasir, Ali Arshad	King Fahd University of Petroleum & Minerals	8	2.17	0	2
Shihada, Basem	King Abdullah University of Science & Technology	8	2.17	0	2
Alanezi, Mohammed A.	Hafr Albatin University	8	0.82	0	0

4.1.12.6 Top 10 countries in terms of publications

The highest number of publications published in this research topic are published by Mainland China (17,120 publications) followed by United States (8,332 publications) and India (2,820 publications) as shown in Figure 105.

The highest citation impact measured by the CNCI is achieved by publications published by Australia, Canada, and the United Kingdom with a CNCI of 2.46, 2.23 and 2.07, respectively.

Six of the top 10 countries in terms of a number of publications published on the research topic are also among the top 10 collaborators with Saudi Arabia. These are Australia, Canada, the United Kingdom, the United States, Mainland China, and India.

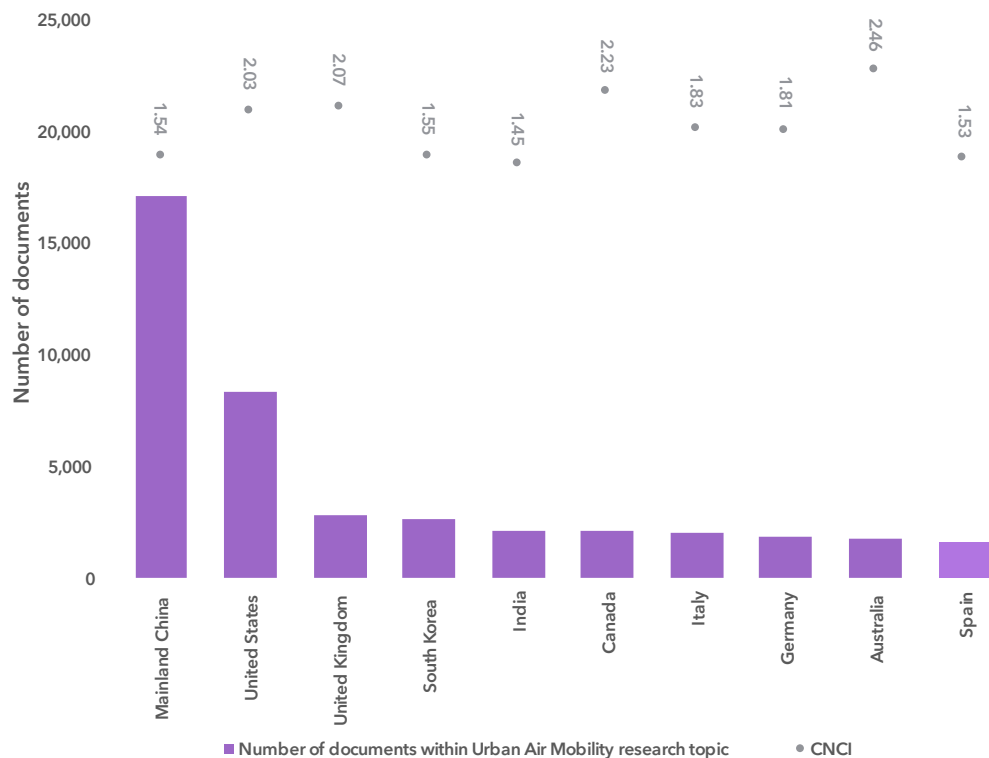


Figure 105: Top 10 countries in terms of the number of publications in the research topic Urban Air Mobility in the period 2014-2023 and their corresponding CNCI

4.1.12.7 Top 20 organizations globally in terms of number of publications

The top 3 organizations in terms of number of publications published in this research topic in the period 2014-2023 are Chinese Academy of Sciences (1,252 publications) followed by Beihang University (1,109 publications) and Nanjing University of Aeronautics & Astronautics (785 publications) respectively as shown in Figure 106.

In terms of citation impact measured by the CNCI, the University of London, followed by the University of New South Wales Sydney and Nanyang Technological University, had the highest CNCI with 3.00, 2.69 and 2.54, respectively.

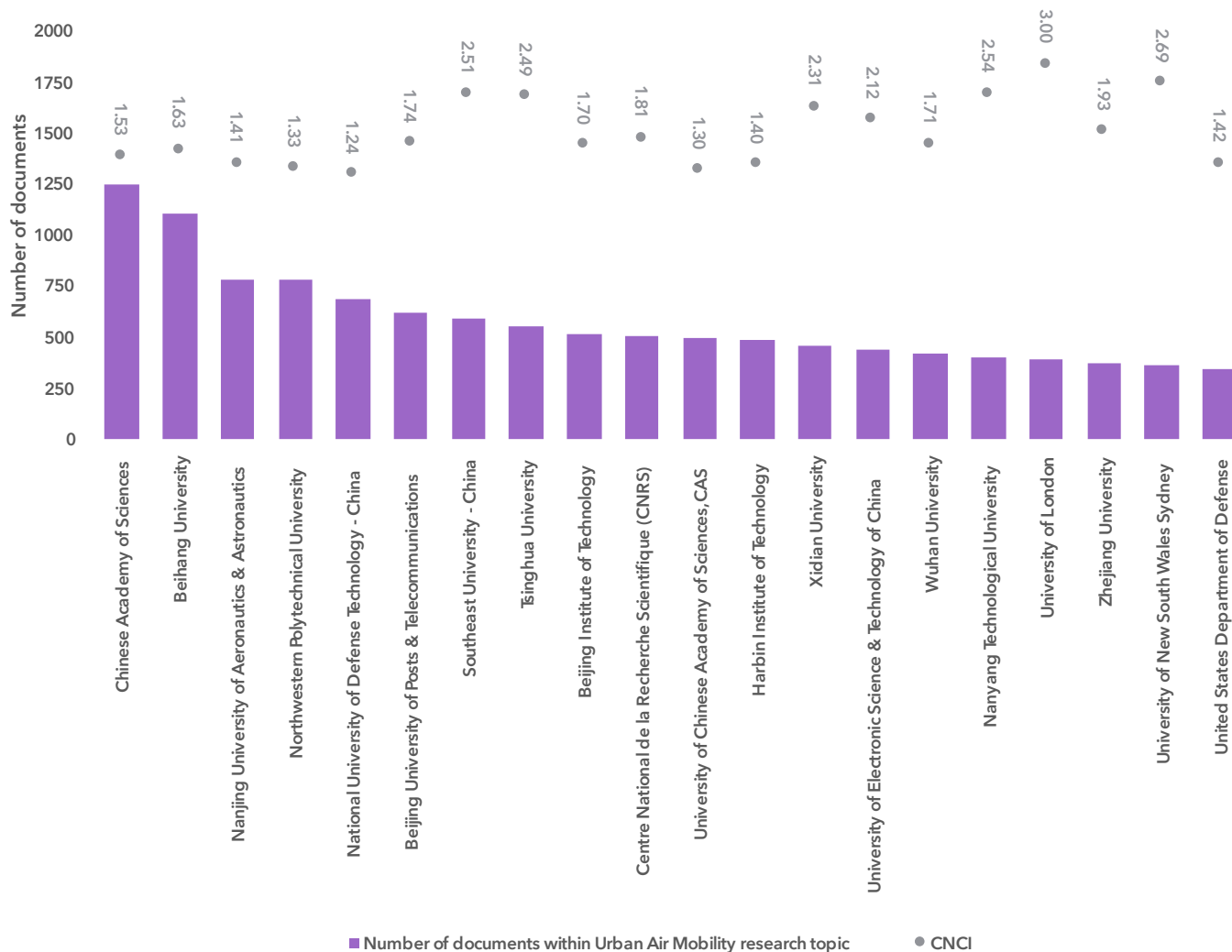


Figure 106: Top 20 organizations globally in terms of the number of publications published in the research topic Urban Air Mobility in the period 2014-2023 and their corresponding CNCI

4.1.12.8 Top 20 researchers globally in terms of number of publications

The top 3 researchers globally in terms of the number of publications in this research topic are Zhu Han, affiliated with the University of Houston, with 127 publications, followed by Youmin Zhang, affiliated to Concordia University - Canada, with 113 publications followed by Walid Saad affiliated to Virginia Polytechnic Institute & State University and Ismail Guvenc affiliated to North Carolina State University with 100 publications as shown in Table 36.

The highest CNCI, Documents in the top 1% and Documents in the top 10% among the top 20 researchers globally is achieved by Rui Zhang, affiliated with the National University of Singapore, with a CNCI of 10.03, 29 publications in the top 1% and 62 publications in the top 10%.

Walid Saad affiliated to Virginia Polytechnic Institute & State University has also the same number of publications in the top 10%.

Table 36: Top 20 researchers globally in terms of the number of publications published on the research topic Urban Air Mobility in the period 2014-2023

Name	Affiliation	Web of Science Publications	CNCI	Documents in the top 1%	Documents in the top 10%	Country
Han, Zhu	University of Houston	127	2.73	8	47	United States
Zhang, Youmin	Concordia University - Canada	113	3.54	14	46	Canada
Saad, Walid	Virginia Polytechnic Institute & State University	100	8.53	21	62	United States
Guvenc, Ismail	North Carolina State University	100	2.40	3	32	United States
Zhao, Nan	Dalian University of Technology	95	4.15	17	42	Mainland China
Zhang, Rui	National University of Singapore	88	10.03	29	62	Singapore
Poor, H. Vincent	Princeton University	87	4.33	9	36	United States
Tsourdos, Antonios	Cranfield University	85	1.44	1	20	England
Lan, Yubin	South China Agricultural University	83	2.32	4	37	Mainland China
Niyato, Dusit	Nanyang Technological University	81	5.42	13	36	Singapore
Duan, Haibin	Beihang University	80	1.78	3	21	Mainland China
Johansen, Tor Arne	Norwegian University of Science & Technology (NTNU)	75	2.71	3	27	Norway
Wang, Xiangke	National University of Defense Technology - China	75	1.17	0	12	Mainland China
Yanikomeroglu, Halim	Carleton University	74	4.51	9	32	Canada
Wu, Qihui	Nanjing University of Aeronautics & Astronautics	73	2.50	3	29	Mainland China
Shen, Lincheng	National University of Defense Technology - China	69	1.45	1	13	Mainland China
Saska, Martin	Czech Technical University Prague	68	2.22	1	25	Czech Republic
Chen, Yunfei	University of Warwick	67	4.55	16	29	England
Yang, Guijun	Beijing Academy of Agriculture & Forestry Sciences (BAAFS)	62	3.87	13	36	Mainland China
Nallanathan, Arumugam	Queen Mary University London	62	3.46	6	31	England

4.1.12.9 Top 20 global funders globally in terms of number of publications

The top 3 organizations in terms of funded publications in this research topic are the National Natural Science Foundation of China (NSFC), with 9,622 publications, followed by the National Science Foundation (NSF), with 1,815 publications, and the National Key Research & Development Program of China, with 1,509 publications, as shown in Figure 107.

The highest citation impact measured by the CNCI is observed in publications funded by National Science Foundation (NSF) followed by Office of Naval Research and United States Navy sharing the same CNCI followed by UK Research & Innovation (UKRI) with 2.91, 2.36 and 2.28, respectively.

Among the top 20 global funding organizations, 11 are also among the top 20 funding organizations of Saudi publications in this research topic.

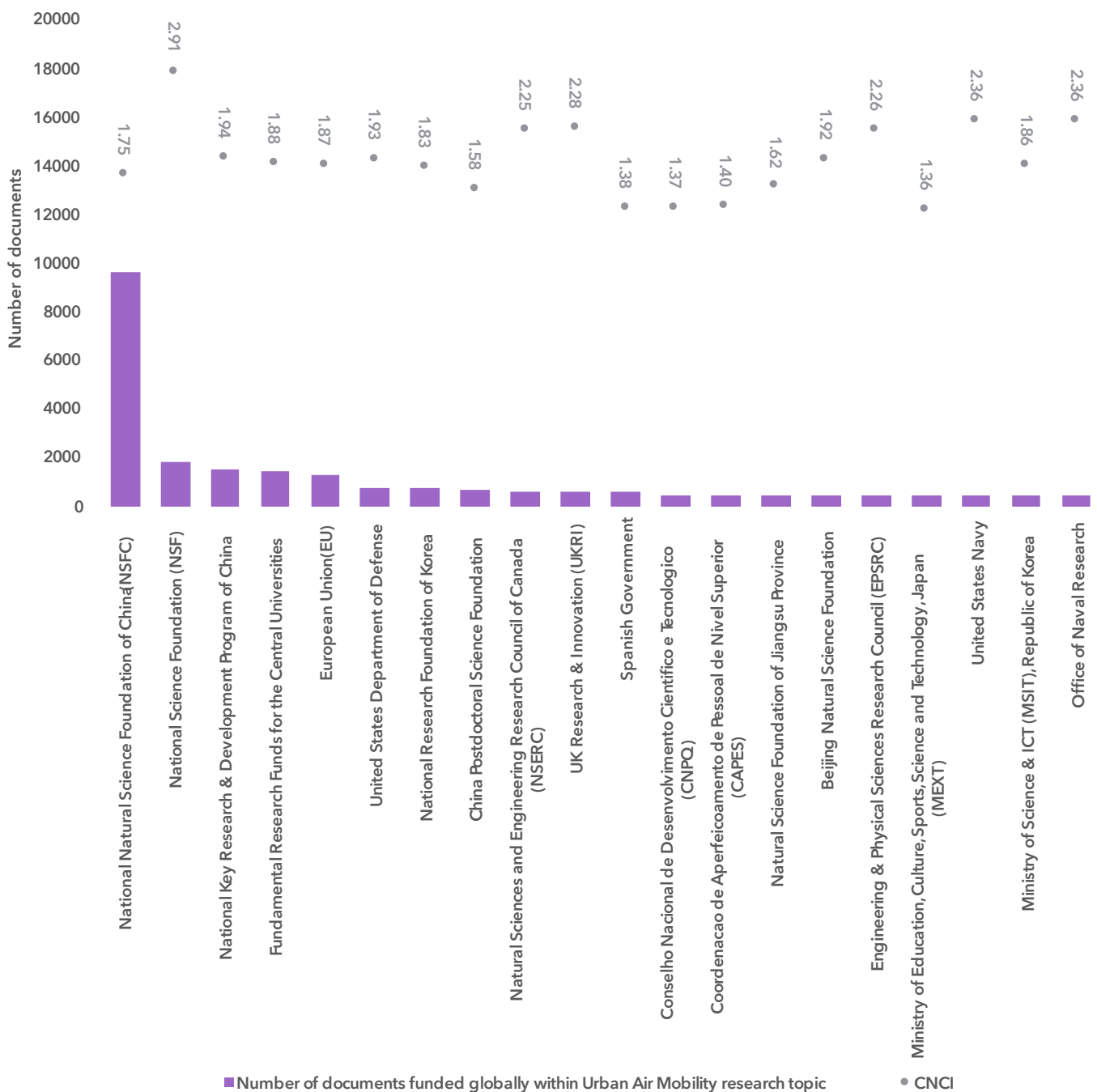


Figure 107: Top 20 funding organizations globally publications in the research topic Urban Air Mobility in terms of number of publications in the period 2014-2023

4.1.12.10 Emerging trends in the research topic globally and in Saudi Arabia

In this section we investigate the emerging trends globally and in Saudi Arabia in the research topic Urban Air Mobility. For more information on the methodology used to identify emerging trends, please see the definition section Emerging Trends.

The top 3 emerging micro-topics globally in this research topic are Computer Vision & Graphics Internet of Things, Deep Learning, followed Telecommunications, Internet of Things, and Wireless Technology: MIMO, as shown in Figure 108. Saudi Arabia has very few publications on this research topic, such that it was not meaningful to identify emerging micro-topics. Table 37 shows the identified top 10 micro-topics in Saudi Arabia's research output on this research topic.

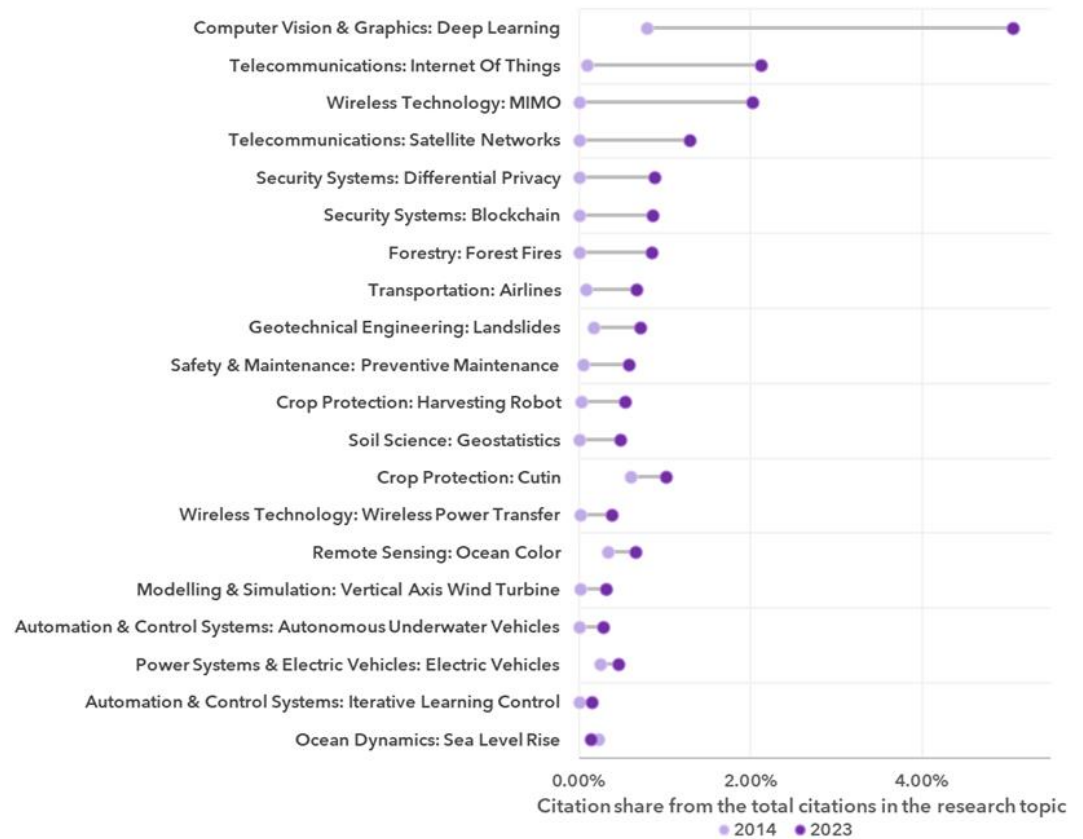


Figure 108: Top 20 emerging micro-topics globally in the research topic Urban Air Mobility in the period 2014-2023

Table 37: Top 10 Micro-topics identified in Saudi Arabia research output in the research topic Urban Air Mobility in the period 2014-2023

Topic	Number of Saudi Arabia publications in the period 2014-2023
Urban Air Mobility research topic	905
Unmanned Aerial Vehicles	423
Adaptive Control	60
Multi Agent Systems	54
NDVI	39
Deep Learning	33
Internet Of Things	33
Blockchain	22
MIMO	16
Random Oracle Model	12
Wireless Sensor Networks	11

4.1.13 Space Architecture Habitats

4.1.13.1 Evolution of Saudi publication share of global publications in the research topic

The share of Saudi Arabia publications from global publications on the research topic increased almost continuously from 2014 till 2023, as shown in Figure 109. This shows that Saudi Arabia was not only able to increase the number of publications on this research topic but also had a growth higher than the global growth rate.

This is evident as the share of Saudi Arabia publications in the research topic is growing. The CNCI of Saudi Arabia publications in this research topic were in all years higher than 1 except for 2015 and 2017, indicating a citation impact performance higher than the global average.

Although the CNCI decreased from 3.17 in 2014 to 0.82 in 2015, it increased to 1.52 in 2023, indicating a 52% higher citation impact performance than the global average.

Overall, Saudi Arabia publications increased with a higher growth rate than the global average in this research topic and had a relatively good citation impact as measured by the CNCI.

Nevertheless, after this high growth rate in terms of publications, one should focus on increasing/preserving the relatively good citation impact.

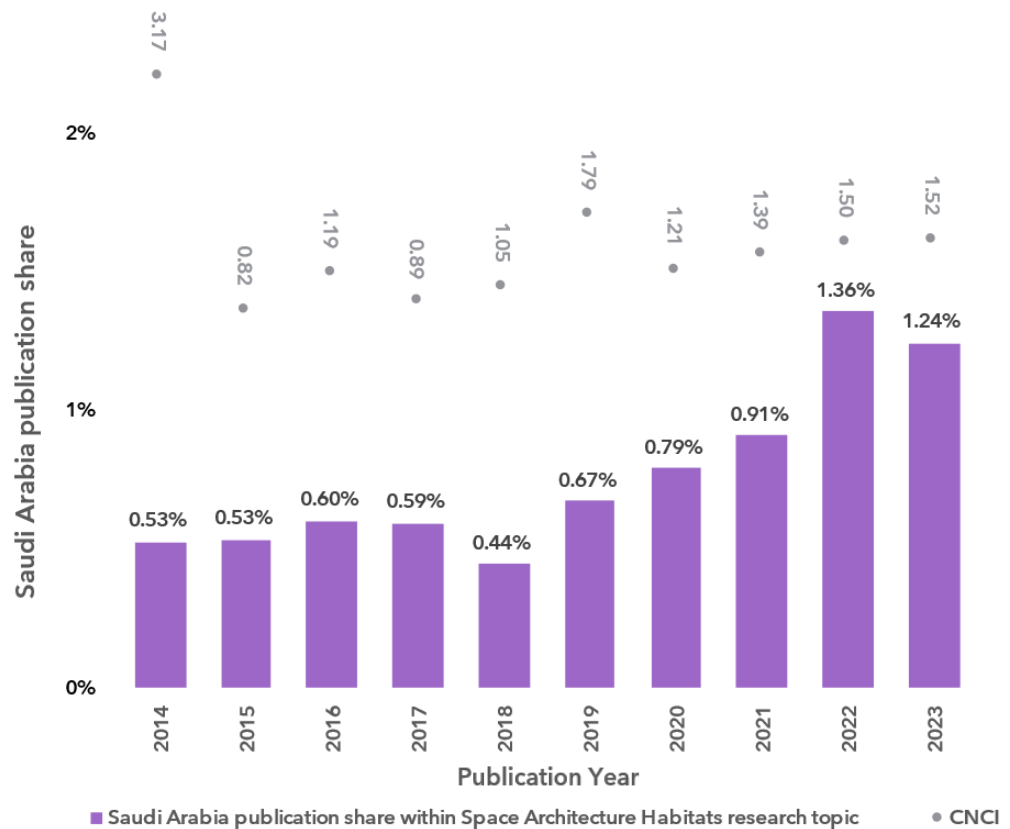


Figure 109: The share of Saudi Arabia from global publications in the research topic and the CNCI of Saudi Arabia publications in the research topic Space Architecture Habitats in the period 2014-2023

4.1.13.2 Top 10 countries collaborating with Saudi Arabia

The top collaborating countries with Saudi Arabia in this research topic in the period 2014-2023 are Egypt, followed by Mainland China and the United States with 141, 134 and 122 publications respectively as shown in Figure 110. In terms of citation impact measured by the CNCI publications published in collaboration with Canada, the United Kingdom and the United States had the highest CNCI with 2.64, 2.62 and 2.29, respectively. Nevertheless, all publications with the top 10 collaborating

countries had a CNCI higher than 1, reflecting a performance higher than the global average.

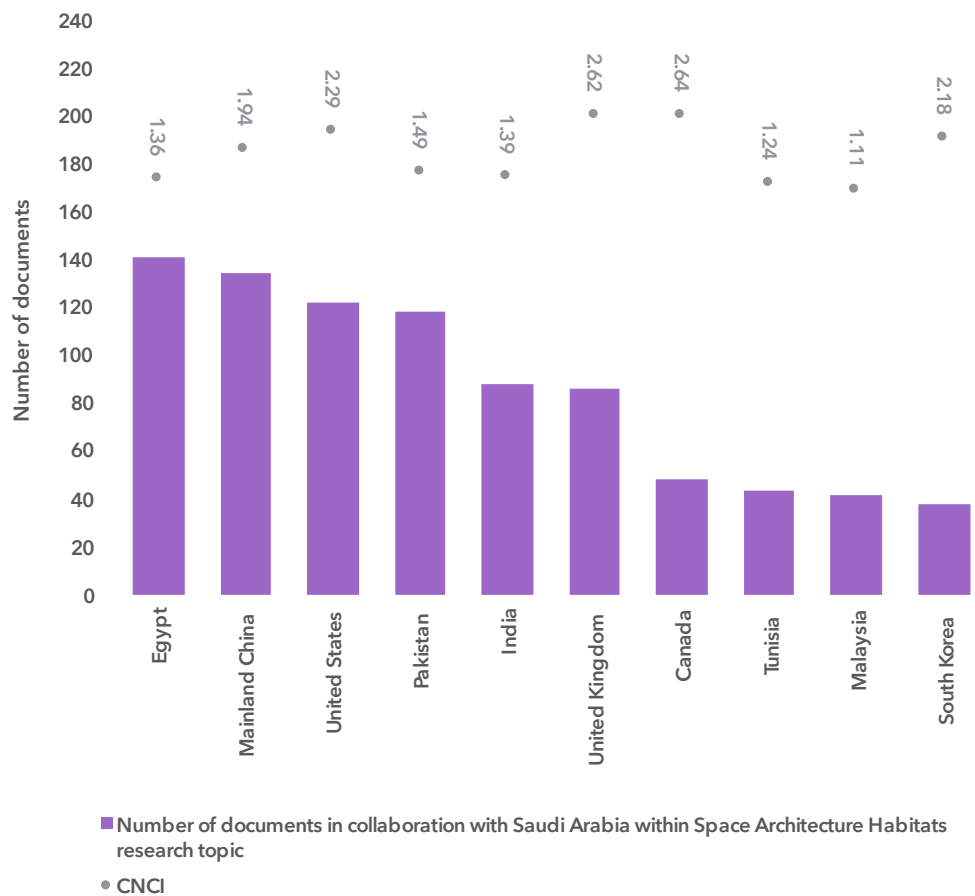


Figure 110: Top 10 collaborating countries with Saudi Arabia in terms of the number of publications in the research topic Space Architecture Habitats in the period 2014-2023

4.1.13.3 Top 20 funders of Saudi publications by number of publications

The top 3 funding organizations of Saudi Arabia publications in this research topic in terms of number of publications mentioning the organization in the funding text in the period 2014-2023 are National Natural Science Foundation of China (NSFC) followed by King Saud University and King Abdullah University of Science & Technology with 71, 62 and 40 publications respectively as shown in Figure 111.

Documents funded by UK Research & Innovation (UKRI) followed by European Union (EU) and United States Department of Energy (DOE) had the highest citation impact measured by the CNCI with 11.79, 9.70 and 7.11 respectively.

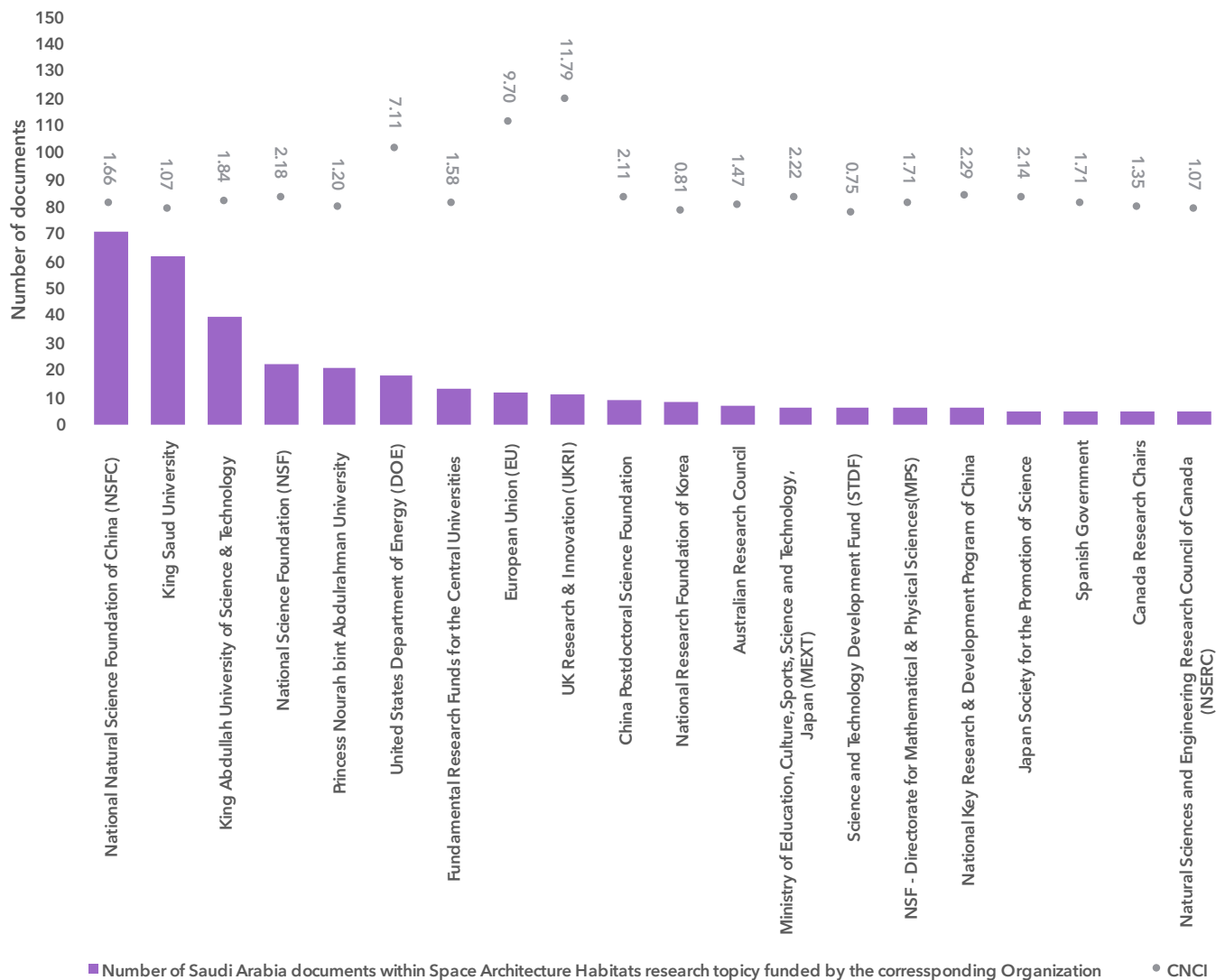


Figure 111: Top 20 funding organizations of Saudi Arabia publications in the research topic Space Architecture Habitats in terms of number of publications in the period 2014-2023

4.1.13.4 Top 20 Saudi Arabia organizations in terms of number of publications

The top 3 organizations in terms of publications published on this research topic in the period 2014-2023 are King Abdulaziz University, followed by King Abdullah University of Science & Technology and King Saud University with 194, 130 and 126 publications, respectively, as shown in Figure 112.

In terms of citation impact as measured by the CNCI, Prince Sultan University, followed by King Abdullah University of Science & Technology and King Abdulaziz University had the highest CNCI with 3.69, 1.96 and 1.90, respectively. Nevertheless, 13 out of top 20 organizations had a CNCI higher than 1, reflecting a citation impact performance higher than the global average.

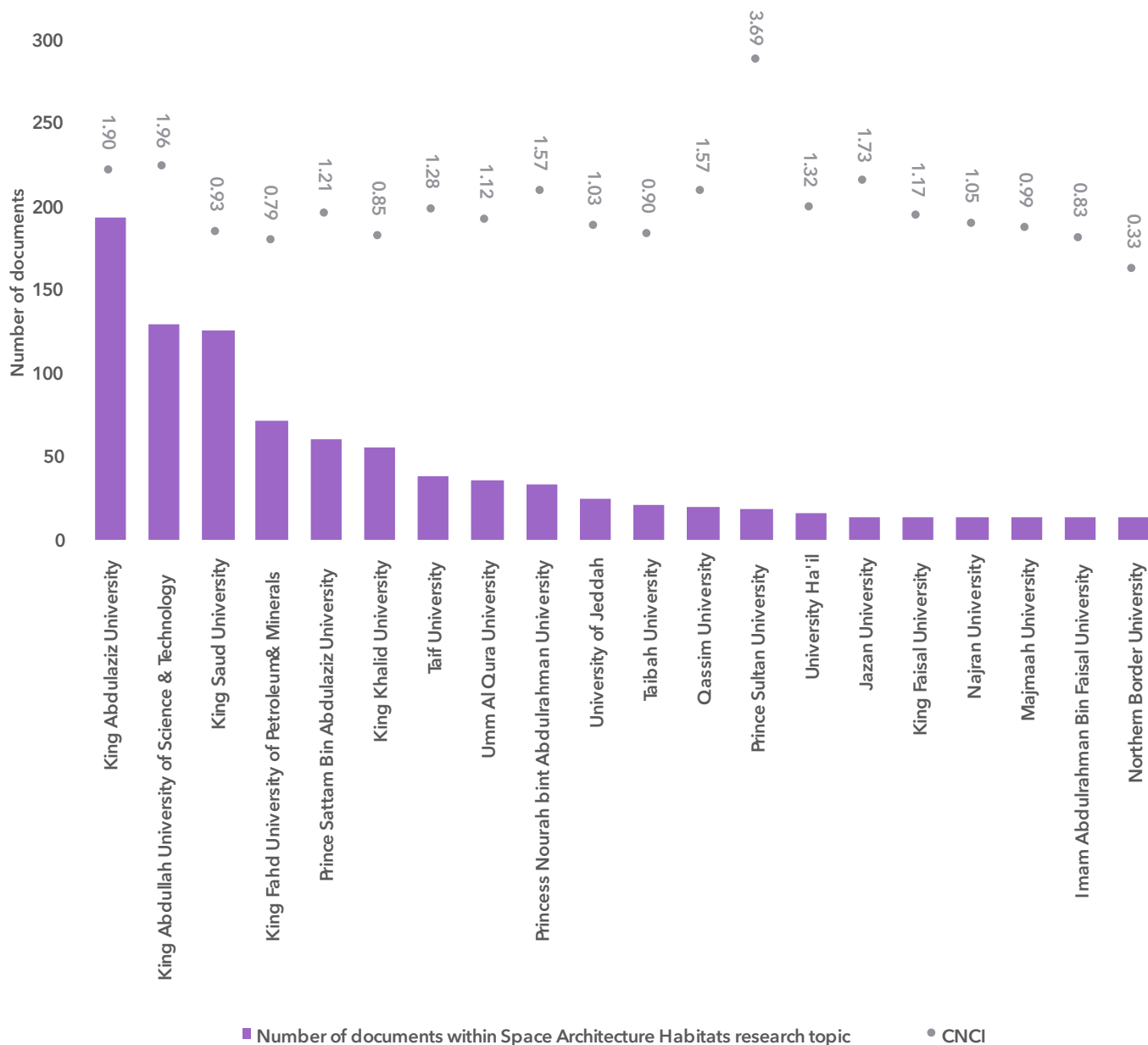


Figure 112: Top 20 Saudi organizations in terms of publications published in the research topic Space Architecture Habitats in the period 2014-2023 and their corresponding CNCI

4.1.13.5 Top 20 researchers affiliated with Saudi organizations in terms of number of publications.

The highest number of publications are published by Mohamed-Slim Alouini affiliated to King Abdullah University of Science & Technology followed by Zekai Sen affiliated to King Abdulaziz University, and Mohammed M. A. Almazah, affiliated with King Khalid University, with 18, 14 and 10 publications respectively as shown in Table 38.

The highest CNCI is achieved by publications published by Peter Wonka affiliated with King Abdullah University of Science & Technology with a CNCI of 6.65.

Matthew F. McCabe affiliated to King Abdullah University of Science & Technology has the highest number of Top 1% amounting to 3 publications and Top 10% publications amounting to 4 publications.

Table 38: Top 20 researchers affiliated with Saudi organizations in terms of the number of publications published in the research topic Space Architecture Habitats in the period 2014-2023

Name	Affiliation	Web of Science Publications	CNCI	Documents in the top 1%	Documents in the top 10%
Alouini, Mohamed-Slim	King Abdullah University of Science & Technology	18	1.40	1	2
Sen, Zekai	King Abdulaziz University	14	0.37	0	0
Almazah, Mohammed M. A.	King Khalid University	10	0.76	0	0
Elashkar, Elsayed Elsherbini	King Saud University	9	0.64	0	0
Bakery, Awad A.	University of Jeddah	8	0.45	0	0
McCabe, Matthew F.	King Abdullah University of Science & Technology	7	6.22	3	4
Al-Rezami, A. Y.	Prince Sattam Bin Abdulaziz University	7	0.69	0	0
Alsaedi, Ahmed	King Abdulaziz University	6	1.90	0	1
Almanjahie, Ibrahim M.	King Khalid University	6	0.96	0	0
Almazroui, Mansour	King Abdulaziz University	6	0.84	0	0
Chung, Suk Ho	King Abdullah University of Science & Technology	6	0.75	0	0
Al-Saggaf, Ubaid M.	King Abdulaziz University	6	0.71	0	0
Mattar, Mohamed A.	King Saud University	5	2.96	1	2
Aljohani, Abdulah Jeza	King Abdulaziz University	5	1.44	0	0
Im, Hong G.	King Abdullah University of Science & Technology	5	0.82	0	0
Ahmed, Shehab	King Abdullah University of Science & Technology	5	0.60	0	0
Moinuddin, Muhammad	King Abdulaziz University	5	0.47	0	0
Gani, Showkat	King Saud University	5	0.38	0	0
Wonka, Peter	King Abdullah University of Science & Technology	4	6.65	1	1
Abdeljawad, Thabet	Prince Sultan University	4	6.35	2	3

4.1.13.6 Top 10 countries in terms of publications

The highest number of publications published in this research topic are published by Mainland China (30,966 publications) followed by United States (30,168 publications) and India (9,038 publications) as shown in Figure 113.

The highest citation impact measured by the CNCI is achieved by publications published by United Kingdom, Canada, and France with a CNCI of 1.45, 1.35 and 1.31, respectively.

Five of the top 10 countries in terms of number of publications published in the research topic are also among the top 10 collaborators with Saudi Arabia. These are United States, Mainland China, United Kingdom, India, and Canada.

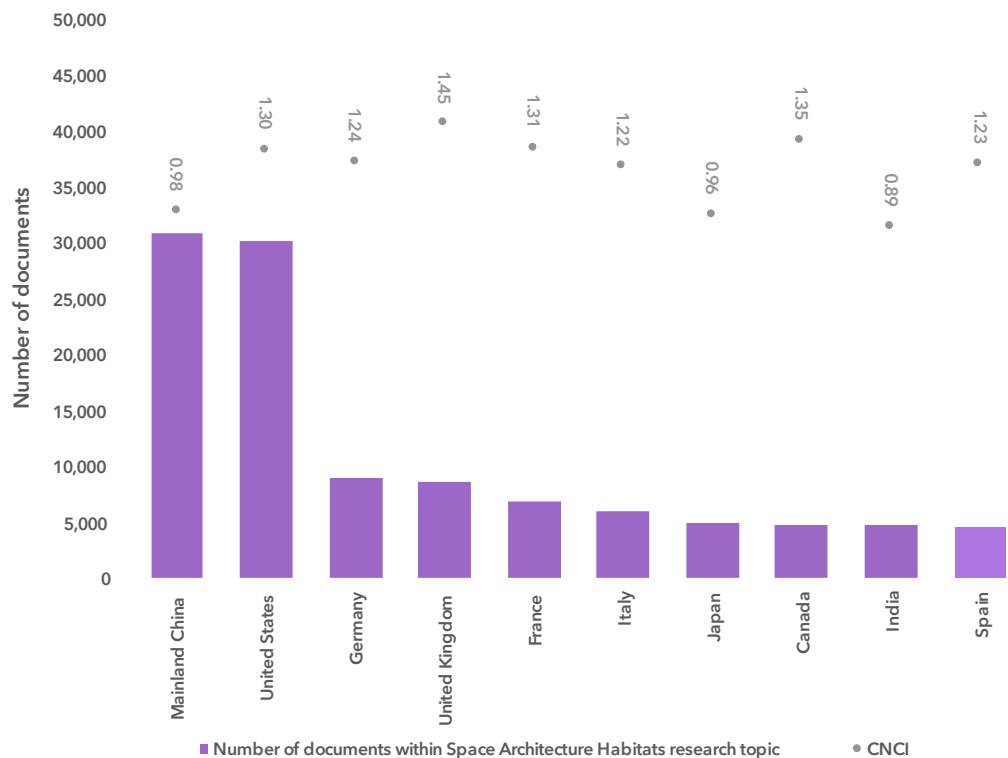


Figure 113: Top 10 countries in terms of the number of publications in the research topic Space Architecture Habitats in the period 2014-2023 and their corresponding CNCI

4.1.13.7 Top 20 organizations globally in terms of number of publications

The top 3 organizations in terms of the number of publications published on this research topic in the period 2014-2023 are National Aeronautics & Space Administration (NASA) (6,329 publications) followed by Chinese Academy of Sciences (5,719 publications) and Centre National de la Recherche Scientifique (4,319 publications) respectively as shown in Figure 114.

In terms of citation impact measured by the CNCI, Max Planck Society and NASA Goddard Space Flight Center sharing same CNCI followed by United States Department of Energy (DOE) followed by University of London and California Institute of Technology sharing the same CNCI had the highest CNCI with 1.94, 1.8 and 1.79, respectively.

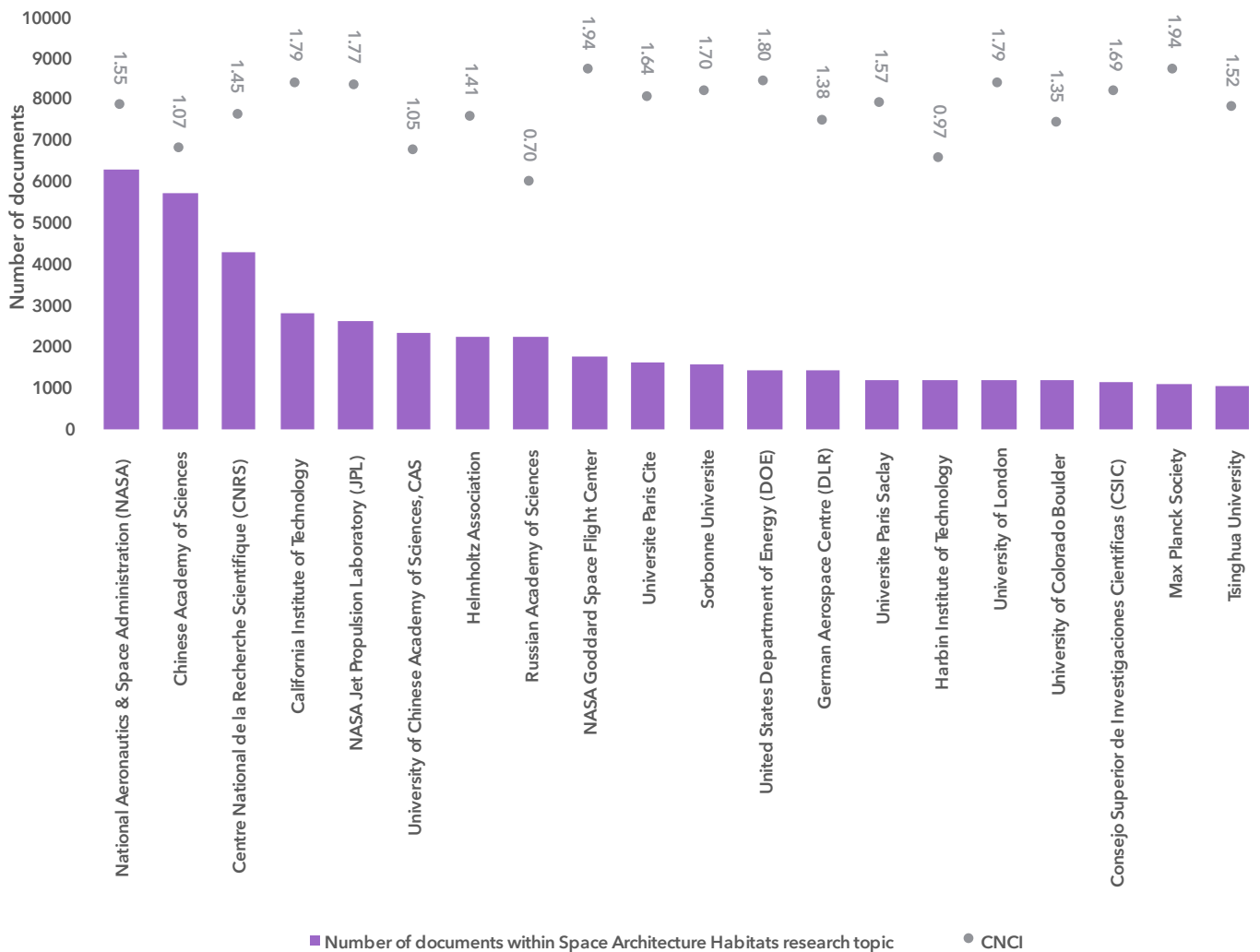


Figure 114: Top 20 organizations globally in terms of the number of publications published in the research topic Space Architecture Habitats in the period 2014-2023 and their corresponding CNCI

4.1.13.8 Top 20 researchers globally in terms of number of publications

The top 3 researchers globally in terms of number of publications in this research topic are B. M. Jakosky affiliated to University of Colorado Boulder with 109 publications followed by Philippe Lognonne affiliated to Universite Paris Cite with 90 publications and Zongquan Deng affiliated to Harbin Institute of Technology with 86 publications as shown in Table 39.

The highest CNCI, Document in top 1% and Documents in top 10% among the top 20 researchers globally is achieved by Wiens R. C. affiliated to Los Alamos National Laboratory with a CNCI of 3.63, 10 publications in top 10%, and 44 publications in top 10%.

Table 39: Top 20 researchers globally in terms of the number of publications published in the research topic Space Architecture Habitats in the period 2014-2023

Name	Affiliation	Web of Science Publications	CNCI	Documents in the top 1%	Documents in the top 10%	Country
Jakosky, B. M.	University of Colorado Boulder	109	1.84	2	27	United States
Lognonne, Philippe	Universite Paris Cite	90	2.59	6	28	France
Deng, Zongquan	Harbin Institute of Technology	86	0.78	0	4	Mainland China
Montmessin, F.	Sorbonne Universite	84	1.82	2	21	France
Head, James W.	Brown University	83	1.34	0	14	United States
Grimm, Daniela	Aarhus University	82	1.03	0	10	Denmark
Venkateswaran, Kasthuri	NASA Jet Propulsion Laboratory (JPL)	81	1.23	1	13	United States
Wiens, R. C.	Los Alamos National Laboratory	80	3.63	10	44	United States
Halekas, J. S.	University of Iowa	75	1.44	1	11	United States
Cockell, Charles S.	University of Edinburgh	72	1.25	2	8	Scotland
Kisi, Ozgur	Ilia State University	70	2.54	6	26	Republic Of Georgia
Mitchell, D. L.	University of California Berkeley	69	1.57	1	13	United States
Maurice, S.	Universite de Toulouse	68	3.41	8	35	France
Smith, Michael D.	NASA Goddard Space Flight Center	68	1.61	0	15	United States
Gasnault, O.	Universite de Toulouse	67	2.79	4	32	France
Mazelle, C.	Universite Toulouse III - Paul Sabatier	67	1.64	2	13	France
Mangold, N.	Nantes Universite	63	3.29	8	27	France
Forget, Francois	Sorbonne Universite	63	2.21	4	14	France
Cui, Jun	Sun Yat Sen University	60	0.80	0	2	Mainland China
Mitrofanov, I. G.	Russian Academy of Sciences	59	0.50	0	2	Russia

4.1.13.9 Top 20 global funders globally in terms of number of publications

The top 3 organizations in terms of funded publications in this research topic are the National Natural Science Foundation of China (NSFC) with 17,404 publications, followed by the National Aeronautics & Space Administration (NASA) with 5,420 publications, and the National Science Foundation (NSF) with 4,935 publications as shown in Figure 115.

The highest citation impact measured by the CNCI is observed in publications funded by European Research Council (ERC) followed by Centre National D'etudes Spatiales and United States Department of Energy (DOE) with 1.89, 1.76 and 1.67, respectively.

Among the top 20 global funding organizations, 12 are also among the top 20 funding organizations of Saudi publications in this research topic.

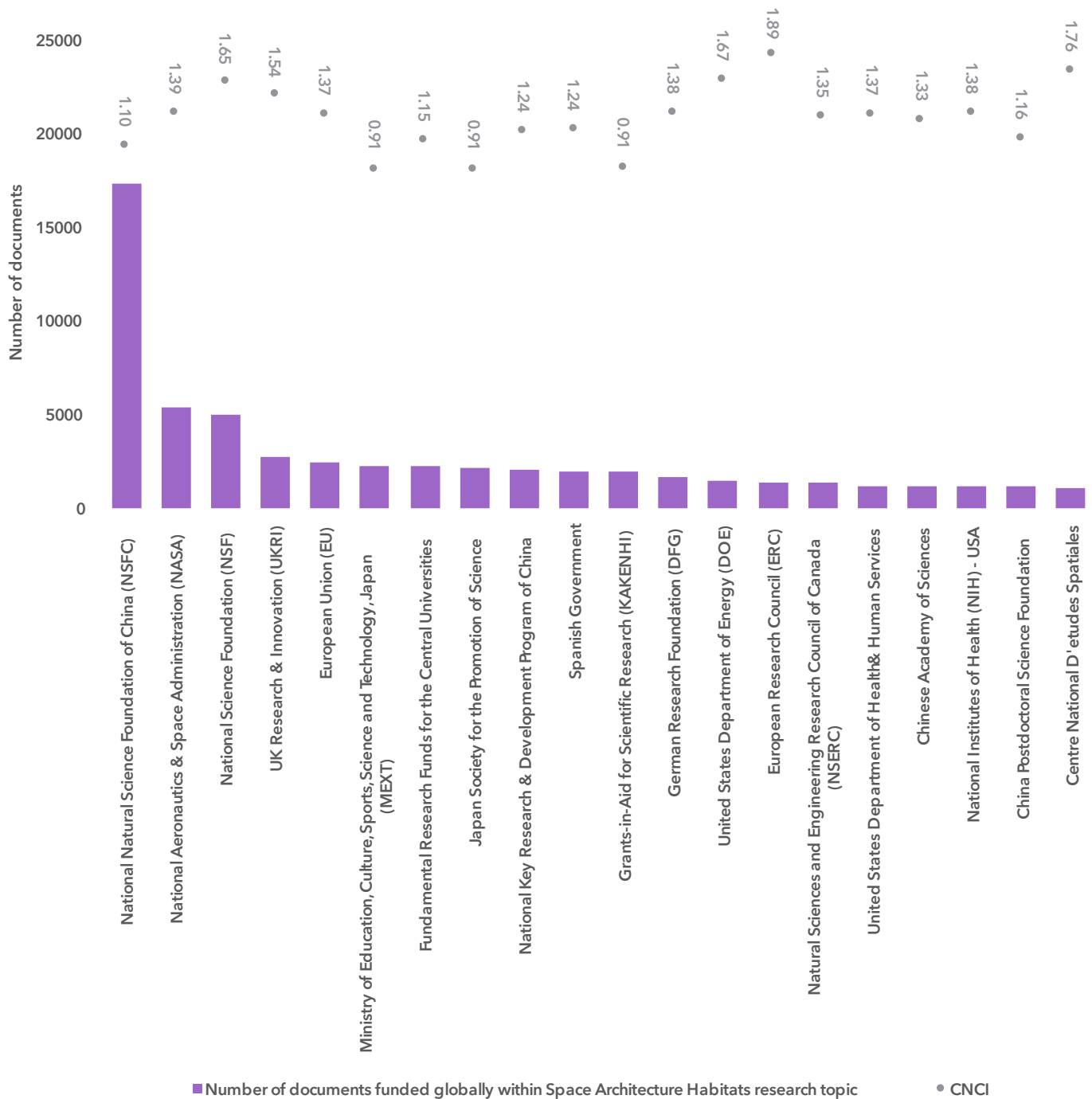


Figure 115: Top 20 funding organizations globally publications in the research topic Space Architecture Habitats in terms of number of publications in the period 2014-2023

4.1.13.10 Emerging trends in the research topic globally and in Saudi Arabia

In this section we investigate the emerging trends globally and in Saudi Arabia in the research topic Space Architecture Habitats. For more information on the methodology used to identify emerging trends, please see the definition section Emerging Trends.

The top 3 emerging micro-topics globally in this research topic are Perovskite Solar Cells: Perovskite Solar Cells followed by Computer Vision & Graphics: Deep Learning and Microfluidic Devices & Superhydrophobicity: Flow Chemistry as shown in Figure 116.

Table 40 shows the identified top 10 micro-topics in Saudi Arabia's research output on this research topic.

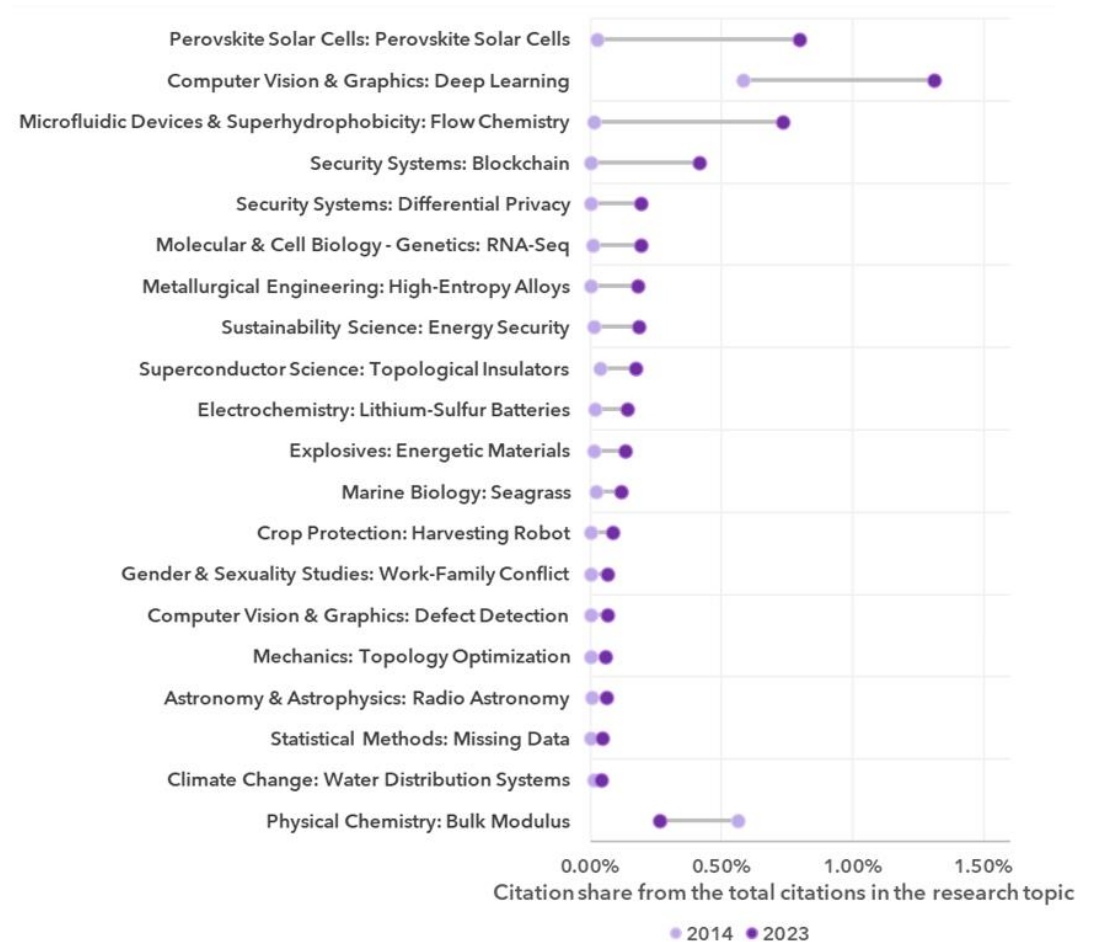


Figure 116: Top 20 emerging micro-topics globally in the research topic Space Architecture Habitats in the period 2014-2023

Table 40: Top 10 Micro-topics identified in Saudi Arabia research output in the research topic Space Architecture Habitats in the period 2014-2023

Topic	Number of Saudi Arabia publications in the period 2014-2023
Space Architecture - Habitats research topic	938
Oceanography, Meteorology & Atmospheric Sciences: Evapotranspiration	75
Thermodynamics: Nanofluid	27
Geometrical Optics: Visible Light Communication	25
Convergence & Optimization: Fixed Point	25
Sustainability Science: Thermal Comfort	23
Power Systems & Electric Vehicles: MPPT	23
Artificial Intelligence & Machine Learning: Rough Sets	17
Modelling & Simulation: Error Estimates	15
Numerical Methods: Fractional Calculus	14
Supply Chain & Logistics: Particle Swarm Optimization	14

4.1.14 Space Architecture Mining

4.1.14.1 Evolution of Saudi publication share of global publications in the research topic

The share of Saudi Arabia publications from global publications in the research topic had a fluctuating growing trend between 2014 till 2018, followed by a vigorous increase between 2019 till 2022 and a drop in 2023 to 1.26% from the previous year peak of 1.57% as shown in Figure 117.

This shows that Saudi Arabia was able to increase the number of publications on this research topic but also had a growth higher than the global growth rate. This is evident as the share of Saudi Arabian publications in the research topic is growing. The CNCI of Saudi Arabia had higher fluctuations between 2014 and 2018, reaching the highest value for the period at 1.55 in 2016 but also the lowest value at 0.72 in 2018.

This dynamic was followed by steady growth in impact in each of the following years, from 0.88 in 2019 to 1.31 in 2023, indicating a citation impact performance higher than the global average.

Overall, Saudi Arabia's publications increased with a higher growth rate than the global average in this research topic and had a relatively good citation, as measured by the CNCI. Nevertheless, after this high growth rate in terms of publications, one should focus on increasing/preserving the relatively good citation impact.

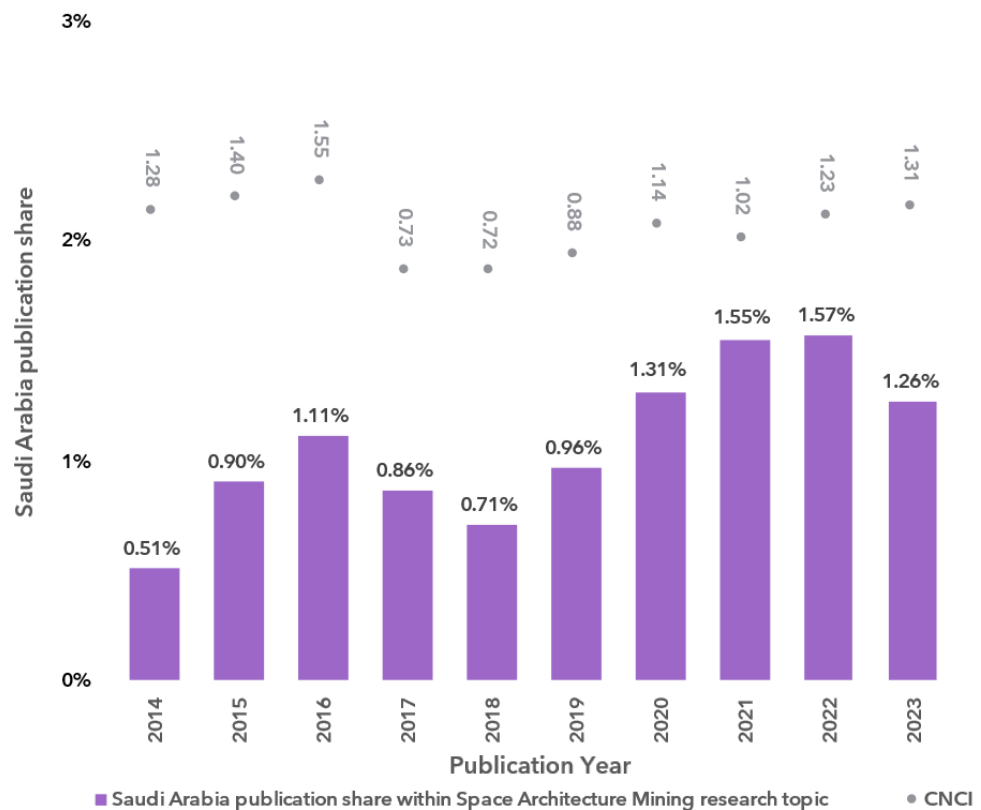


Figure 117: The share of Saudi Arabia from global publications in the research topic and the CNCI of Saudi Arabia publications in the research topic Space Architecture Mining in the period 2014-2023

4.1.14.2 Top 10 countries collaborating with Saudi Arabia

The top collaborating countries with Saudi Arabia in this research topic in the period 2014-2023 are Egypt followed by Pakistan and Mainland China with 72, 51 and 49 publications respectively as shown in Figure 118.

In terms of citation impact measured by the CNCI, Saudi publications published in collaboration with Malaysia, Mainland China and the United Kingdom had the highest CNCI with 1.72, 1.71 and 1.70, respectively. Except for Canada, all publications with the top 10 collaborating countries had a CNCI higher than 1, reflecting a performance

higher than the global average.

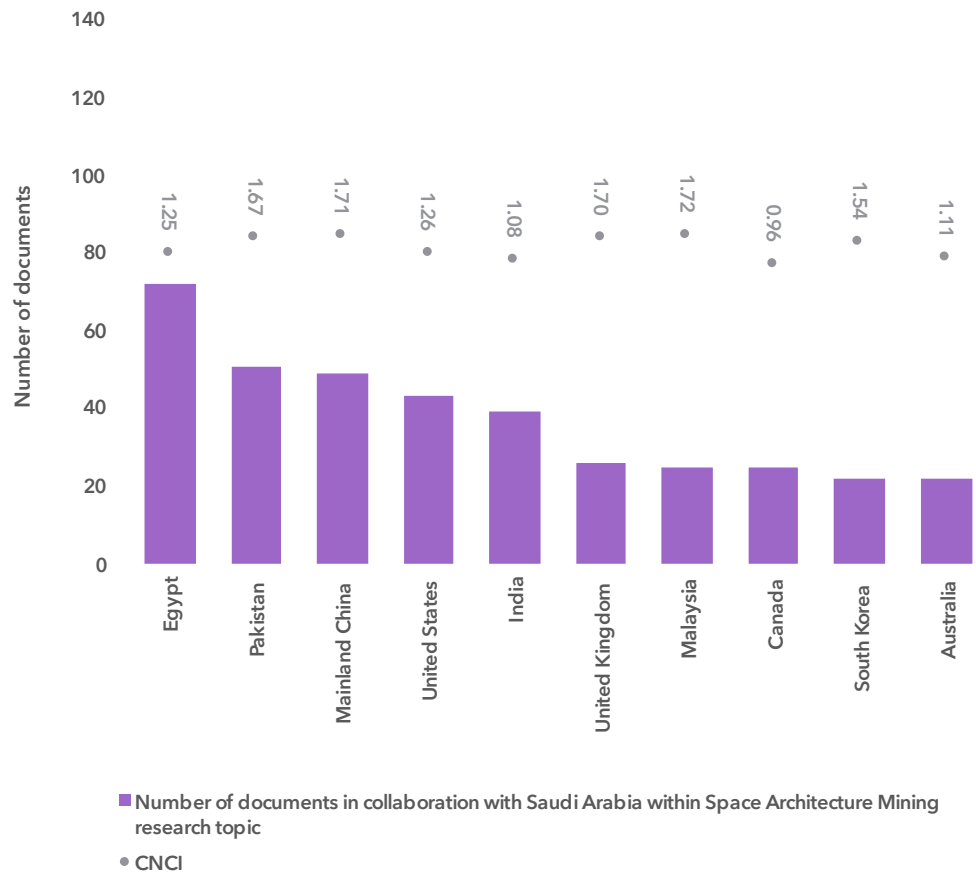


Figure 118: Top 10 collaborating countries with Saudi Arabia in terms of the number of publications in the research topic Space Architecture Mining in the period 2014-2023

4.1.14.3 Top 20 funders of Saudi publications by number of publications

The top 3 funding organizations of Saudi Arabia publications in this research topic in terms of number of publications mentioning the organization in the funding text in the period 2014-2023 are King Saud University followed by National Natural Science Foundation of China (NSFC) and National Science Foundation (NSF) with 33, 19 and 10 publications respectively as shown in Figure 119.

Documents funded by the European Social Fund (ESF), followed by the National Science Foundation (NSF) and the National Natural Science Foundation of China (NSFC), had the highest citation impact measured by the CNCI with 2.81, 1.79 and 1.73, respectively.

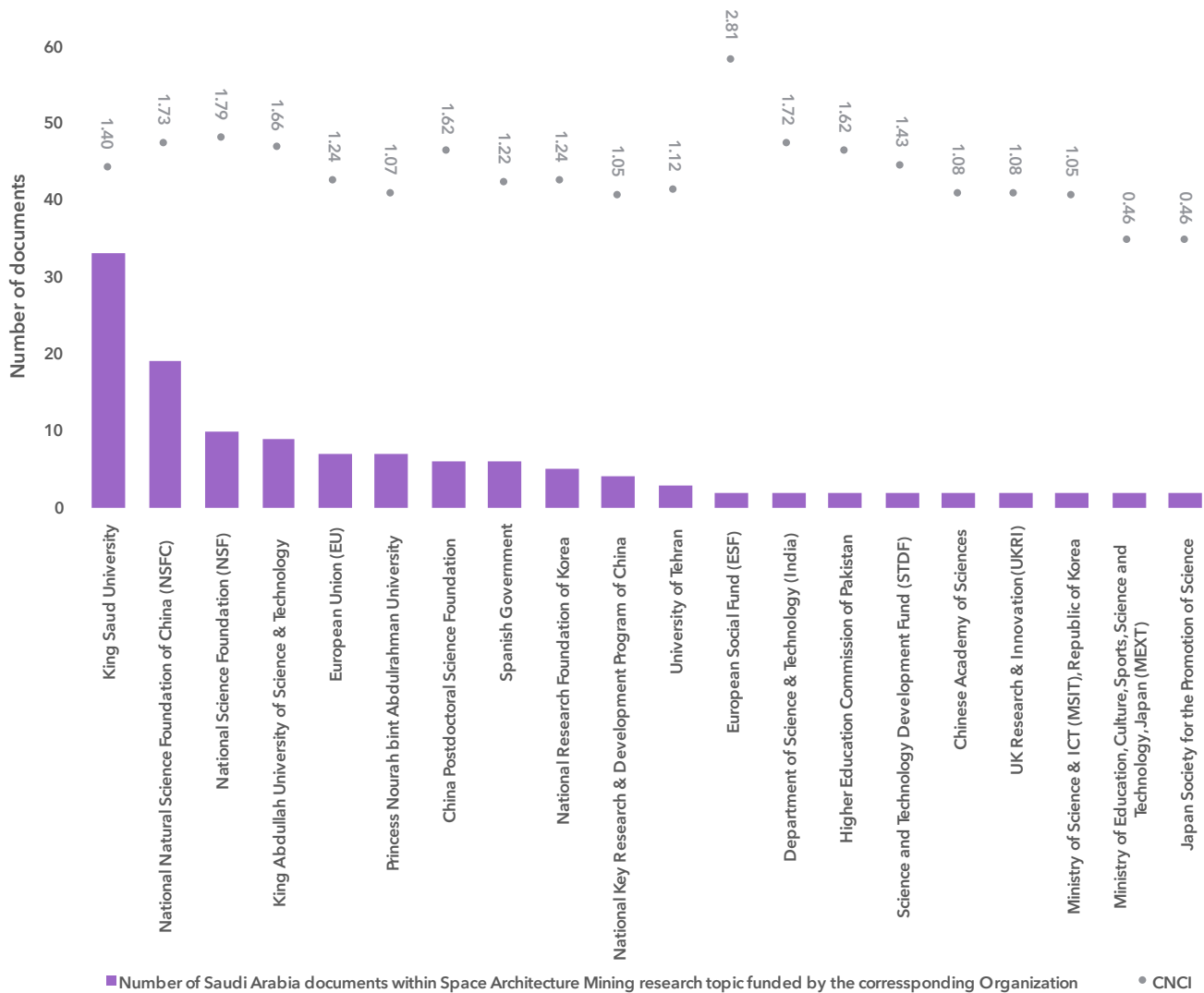


Figure 119: Top 20 funding organizations of Saudi Arabia publications in the research topic Space Architecture Mining in terms of number of publications in the period 2014-2023

4.1.14.4 Top 20 Saudi Arabia organizations in terms of number of publications

The top 3 organizations in terms of publications published on this research topic in the period 2014-2023 are King Saud University, followed by King Abdulaziz University and King Abdullah University of Science & Technology, with 78, 69 and 27 publications, respectively, as shown in Figure 120.

In terms of citation impact as measured by the CNCI, the University of Tabuk, followed by Umm Al Qura University and Taibah University, had the highest CNCI with 2.35, 2.11 and 1.73, respectively. Eleven of the top 20 organizations had a CNCI higher than 1, reflecting a citation impact performance higher than the global average.

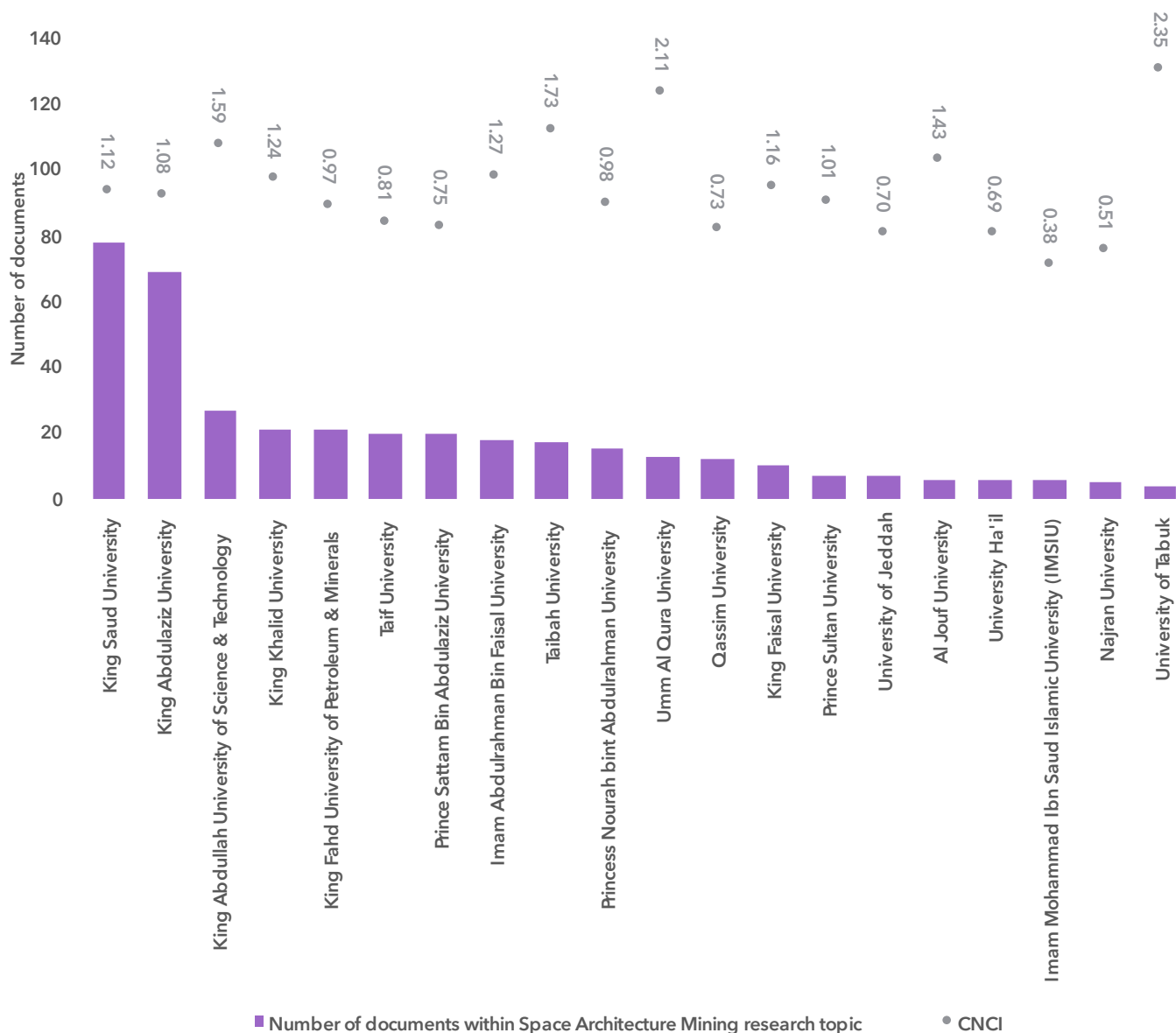


Figure 120: Top 20 Saudi organizations in terms of publications published in the research topic Space Architecture Mining in the period 2014-2023 and their corresponding CNCI

4.1.14.5 Top 20 researchers affiliated with Saudi organizations in terms of number of publications.

The highest number of publications are published by Muhammad Imtiaz Rashid, affiliated with King Abdulaziz University, followed by Abdelmohsen A. Nassani, affiliated with King Saud University and Alaa Abdelhamid, affiliated with Qassim University, with 8, 5 and 4 publications, respectively as shown in Table 41.

The highest CNCI is achieved by publications published by Abdelmohsen A. Nassani, affiliated with King Saud University, with a CNCI of 5.27. The latter researcher also has the highest number of Top 10%, amounting to 3 publications, and the Top 1% publications, amounting to 1 document, the same value as Ehab Abdelhamid and Panos Kalnis, both affiliated with King Abdullah University of Science & Technology.

Table 41: Top 20 researchers affiliated with Saudi organizations in terms of the number of publications published on the research topic Space Architecture Mining in the period 2014-2023

Name	Affiliation	Web of Science Publications	CNCI	Documents in the top 1%	Documents in the top 10%
Rashid, Muhammad Imtiaz	King Abdulaziz University	8	0.89	0	0
Nassani, Abdelmohsen A.	King Saud University	5	5.27	1	3
Abdelhamid, Alaa	Qassim University	4	0.99	0	0
Kalnis, Panos	King Abdullah University of Science & Technology	3	3.58	1	1
Hussain, Shahzad	King Saud University	3	1.59	0	1
Omran, Mostafa	Qassim University	3	1.24	0	0
Ismail, Iqbal M. I.	King Abdulaziz University	3	1.19	0	0
Mahmoud, Mohamed	King Fahd University of Petroleum & Minerals	3	0.85	0	0
Ghafoor, Kashif	King Saud University	3	0.65	0	0
Zhang, Xiangliang	King Abdullah University of Science & Technology	3	0.64	0	0
Ali, Nadeem	King Abdulaziz University	3	0.46	0	0
Omar, Abdulfattah	Prince Sattam Bin Abdulaziz University	3	0.27	0	0
Abdelhamid, Ehab	King Abdullah University of Science & Technology	2	5.23	1	1
Mezni, Haithem	Taibah University	2	4.34	0	2
Alamri, Saad	King Khalid University	2	3.97	0	2
Aldakhil, Abdullah Mohammed	King Saud University	2	3.85	0	1
Ihm, Seungwon	Saline Water Conversion Corporation (SWCC)	2	3.47	0	2
Houborg, Rasmus	King Abdullah University of Science & Technology	2	3.12	0	1
McCabe, Matthew F.	King Abdullah University of Science & Technology	2	3.12	0	1
Jonsson, Sigurjon	King Abdullah University of Science & Technology	2	2.10	0	1

4.1.14.6 Top 10 countries in terms of publications

The highest number of publications within this research topic are published by Mainland China (9,484 publications), followed by the United States (5143 publications) and Australia (1,835 publications), as shown in Figure 121.

The highest citation impact measured by the CNCI is achieved by publications published in Australia, the United States and the United Kingdom with a CNCI of 1.81, 1.54 and 1.46, respectively.

Six of the top 10 countries in terms of a number of publications published on the research topic are also among the top 10 collaborators with Saudi Arabia. These are Australia, the United States, the United Kingdom, Canada, Mainland China, and India.

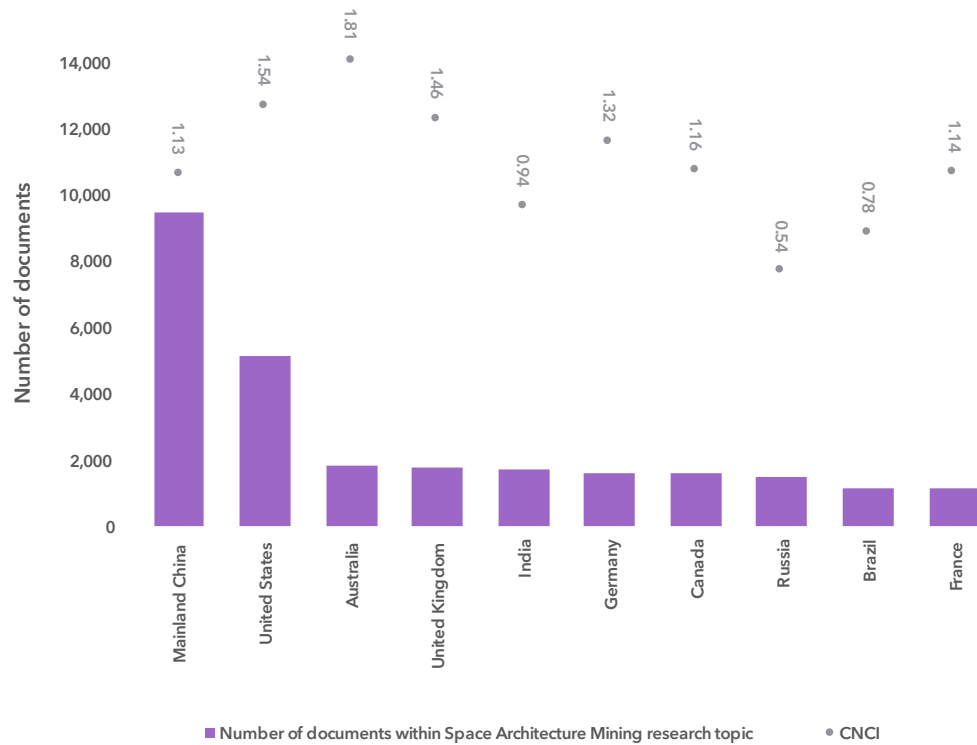


Figure 121: Top 10 countries in terms of the number of publications in the research topic Space Architecture Mining in the period 2014-2023 and their corresponding CNCI

4.1.14.7 Top 20 organizations globally in terms of number of publications

The top 3 organizations in terms of number of publications published in this research topic in the period 2014-2023 are Chinese Academy of Sciences (1099 publications) followed by China University of Mining & Technology (781 publications) and Russian Academy of Sciences (663 publications) respectively as shown in Figure 122.

In terms of citation impact measured by the CNCI, University of London followed by Tsinghua University and Swiss Federal Institutes of Technology Domain had the highest CNCI with 2.27, 2.23 and 1.63, respectively.

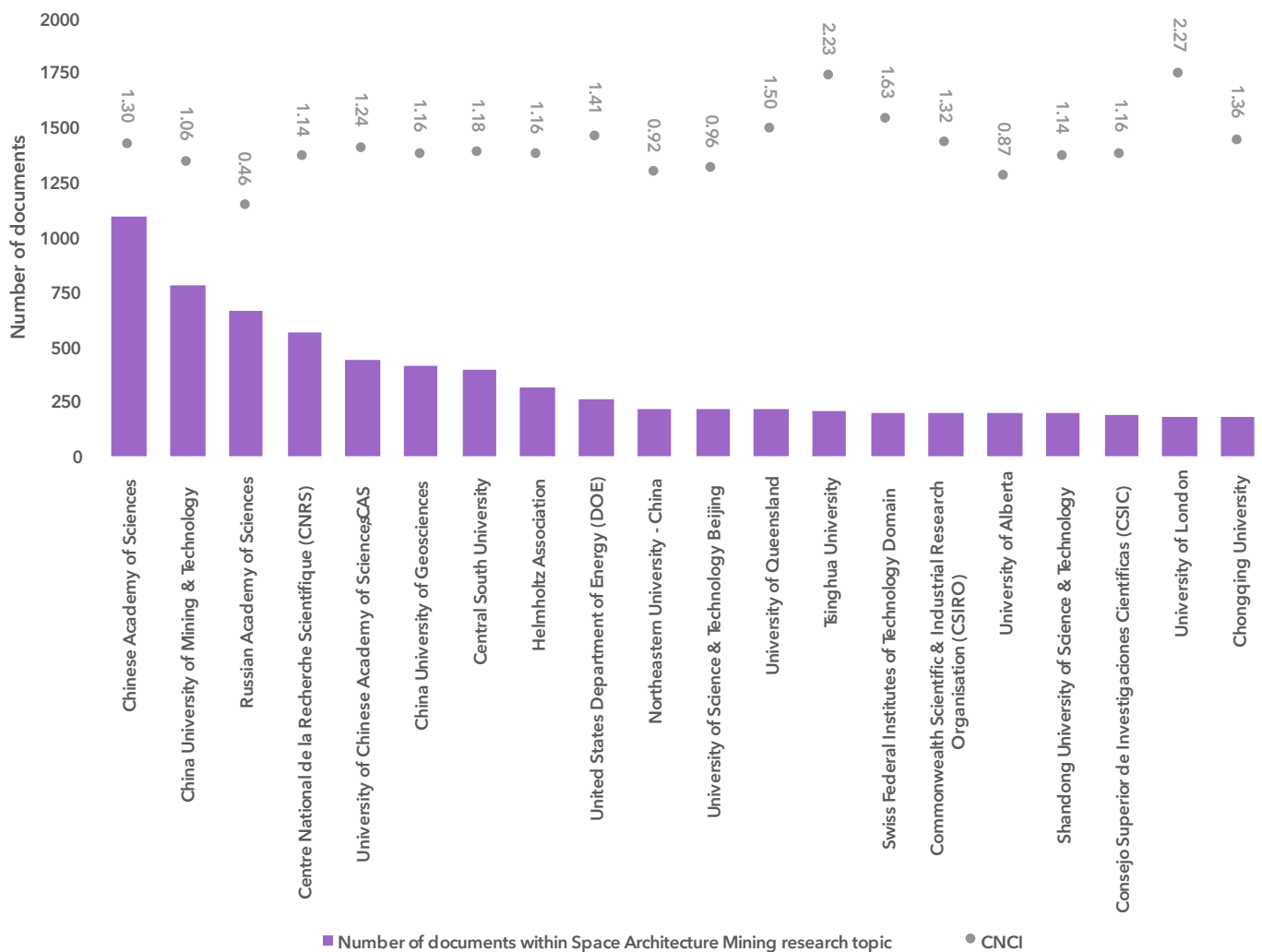


Figure 122: Top 20 organizations globally in terms of number of publications published in the research topic Space Architecture Mining in the period 2014-2023 and their corresponding CNCI

4.1.14.8 Top 20 researchers globally in terms of number of publications

The top 3 researchers globally in terms of number of publications in this research topic are Philippe Fournier-Viger affiliated to Harbin Institute of Technology with 64 publications followed by Cristian Biagioni affiliated to University of Pisa with 41 publications and Lizhen Wang affiliated to Yunnan University with 39 publications as shown in Table 42.

The highest CNCI among the top 20 researchers globally is achieved by Philip S. Yu affiliated to University of Illinois Chicago with a CNCI of 16.75. Richard Gloaguen affiliated to Helmholtz-Zentrum Dresden-Rossendorf (HZDR) has the highest Top 1% publications amounting to 2 publications.

The highest Top 10% publications were achieved by Philippe Fournier-Viger affiliated to Harbin Institute of Technology amounting to 20 publications who is also the researcher with the highest number of overall publications globally, as mentioned above.

Table 42: Top 20 researchers globally in terms of number of publications published in the research topic Space Architecture Mining in the period 2014-2023

Name	Affiliation	Web of Science Publications	CNCI	Documents in top 1%	Documents in top 10%	Country
Fournier-Viger, Philippe	Harbin Institute of Technology	64	1.63	1	20	Mainland China
Biagioni, Cristian	University of Pisa	41	0.31	0	0	Italy
Wang, Lizhen	Yunnan University	39	0.59	0	1	Mainland China
Bindi, Luca	University of Florence	39	0.34	0	0	Italy
Lin, Jerry Chun-Wei	Western Norway University of Applied Sciences	36	1.58	1	8	Norway
Jiang, Tao	Central South University	28	1.34	0	6	Mainland China
Downs, Robert T.	University of Arizona	28	0.19	0	0	United States
Plasil, Jakub	Czech Academy of Sciences	27	0.36	0	0	Czech Republic
Yu, Philip S.	University of Illinois Chicago	25	16.75	1	14	United States
Hong, Tzung-Pei	National University Kaohsiung	25	1.42	0	9	Taiwan
Tsang, Daniel C. W.	Hong Kong Polytechnic University	24	2.08	0	10	Hong Kong
Yun, Unil	Sejong University	24	1.45	0	6	South Korea
Gan, Wensheng	Jinan University	24	1.22	0	6	Mainland China
Yang, Hexiong	University of Arizona	24	0.19	0	0	United States
Liu, Qi	University of Alberta	23	0.66	0	1	Canada
Hilson, Gavin	University of Surrey	20	3.65	1	11	England
Gloaguen, Richard	Helmholtz-Zentrum Dresden-Rossendorf (HZDR)	20	1.79	2	4	Germany
Bac Le	Vietnam National University Hochiminh City	19	0.96	0	2	Vietnam
Hower, James C.	University of Kentucky	18	2.15	1	7	United States
Kohlenbach, Ulrich	Technical University of Darmstadt	18	1.65	0	7	Germany

4.1.14.9 Top 20 global funders globally in terms of number of publications

The top 3 organizations in terms of funded publications in this research topic are the National Natural Science Foundation of China (NSFC) with 5309 publications, followed by the National Science Foundation (NSF) with 953 publications, and Fundamental Research Funds for the Central Universities with 824 publications as shown in Figure 123.

The highest citation impact measured by the CNCI is observed in publications funded by the Australian Research Council, followed by the National Science Foundation (NSF) and the United States Department of Health & Human Services, with 3.53, 2.21 and 1.83, respectively.

Among the top 20 global funding organizations, nine are also among the top 20 funding organizations of Saudi publications in this research topic.

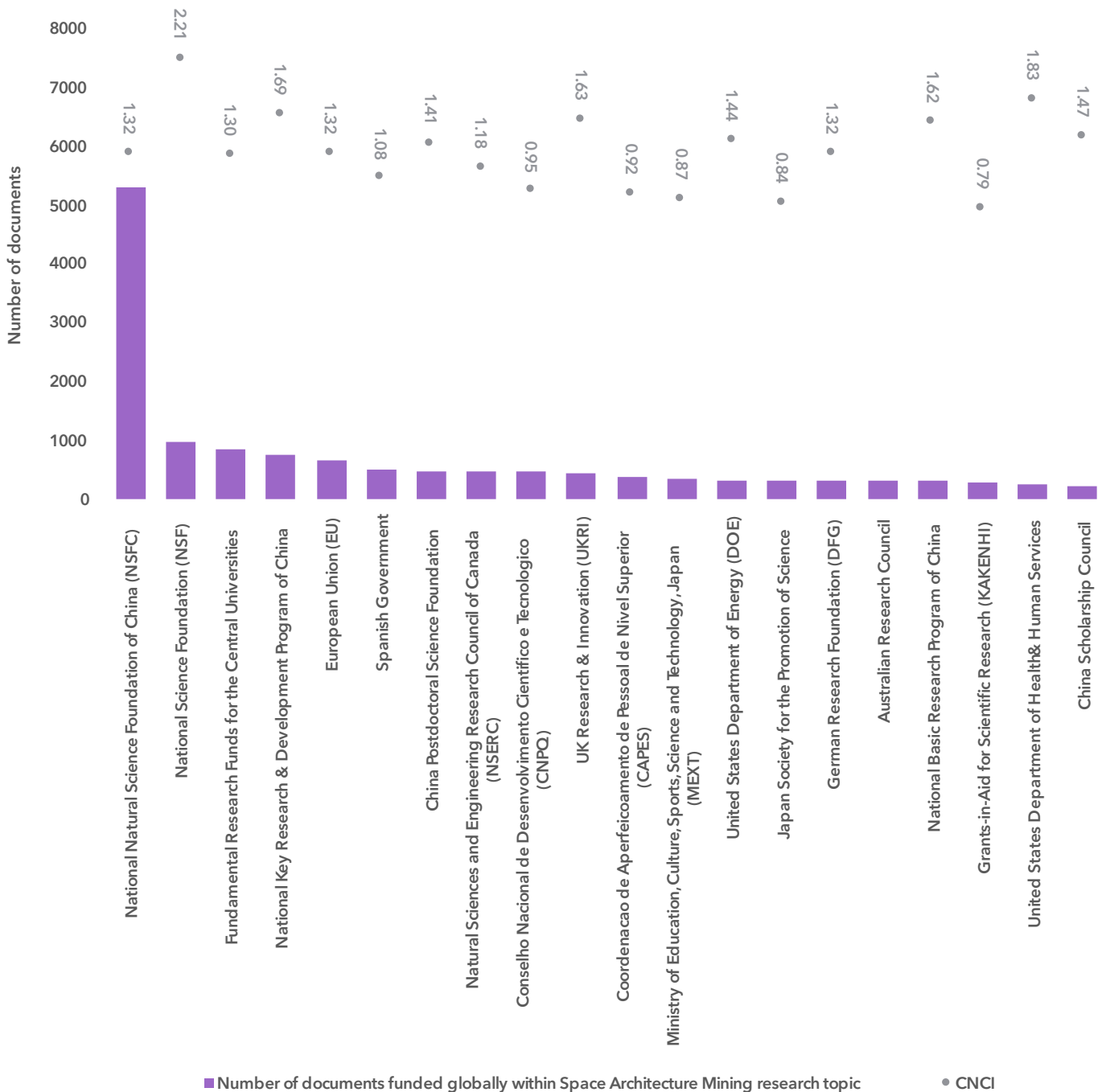


Figure 123: Top 20 funding organizations globally publications in the research topic Space Architecture Mining in terms of number of publications in the period 2014-2023

4.1.14.10 Emerging trends in the research topic globally and in Saudi Arabia

In this section we investigate the emerging trends globally and in Saudi Arabia in the research topic Space Architecture Mining. For more information on the methodology used to identify emerging trends, please see the definition section Emerging Trends.

The top 3 emerging micro-topics globally in this research topic are Communication: Fake News Detection followed by Anthropology: Artisanal Mining and Mineral & Metal Processing: Red Mud as shown in Figure 124.

Saudi Arabia has very few publications on this research topic, so it was not meaningful to identify emerging micro-topics. Table 43 shows the identified top 10 micro-topics in Saudi Arabia's research output on this topic.

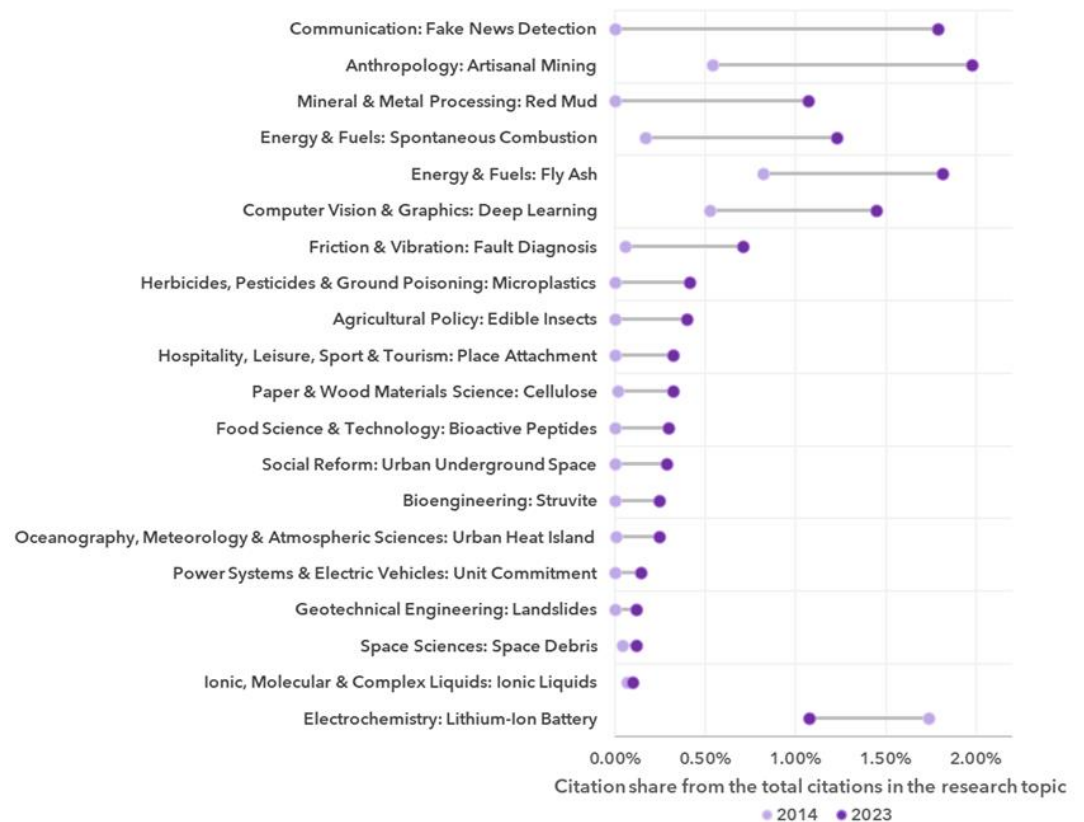


Figure 124: Top 20 emerging micro-topics globally in the research topic Space Architecture Mining in the period 2014-2023

Table 43: Top 10 Micro-topics identified in Saudi Arabia research output in the research topic Space Architecture Mining in the period 2014-2023

Topic	Number of Saudi Arabia publications in the period 2014-2023
Space Architecture Mining research topic	368
Artificial Intelligence & Machine Learning: Feature Selection	15
Artificial Intelligence & Machine Learning: Association Rules	14
Knowledge Engineering & Representation: Natural Language Processing	13
Supply Chain & Logistics: Particle Swarm Optimization	13
Phytochemicals: Antioxidant Activity	13
Artificial Intelligence & Machine Learning: Clustering	12
Dentistry & Oral Medicine: Dental Implants	10
Geochemistry, Geophysics & Geology: Geochemistry	9
Dentistry & Oral Medicine: Endodontics	8
Knowledge Engineering & Representation: Complex Networks	7

4.1.15 AI in ICT

4.1.15.1 Evolution of Saudi publication share of global publications in the research topic

The share of Saudi Arabia publications from global publications in the research topic had a small growth from 2014 till 2018 followed by a vigorous growth from 2019 till 2023 as shown in Figure 125.

This shows that Saudi Arabia was not only able to increase the number of publications on this research topic but also had a growth higher than the global growth rate. This is evident as the share of Saudi Arabian publications on the research topic is growing.

The CNCI of Saudi Arabia publications in this research topic were in all years higher than 1 and had a stable evolution ranging from 1.50 to 1.89, indicating a citation impact performance higher than the global average. We are observing that the CNCI value was steady during the high growth in share of publication.

This means that the new publications contributed to the impact value consolidation as measured by CNCI rather than diluting it as is expected in similar scenarios.

Overall, Saudi Arabia publications increased with a higher growth rate than the global average in this research topic and had a relatively good citation impact as measured by the CNCI.

Nevertheless, after this high growth rate in terms of publications, one should focus on increasing/preserving the relatively good citation impact.

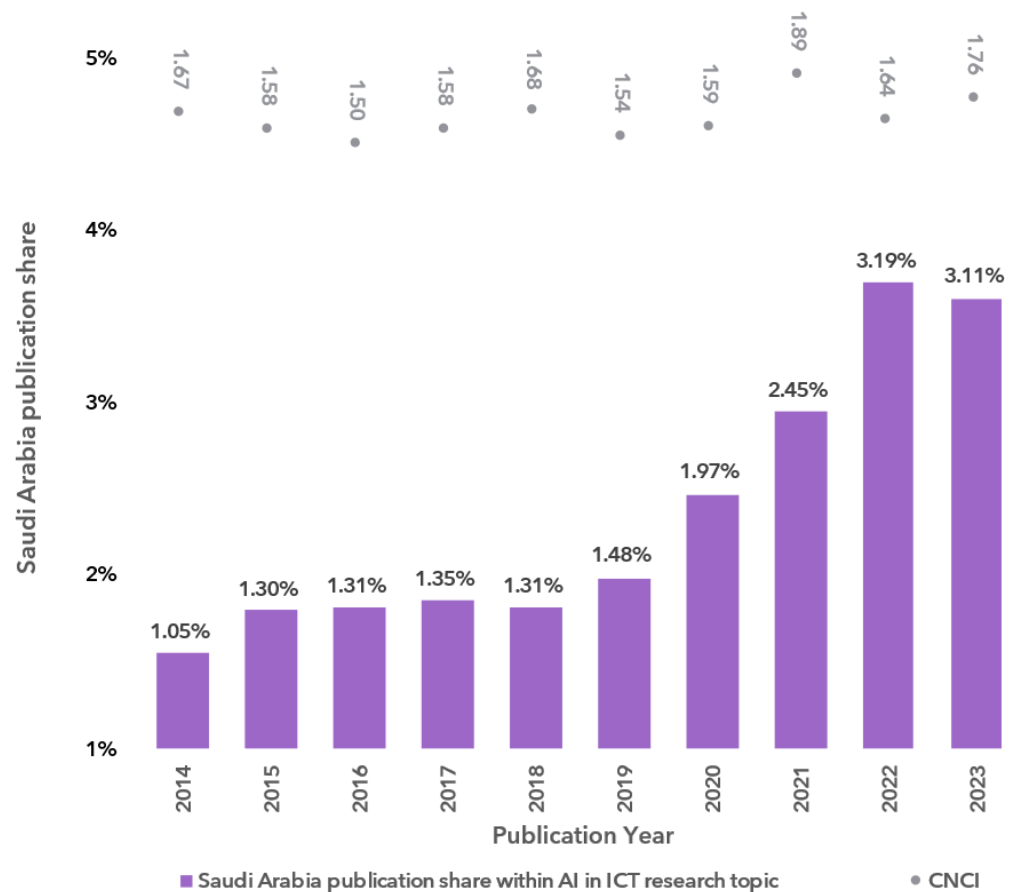


Figure 125: The share of Saudi Arabia from global publications in the research topic and the CNCI of Saudi Arabia publications in the research topic AI in ICT in the period 2014-2023

4.1.15.2 Top 10 countries collaborating with Saudi Arabia

The top collaborating country with Saudi Arabia in this research topic in the period 2014-2023 are Pakistan followed by India and Mainland China with 3711, 3519 and 3182 publications respectively as shown in Figure 126.

In terms of citation impact measured by the CNCI publications published in collaboration with Australia, the United States and Mainland China had the highest CNCI with 2.84, 2.63 and 2.55, respectively.

Nevertheless, all publications with the top 10 collaborating countries had a CNCI higher than 1, ranging from 1.79 to 2.84, reflecting a performance higher than the global average.

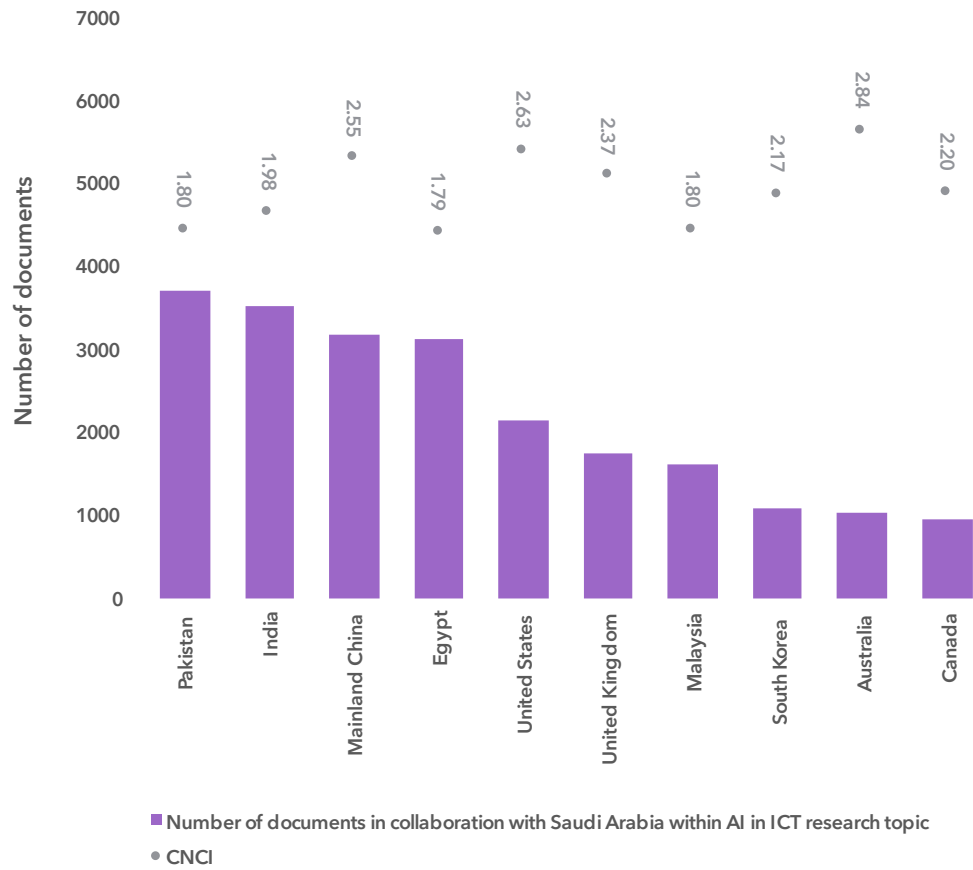


Figure 126: Top 10 collaborating countries with Saudi Arabia in terms of the number of publications in the research topic AI in ICT in the period 2014-2023

4.1.15.3 Top 20 funders of Saudi publications by number of publications

The top 3 funding organizations of Saudi Arabia publications in this research topic in terms of number of publications mentioning the organization in the funding text in the period 2014-2023 are King Saud University followed by National Natural Science Foundation of China (NSFC) and Princess Nourah bint Abdulrahman University with 1674, 1318 and 1073 publications respectively as shown in Figure 127.

Documents funded by the National Institutes of Health (NIH) - USA, followed by United States Department of Health & Human Services and National Science Foundation (NSF) had the highest citation impact measured by the CNCI with 8.10, 7.96 and 5.57, respectively.

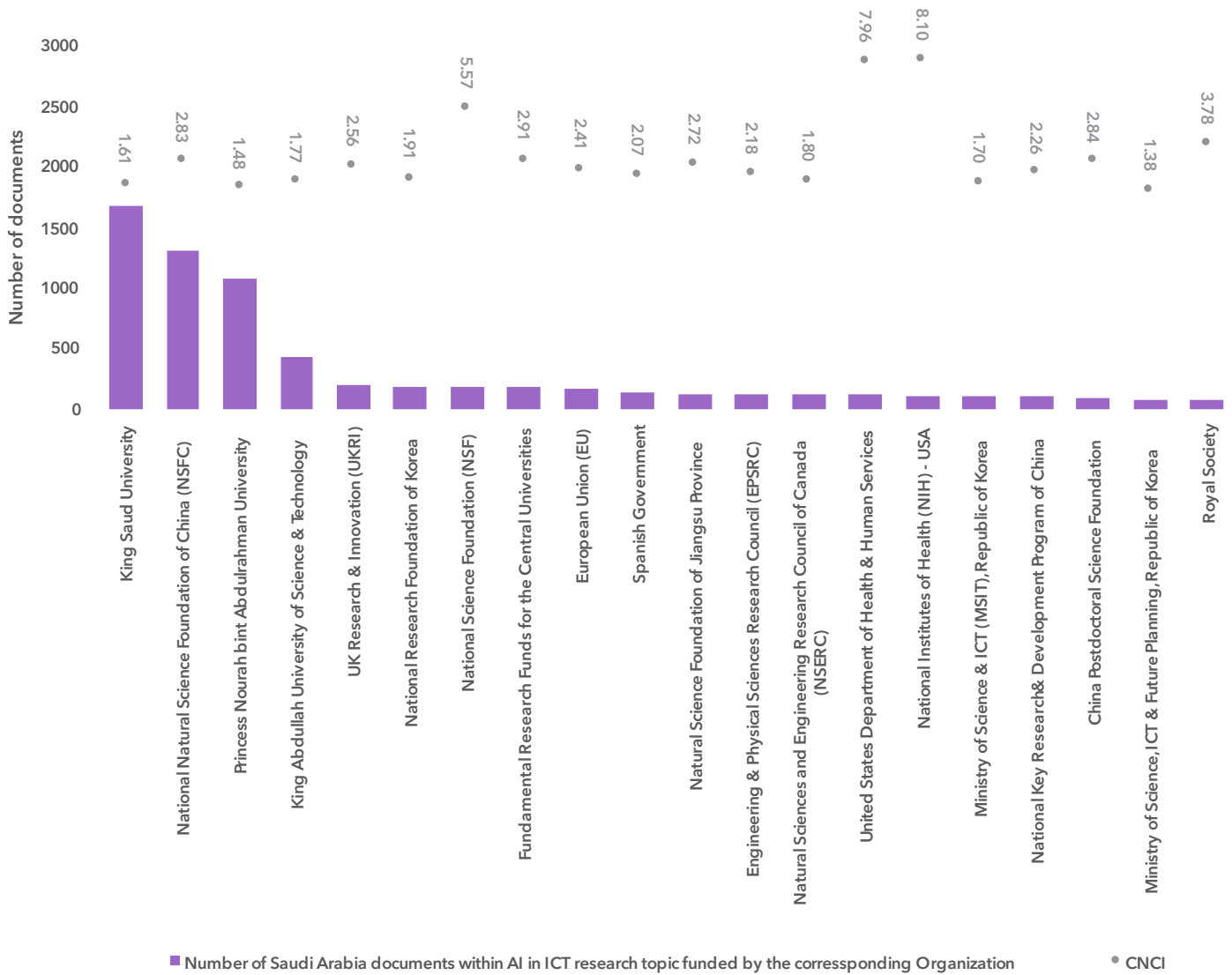


Figure 127: Top 20 funding organizations of Saudi Arabia publications in the research topic AI in ICT in terms of number of publications in the period 2014-2023

4.1.15.4 Top 20 Saudi Arabia organizations in terms of number of publications

The top 3 organizations in terms of publications published in this research topic and in the period 2014-2023 are King Abdulaziz University, followed by King Saud University and Prince Sattam Bin Abdulaziz University, with 3799, 3367 and 1982 publications, respectively, as shown in Figure 128.

In terms of citation impact as measured by the CNCI, King Abdulaziz University, followed by Prince Sultan University and King Faisal University, had the highest CNCI with 2.32, 2.02 and 1.92, respectively.

Nevertheless, all top 20 organizations had a CNCI higher than 1, ranging from 1.18 to 2.32, reflecting a citation impact performance higher than the global average.

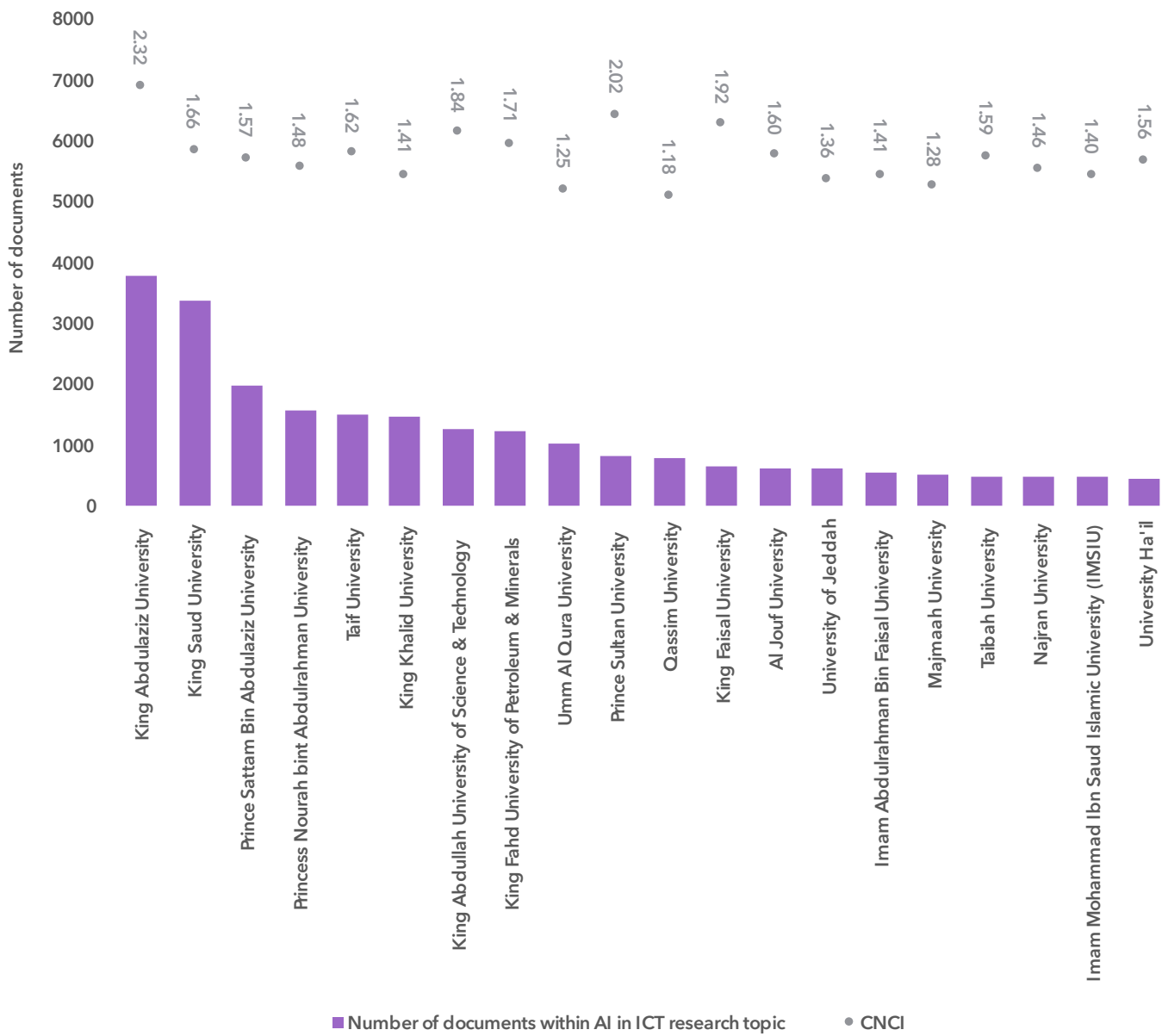


Figure 128: Top 20 Saudi organizations in terms of publications published on the research topic AI in ICT in the period 2014-2023 and their corresponding CNCI

4.1.15.5 Top 20 researchers affiliated with Saudi organizations in terms of number of publications

The highest number of publications are published by M. Shamim Hossain affiliated to King Saud University followed by Fuad E. Alsaadi affiliated to King Abdulaziz University and Tanzila Saba affiliated to Prince Sultan University with 153, 152 and 148 publications respectively as shown in Table 44.

The highest CNCI is achieved by publications published by Ghulam Muhammad affiliated to King Saud University with a CNCI of 3.38. The latter researcher has also the highest number of Top 10% amounting to 74 publications while the highest number of Top 1% publications was achieved by Tanzila Saba affiliated to Prince Sultan University amounting to 10 publications.

Table 44: Top 20 researchers affiliated with Saudi organizations in terms of the number of publications published on the research topic AI in ICT in the period 2014-2023

Name	Affiliation	Web of Science Publications	CNCI	Documents in the top 1%	Documents in the top 10%
Hossain, M. Shamim	King Saud University	153	3.23	15	72
Alsaadi, Fuad E.	King Abdulaziz University	152	2.53	5	58
Saba, Tanzila	Prince Sultan University	148	2.71	17	68
Hassan, Mohammad Mehedi	King Saud University	146	2.31	8	54
Muhammad, Ghulam	King Saud University	135	3.38	12	74
Tariq, Usman	Prince Sattam Bin Abdulaziz University	120	2.43	7	43
Elkatatny, Salaheldin	King Fahd University of Petroleum & Minerals	117	0.98	1	9
Gao, Xin	King Abdullah University of Science & Technology	108	2.28	5	45
Hamza, Manar Ahmed	Prince Sattam Bin Abdulaziz University	107	0.73	0	6
Hilal, Anwer Mustafa	Prince Sattam Bin Abdulaziz University	106	0.80	1	7
Masud, Mehedi	Taif University	104	2.00	4	34
Alsaedi, Ahmed	King Abdulaziz University	103	2.41	6	44
Motwakel, Abdelwahed	Prince Sattam Bin Abdulaziz University	97	0.71	0	4
Al Duhayyim, Mesfer	Prince Sattam Bin Abdulaziz University	97	0.69	0	4
Al-Wesabi, Fahd N.	King Khalid University	93	1.07	2	8
Rezk, Hegazy	Prince Sattam Bin Abdulaziz University	88	1.85	4	29
Ooi, Boon S.	King Abdullah University of Science & Technology	87	1.60	3	22
Abdulraheem, Abdulazeez	King Fahd University of Petroleum & Minerals	83	1.21	0	11
Rehman, Amjad	Prince Sultan University	81	2.59	6	33
Irfan, Muhammad	Najran University	76	1.63	3	14

4.1.15.6 Top 10 countries in terms of publications

The highest number of publications published on this research topic are published by Mainland China (325,460 publications), followed by the United States (180,678 publications) and India (71,528 publications), as shown in Figure 129.

The highest citation impact measured by the CNCI is achieved by publications published in Australia, United Kingdom, and United States with a CNCI of 2.08, 1.97 and 1.89, respectively.

Seven of the top 10 countries in terms of number of publications published in the research topic are also among the top 10 collaborators with Saudi Arabia. These are Australia, United Kingdom, United States, Canada, Mainland China, South Korea, and India.

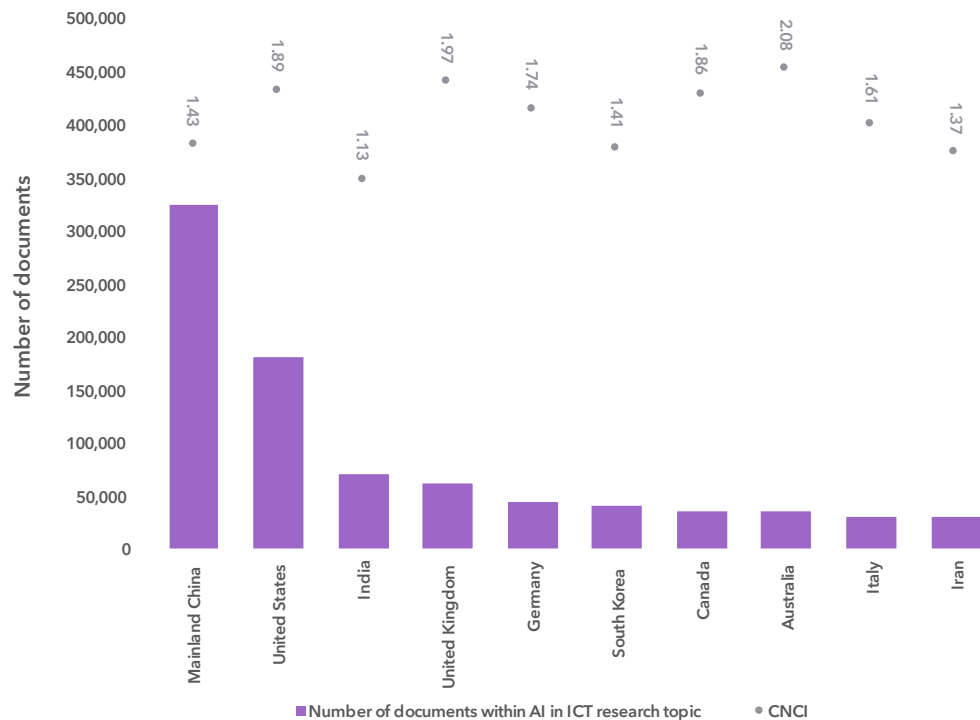


Figure 129: Top 10 countries in terms of the number of publications on the research topic AI in ICT in the period 2014-2023 and their corresponding CNCI

4.1.15.7 Top 20 organizations globally in terms of number of publications

The top 3 organizations in terms of the number of publications published on this research topic in the period 2014-2023 are the Chinese Academy of Sciences (30192 publications) followed by the University of Chinese Academy of Sciences, CAS (11931 publications) and the Centre National de la Recherche Scientifique (CNRS) (11869 publications) respectively as shown in Figure 130.

In terms of citation impact measured by the CNCI, Stanford University followed by Harvard University and Swiss Federal Institutes of Technology Domain had the highest CNCI with 3.14, 2.63 and 2.36, respectively.

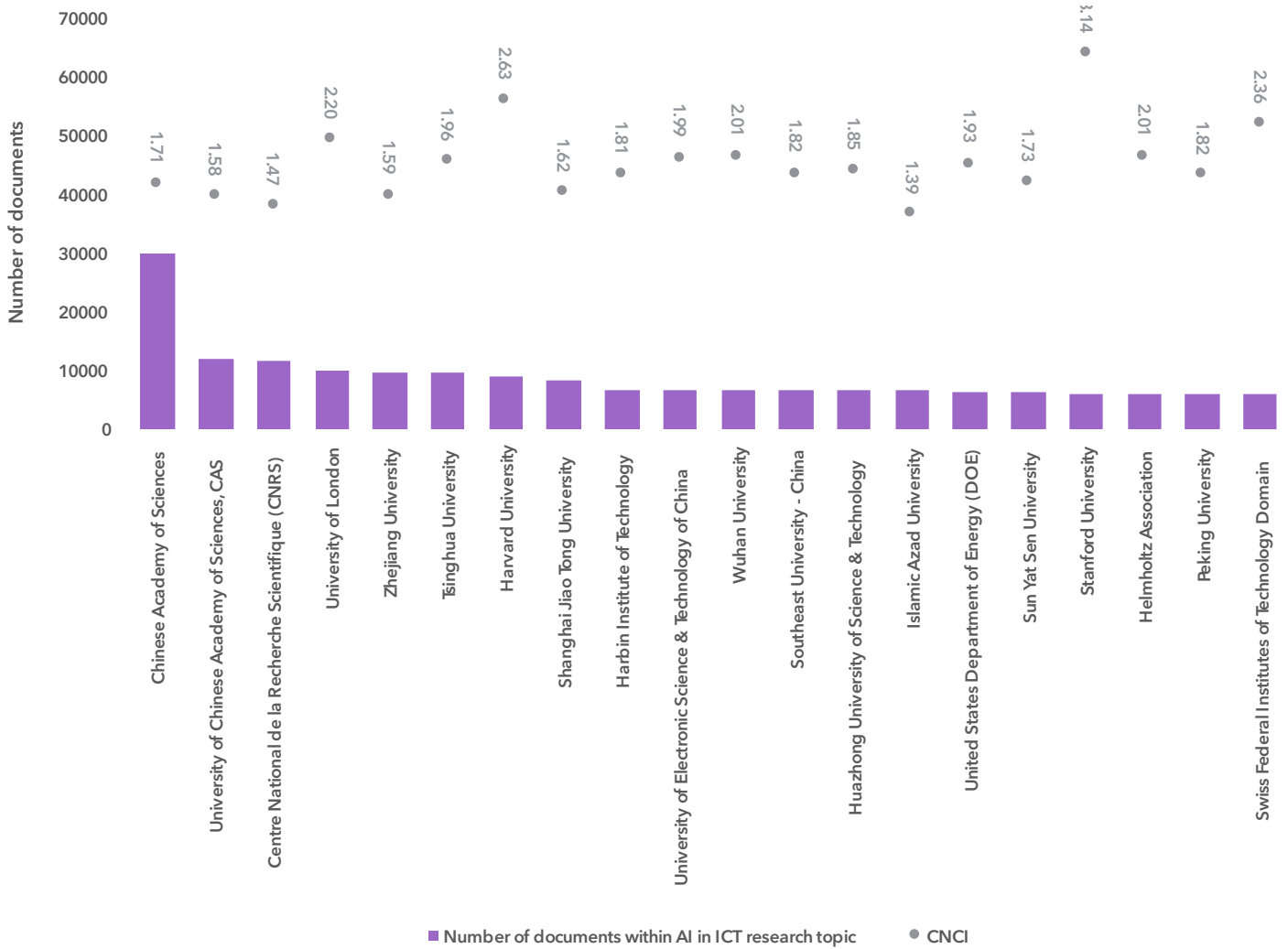


Figure 130: Top 20 organizations globally in terms of the number of publications published in the research topic AI in ICT in the period 2014-2023 and their corresponding CNCI

4.1.15.8 Top 20 researchers globally in terms of number of publications

The top 3 researchers globally in terms of the number of publications in this research topic are Jinde Cao, affiliated with Southeast University - China, with 773 publications, followed by Yue Hao, affiliated with Xidian University, with 527 publications, and Licheng Jiao, affiliated with Xidian University, with 452 publications as shown in Table 45.

The highest CNCI among the top 20 researchers globally is achieved by Huiling Chen affiliated to Wenzhou University with a CNCI of 5.84.

Jinde Cao, affiliated with Southeast University, the researcher with the highest number of overall publications, also achieved the highest numbers of publications in the Top 1%, amounting to 57 publications and in the Top 10%, amounting to 331 publications.

Table 45: Top 20 researchers globally in terms of the number of publications published on the research topic AI in ICT in the period 2014-2023

Name	Affiliation	Web of Science Publications	CNCI	Documents in the top 1%	Documents in the top 10%	Country
Cao, Jinde	Southeast University - China	773	2.67	57	331	Mainland China
Hao, Yue	Xidian University	527	0.84	4	38	Mainland China
Jiao, Licheng	Xidian University	452	1.96	17	141	Mainland China
Huang, Tingwen	Qatar Foundation (QF)	415	2.50	20	164	Qatar
Pedrycz, Witold	University of Alberta	384	1.72	10	79	Canada
Park, Ju H.	Yeungnam University	314	3.27	31	177	South Korea
Zeng, Zhigang	Huazhong University of Science & Technology	278	2.28	8	108	Mainland China
Pradhan, Biswajeet	University of Technology Sydney	276	2.87	24	131	Australia
Zhang, Huaguang	Northeastern University - China	275	2.11	8	85	Mainland China
Raja, Muhammad Asif Zahoor	National Yunlin University Science & Technology	273	2.62	16	111	Taiwan
Zhong, Shouming	University of Electronic Science & Technology of China	269	2.27	17	80	Mainland China
Tong, Shaocheng	Liaoning University of Technology	249	5.03	56	141	Mainland China
Chen, C. L. Philip	South China University of Technology	246	2.65	17	102	Mainland China
Li, Xuelong	Northwestern Polytechnical University	242	2.28	14	85	Mainland China
Chen, Huiling	Wenzhou University	239	5.84	46	131	Mainland China
Zhang, Liangpei	Wuhan University	235	5.09	51	144	Mainland China
Shi, Peng	University of Adelaide	235	3.43	24	138	Australia
He, Yong	Zhejiang University	233	1.93	8	71	Mainland China
Wang, Fei-Yue	Chinese Academy of Sciences	222	3.63	24	96	Mainland China
Han, Zhu	University of Houston	218	3.05	22	78	United States

4.1.15.9 Top 20 global funders globally in terms of number of publications

The top 3 organizations in terms of funded publications in this research topic are the National Natural Science Foundation of China (NSFC) with 191334 publications, followed by the National Science Foundation (NSF) with 30464 publications, and the United States Department of Health & Human Services with 29186 publications, as shown in Figure 131.

The highest citation impact measured by the CNCI is observed in publications funded by United States Department of Defense followed by United States Department of Energy (DOE) and National Science Foundation (NSF) with 2.36, 2.14 and 2.10, respectively.

Among the top 20 global funding organizations, 13 are also among the top 20 funding organizations of Saudi publications in this research topic.

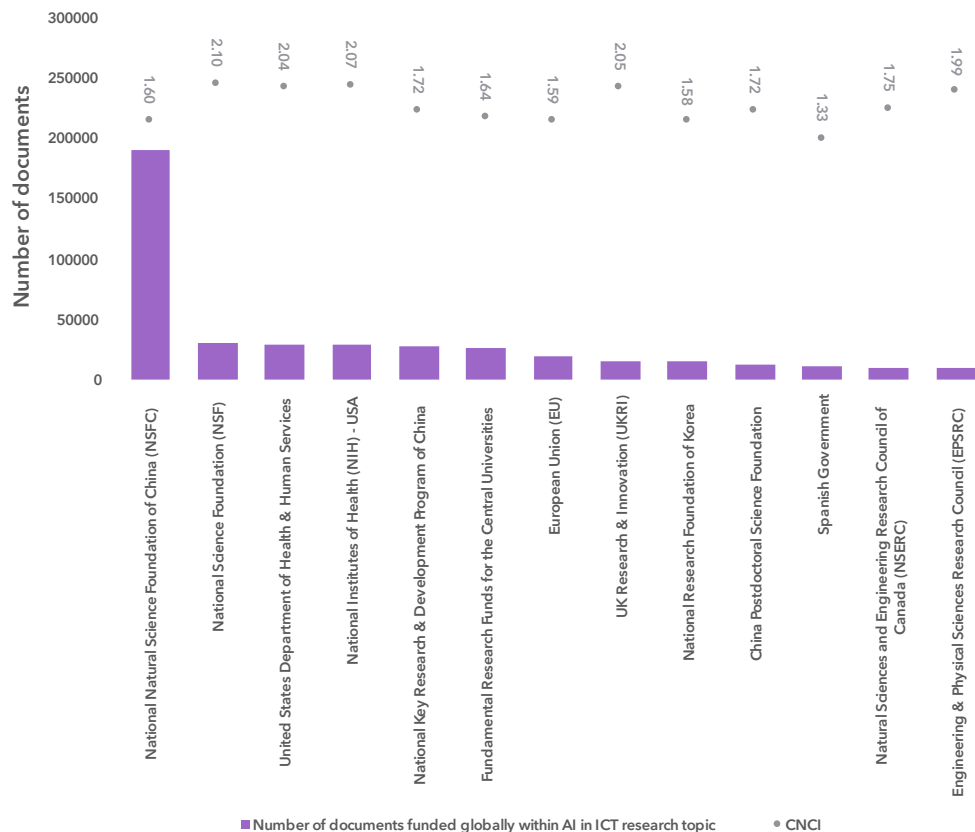


Figure 131: Top 20 funding organizations globally publications in the research topic AI in ICT in terms of number of publications in the period 2014-2023

4.1.15.10 Emerging trends in the research topic globally and in Saudi Arabia

In this section, we investigate the emerging trends globally and in Saudi Arabia in the research topic of AI in ICT. For more information on the methodology used to identify emerging trends, please see the definition section Emerging Trends.

The top 3 Global emerging micro-topics in this research topic are Modelling & Simulation: Model Order Reduction followed by Security Systems: Blockchain and Telecommunications: Unmanned Aerial Vehicles as shown in Figure 132. The top 3 emerging micro-topics in Saudi Arabia in this research topic are Concrete Science: Compressive Strength followed by Thermodynamics: Nanofluid and Telecommunications: Internet of Things as shown in Figure 133.

Saudi Arabia has publications in the following identified global emerging topics; Security Systems: Blockchain, Communication: Fake News Detection, Telecommunications: Unmanned Aerial Vehicles and Human Computer Interaction: Artificial Intelligence.



Figure 132: Top 20 emerging micro-topics globally in the research topic AI in ICT in the period 2014-2023

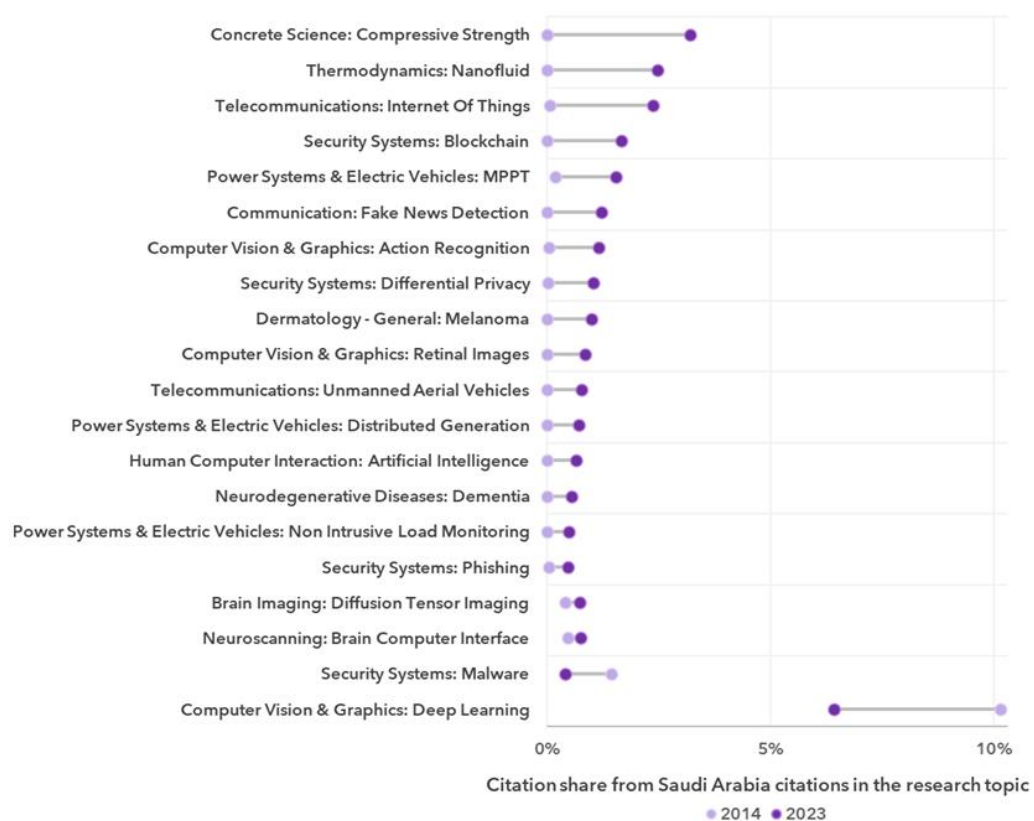


Figure 133: Top 20 Micro-topics identified in Saudi Arabia research output in the research topic AI in ICT in the period 2014-2023

4.1.16 Quantum Computing

4.1.16.1 Evolution of Saudi publication share of global publications in the research topic

The share of Saudi Arabia publications among global publications in the research topic had a positive dynamic trend from 2014 to 2023, as shown in Figure 134. The first half of the observed period had fluctuations from 2014 to 2019, followed by a major growth from 2020 to 2023, reaching a peak of 1.81% share of global publications in the research topic in 2023.

This shows that Saudi Arabia was not only able to increase the number of publications in this research topic but also having a growth higher than the global growth rate. This is evident as the share of Saudi Arabia publications in the research topic is growing. The CNCI of Saudi Arabia publications in this research topic was higher than 1 only in the three years out the ten of the observed periods.

The highest values of the CNCI are achieved in the 2022 and 2023 with 1.47 and 1.35, respectively. Worth mentioning that the highest values in impact are achieved in the years with the highest share of Saudi Arabia publications of global publications in the research topic.

This means the newer papers had a positive contribution to the impact as measured by CNCI, rather than diluting it as is expected in periods with high growth in publications.

Overall, Saudi Arabia publications increased with a higher growth rate than the global average in this research topic and had a relatively good citation impact as measured by the CNCI.

Nevertheless, after this high growth rate in terms of publications, one should focus on increasing/preserving the relatively good citation impact and publication pace.

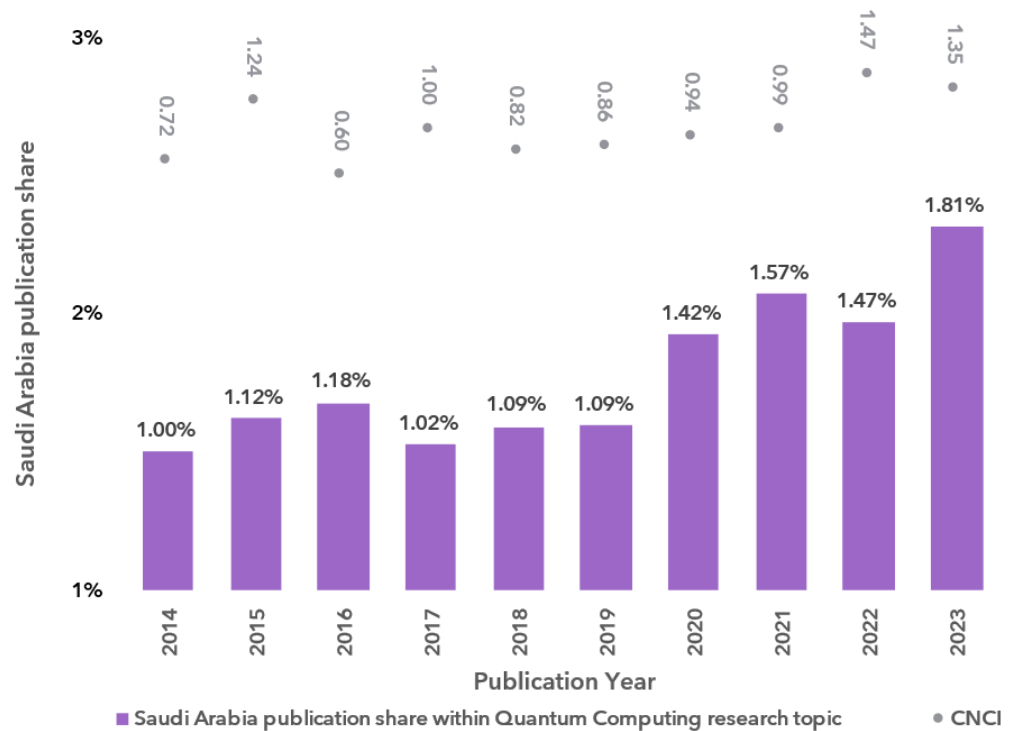


Figure 134: The share of Saudi Arabia from global publications in the research topic and the CNCI of Saudi Arabia publications in the research topic Quantum Computing in the period 2014-2023

4.1.16.2 Top 10 countries collaborating with Saudi Arabia

The top collaborating countries with Saudi Arabia in this research topic in the period 2014-2023 are Egypt, followed by Mainland China and India, with 239,104 and 94 publications, respectively, as shown in Figure 135.

In terms of citation impact measured by the CNCI publications published in collaboration with Canada followed by United Kingdom and Mainland China had the highest CNCI with 2.43, 2.40 and 2.04, respectively.

Except for Egypt, UAE and Italy, the rest of the publications with the top 10 collaborating countries had a CNCI higher than 1, reflecting a performance higher than the global average.

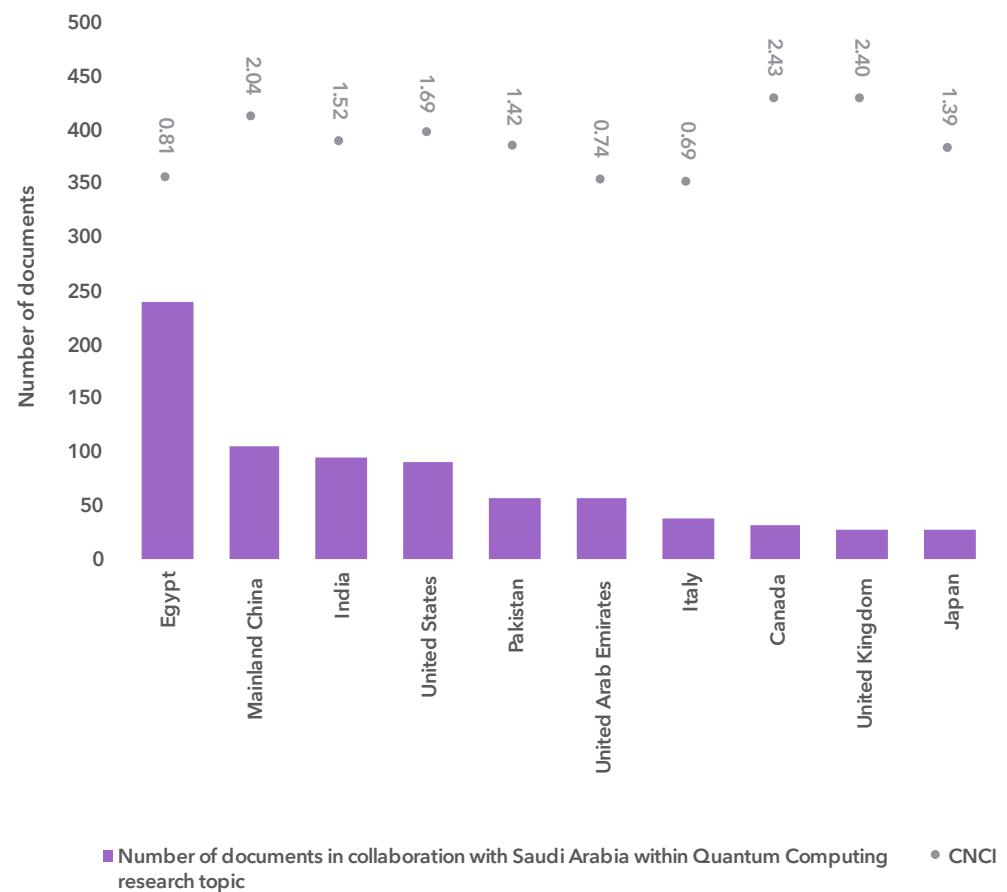


Figure 135: Top 10 collaborating countries with Saudi Arabia in terms of the number of publications in the research topic Quantum Computing in the period 2014-2023

4.1.16.3 Top 20 funders of Saudi publications by number of publications

The top 3 funding organizations of Saudi Arabia publications in this research topic in terms of number of publications mentioning the organization in the funding text in the period 2014-2023 are National Natural Science Foundation of China (NSFC) followed by Princess Nourah bint Abdulrahman University and King Saud University with 43, 37 and 35 publications respectively as shown in Figure 136.

Documents funded by NSF - Directorate for Mathematical & Physical Sciences (MPS) followed by the National Science Foundation (NSF) and the United States Department of Defense with the same CNCI followed by Menoufia University had the highest citation impact measured by the CNCI with 9.94, 6.25 and 5.59, respectively.

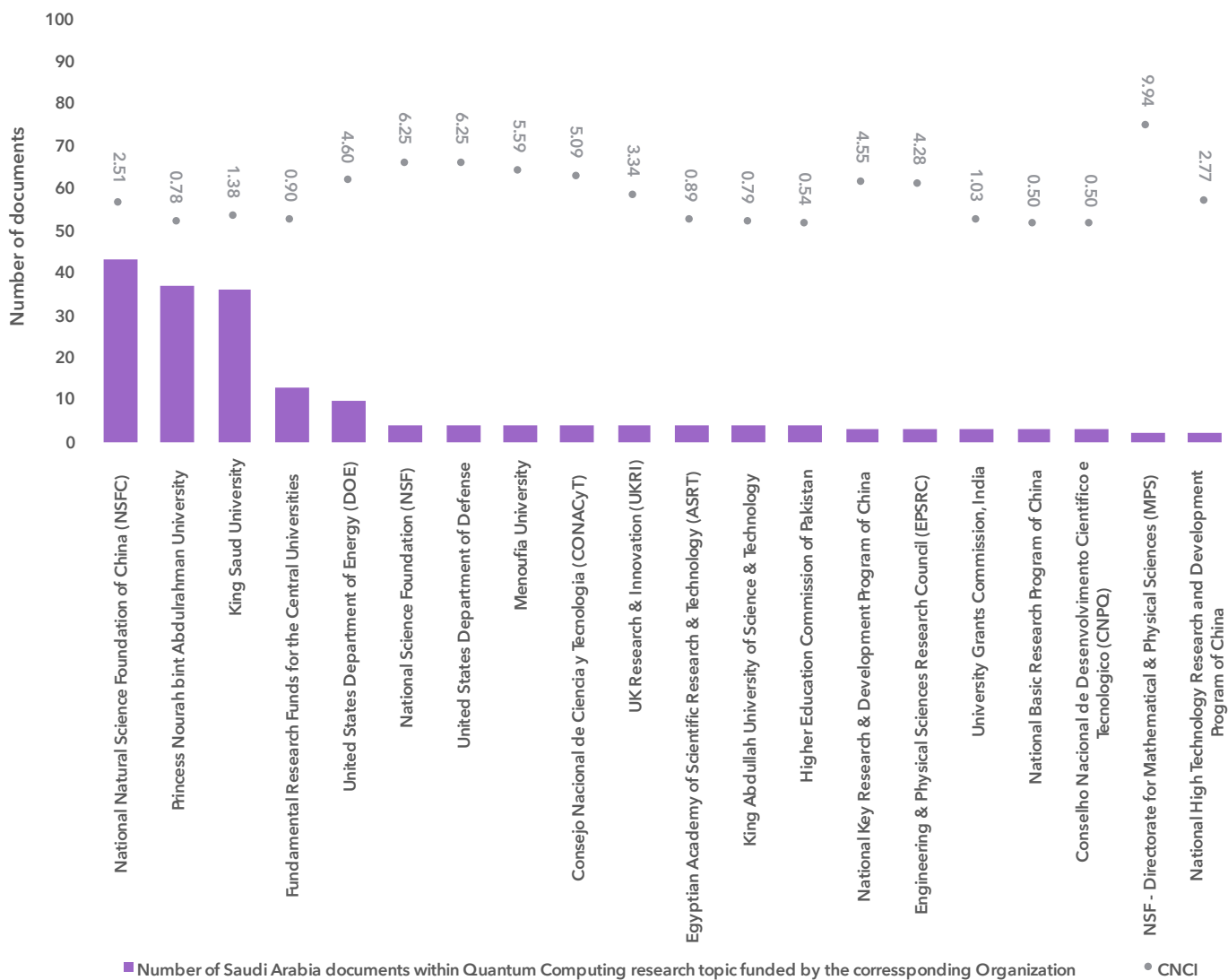


Figure 136: Top 20 funding organizations of Saudi Arabia publications in the research topic Quantum Computing in terms of number of publications in the period 2014-2023

4.1.16.4 Top 20 Saudi Arabia organizations in terms of number of publications

The top 3 organizations in terms of publications published in this research topic and in the period 2014-2023 are Prince Sattam Bin Abdulaziz University followed by Taif University and King Abdulaziz University with 135, 105 and 97 publications respectively as shown in Figure 137.

In terms of citation impact as measured by the CNCI, Prince Sultan University, followed by King Abdulaziz University and the University of Jeddah, had the highest CNCI with 2.03, 1.59 and 1.50, respectively. Nevertheless, all top 20 organizations had a CNCI higher than 1, reflecting a citation impact performance higher than the global average.

Saudi Arabia has publications on the following identified global emerging topics: Hyperpolarizability.

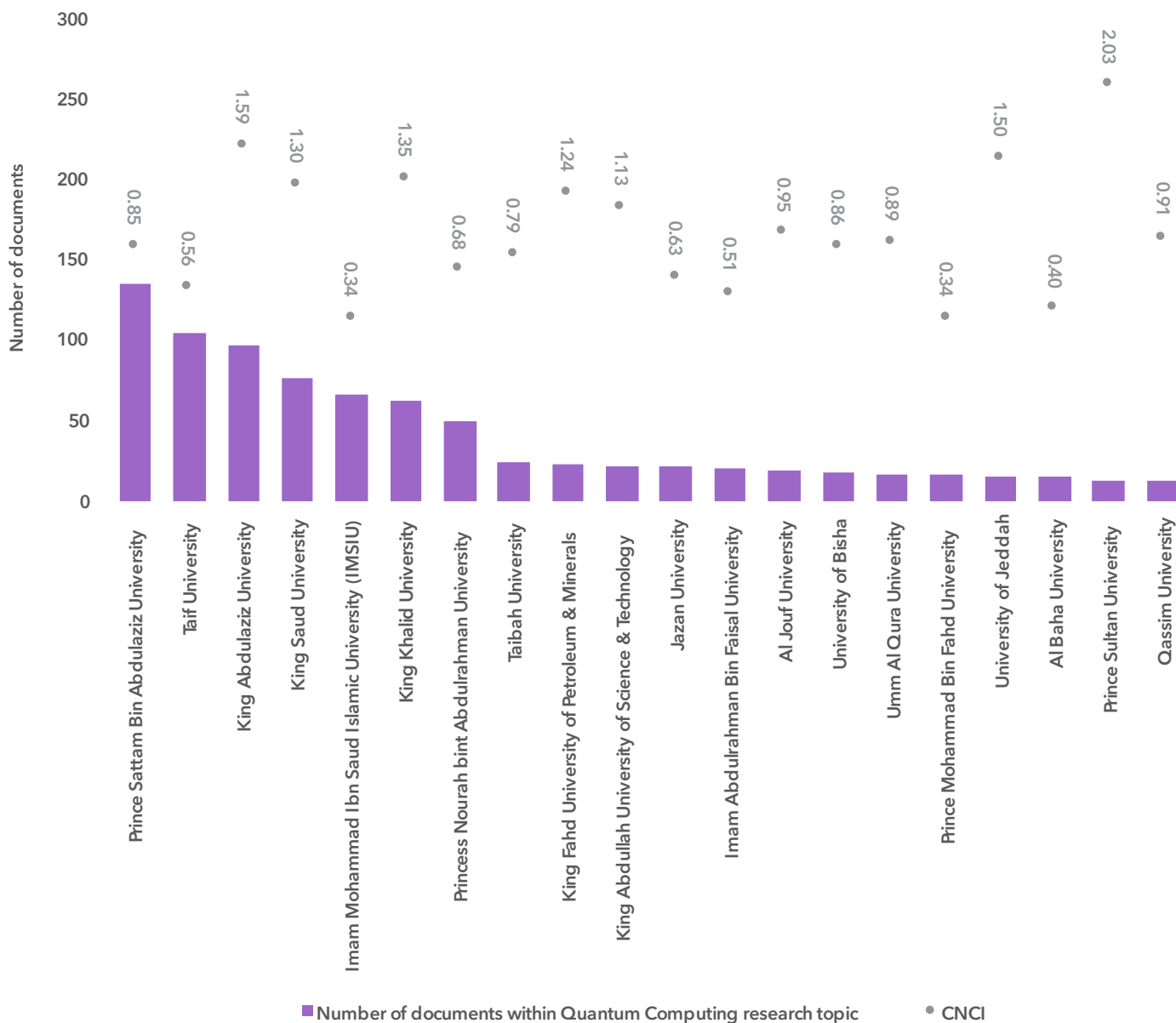


Figure 137: Top 20 Saudi organizations in terms of publications published in the research topic Quantum Computing in the period 2014-2023 and their corresponding CNCI

4.1.16.5 Top 20 researchers affiliated with Saudi organizations in terms of number of publications.

The highest number of publications is published by S. Abdel-Khalek, affiliated with Taif University, followed by K. Berrada, affiliated with Imam Mohammad Ibn Saud Islamic University (IMSIU), and Abdullah M. Ilyasu, affiliated with Prince Sattam Bin Abdulaziz University, with 55, 46 and 33 publications respectively as shown in Table 46. The highest CNCI is achieved by publications published by Ahmad Irfan, affiliated with King Khalid University, with a CNCI of 2.07.

The latter researcher also has the highest number of Top 1%, amounting to 2 publications, while the highest number of Top 10% publications was achieved by Abdullah M. Ilyasu, affiliated with Prince Sattam Bin Abdulaziz University.

Table 46: Top 20 researchers affiliated with Saudi organizations in terms of the number of publications published on the research topic Quantum Computing in the period 2014-2023

Name	Affiliation	Web of Science Publications	CNCI	Documents in the top 1%	Documents in the top 10%
Abdel-Khalek, S.	Taif University	55	0.34	0	1
Berrada, K.	Imam Mohammad Ibn Saud Islamic University (IMSIU)	46	0.19	0	0
Ilyyasu, Abdullah M.	Prince Sattam Bin Abdulaziz University	33	1.16	0	6
Mohamed, A. -B. A.	Prince Sattam Bin Abdulaziz University	33	0.33	0	0
Khalil, E. M.	Taif University	32	0.47	0	1
Mohamed, A-B A.	Prince Sattam Bin Abdulaziz University	29	0.62	0	1
Muhammad, Shabbir	King Khalid University	18	1.52	0	5
Irfan, Ahmad	King Khalid University	15	2.07	2	5
Nagy, Naya	Imam Abdulrahman Bin Faisal University	14	0.16	0	0
Al-Sehemi, Abdullah G.	King Khalid University	13	1.27	0	3
Nagy, Marius	Prince Mohammad Bin Fahd University	13	0.14	0	0
Abdel-Khalek, Sayed	Taif University	11	0.74	0	1
Berrada, Kamal	Imam Mohammad Ibn Saud Islamic University (IMSIU)	11	0.68	0	1
Hobiny, Aatef	King Abdulaziz University	8	1.06	0	1
Abdalla, S.	King Abdulaziz University	8	0.86	0	1
Aldosari, F. M.	Prince Sattam Bin Abdulaziz University	8	0.64	0	0
Gharibi, Wajeb	Jazan University	8	0.33	0	0
Alsaedi, Ahmed	King Abdulaziz University	7	0.63	0	0
Khalil, Eied M.	Taif University	7	0.57	0	0
Zidan, Nour	Al Jouf University	6	1.27	0	2

4.1.16.6 Top 10 countries in terms of publications

The highest number of publications published on this research topic is published by the United States (12,866 publications), followed by Mainland China (12,702 publications) and Germany (4,746 publications), as shown in Figure 138.

The highest citation impact measured by the CNCI is achieved by publications published in the United States, United Kingdom, and Canada with a CNCI of 2.17, 2.09 and 2.08, respectively.

Seven of the top 10 countries in terms of number of publications published in the research topic are also among the top 10 collaborators with Saudi Arabia. These are the United States, United Kingdom, Canada, Japan, Italy, Mainland China, and India.

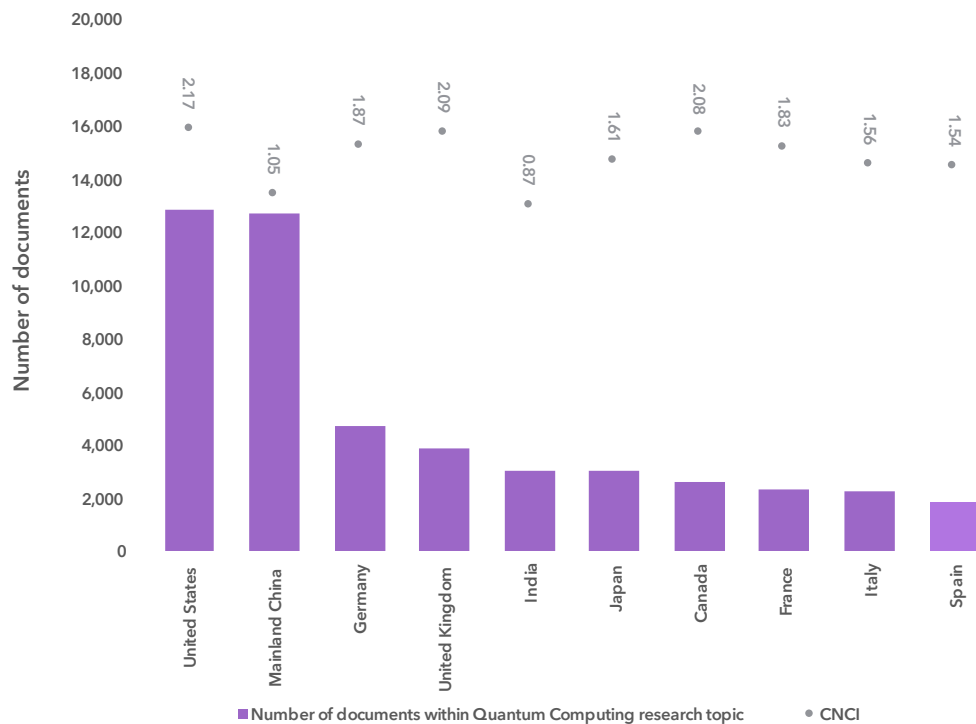


Figure 138: Top 10 countries in terms of the number of publications in the research topic Quantum Computing in the period 2014-2023 and their corresponding CNCI

4.1.16.7 Top 20 organizations globally in terms of number of publications

The top 3 organizations in terms of the number of publications published in this research topic in the period 2014-2023 are the Chinese Academy of Sciences (2684 publications) followed by the United States Department of Energy (DOE) (1731 publications) and Centre National de la Recherche Scientifique (CNRS) (1628 publications) respectively as shown in Figure 139.

In terms of citation impact measured by the CNCI, Massachusetts Institute of Technology (MIT), followed by the Delft University of Technology and Swiss Federal Institutes of Technology Domain, had the highest CNCI with 3.57, 3.33 and 3.06, respectively.

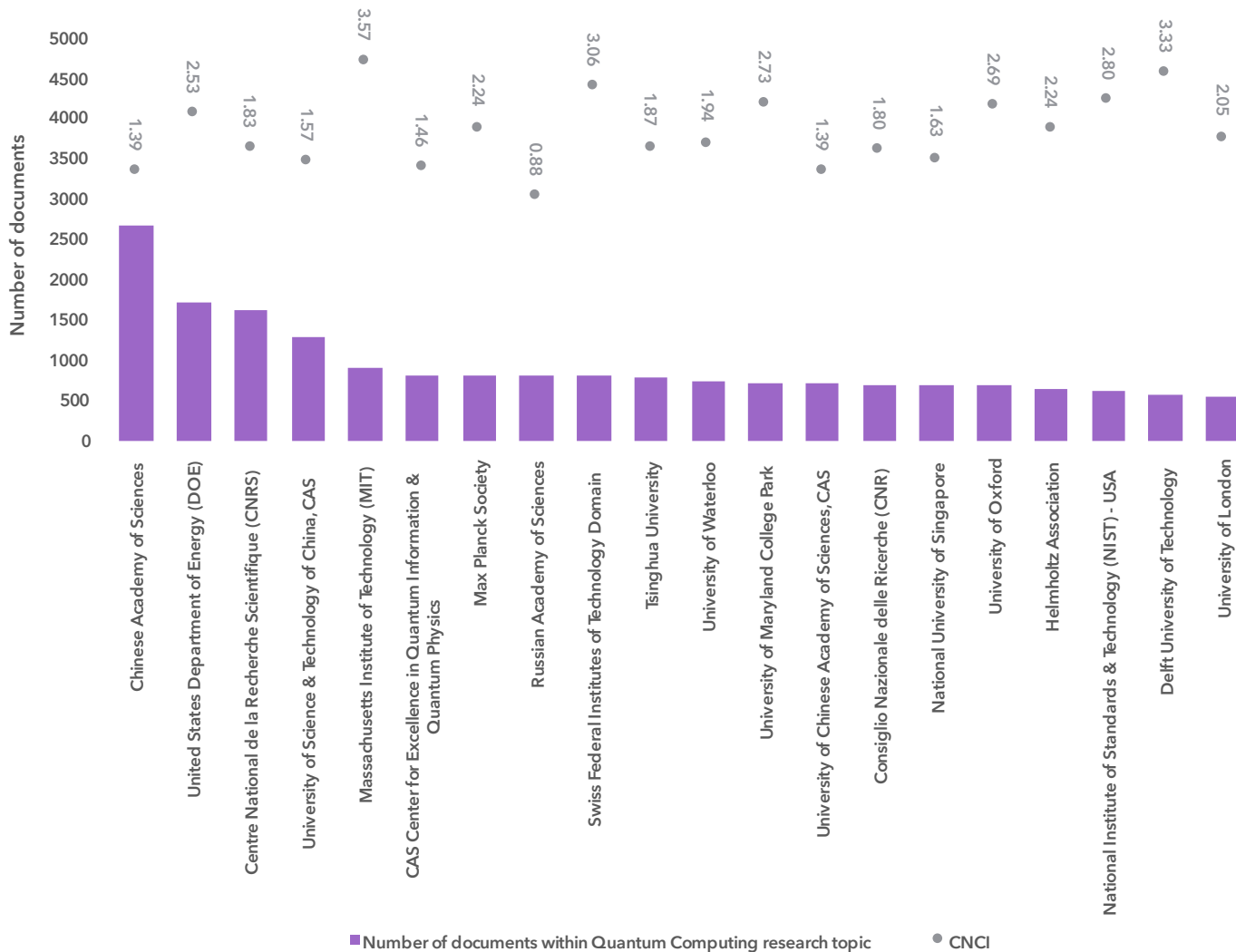


Figure 139: Top 20 organizations globally in terms of the number of publications published in the research topic Quantum Computing in the period 2014-2023 and their corresponding CNCI

4.1.16.8 Top 20 researchers globally in terms of number of publications

The top 3 researchers globally in terms of the number of publications on this research topic are Guang-Can Guo, affiliated with the University of Science & Technology of China, CAS, with 259 publications, followed by Chuan-Feng Li, affiliated to the University of Science & Technology of China, CAS with 170 publications and Franco Nori affiliated to University of Michigan with 149 publications as shown in Table 47.

The highest CNCI among the top 20 researchers globally is achieved by Jian-Wei Pan, affiliated with the University of Science & Technology of China, CAS, with a CNCI of 5.21.

The latter researcher also has the highest number of Top 1%, amounting to 16 publications, while the highest number of Top 10% was achieved by Franco Nori, affiliated with the University of Michigan, amounting to 16 publications.

Table 47: Top 20 researchers globally in terms of the number of publications published on the research topic Quantum Computing in the period 2014-2023

Name	Affiliation	Web of Science Publications	CNCI	Documents in the top 1%	Documents in the top 10%	Country
Guo, Guang-Can	University of Science & Technology of China, CAS	259	1.53	4	56	Mainland China
Li, Chuan-Feng	University of Science & Technology of China, CAS	170	1.44	1	36	Mainland China
Nori, Franco	University of Michigan	149	2.96	7	58	United States
Fei, Shao-Ming	Capital Normal University	138	0.73	0	5	Mainland China
Pan, Jian-Wei	University of Science & Technology of China, CAS	108	5.21	16	46	Mainland China
Ye, Liu	Anhui University	98	1.14	0	21	Mainland China
Fan, Heng	Chinese Academy of Sciences	91	1.90	3	27	Mainland China
Xia, Yan	Fuzhou University	91	1.18	0	16	Mainland China
Xue, Zheng-Yuan	South China Normal University	82	1.41	0	18	Mainland China
Wille, Robert	Johannes Kepler University Linz	75	2.48	5	25	Austria
Englund, Dirk	Massachusetts Institute of Technology (MIT)	74	3.07	9	36	United States
Zhang, Shou	Yanbian University	74	0.98	0	9	Mainland China
Wang, Dong	Anhui University	73	1.42	0	21	Mainland China
Song, Jie	Harbin Institute of Technology	73	1.29	0	16	Mainland China
Kais, Sabre	Purdue University	71	1.29	0	15	United States
Guo, Guo-Ping	University of Science & Technology of China, CAS	71	1.19	1	10	Mainland China
Sciarrino, Fabio	Sapienza University Rome	70	2.14	2	25	Italy
Burkard, Guido	University of Konstanz	69	1.79	3	12	Germany
Chong, Frederic T.	University of Chicago	68	4.23	9	31	United States
Wang, Hong-Fu	Yanbian University	68	0.82	0	5	Mainland China

4.1.16.9 Top 20 global funders globally in terms of number of publications

The top 3 organizations in terms of funded publications in this research topic are the National Natural Science Foundation of China (NSFC) with 9568 publications, followed by the National Science Foundation (NSF) with 4488 publications, and the United States Department of Energy (DOE) with 2610 publications as shown in Figure 140.

The highest citation impact measured by the CNCI is observed in publications funded by NSF - Directorate for Mathematical & Physical Sciences (MPS) followed by Air Force Office of Scientific Research (AFOSR) and United States Department of Defense with 3.06, 2.89 and 2.78, respectively.

Among the top 20 global funding organizations, 10 are also among the top 20 funding organizations of Saudi publications in this research topic.

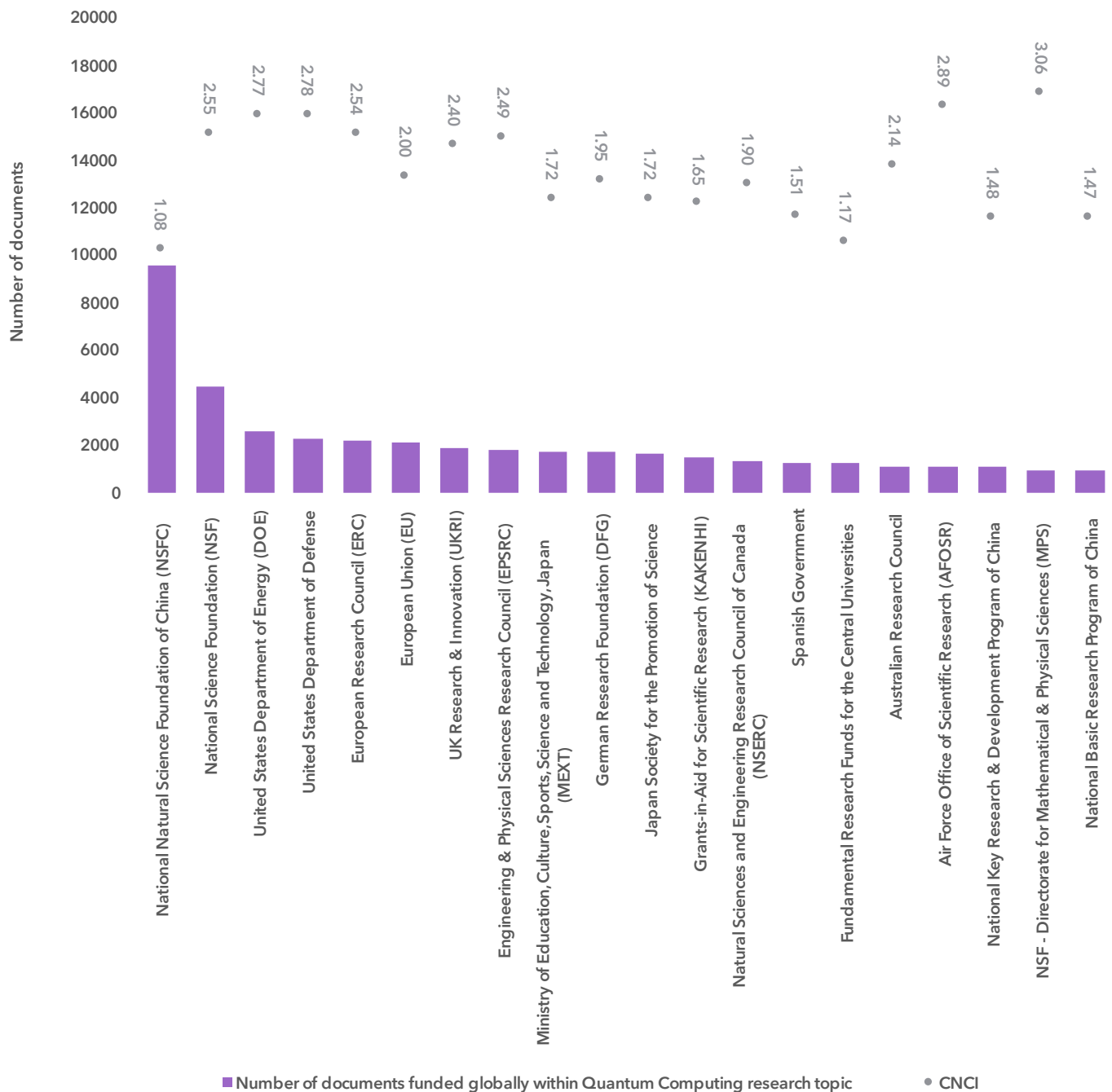


Figure 140: Top 20 funding organizations globally publications in the research topic Quantum Computing in terms of number of publications in the period 2014-2023

4.1.16.10 Emerging trends in the research topic globally and in Saudi Arabia

In this section we investigate the emerging trends globally and in Saudi Arabia in the research topic Quantum Computing. For more information on the methodology used to identify emerging trends, please see the definition section Emerging Trends.

The top 3 emerging micro-topics globally in this research topic Optical Electronics & Engineering: Silicon Photonics followed by Security Systems: Blockchain and 2D Materials: MoS2 as shown in Figure 141.

Saudi Arabia has few publications on this research topic, such that it was not meaningful to identify emerging micro-topics. Table 48 shows the identified top 10 micro-topics in Saudi Arabia's research output on this research topic.

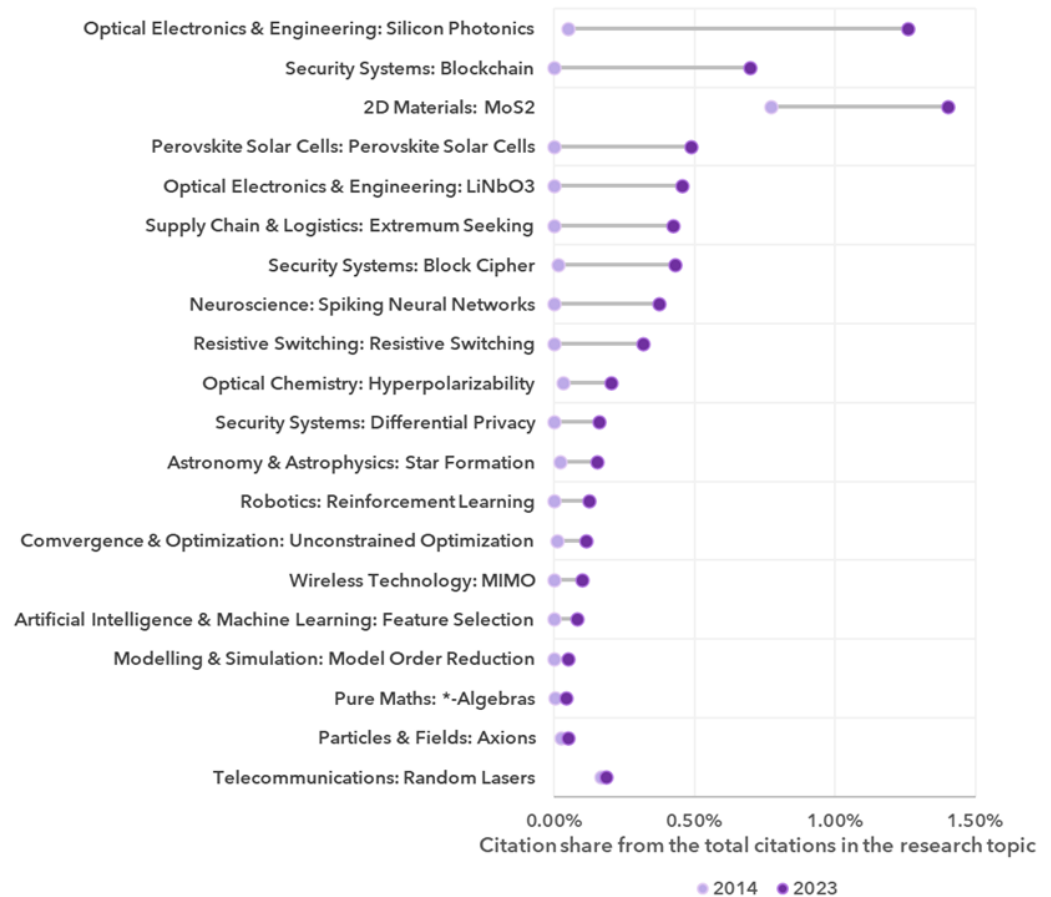


Figure 141: Top 20 emerging micro-topics globally in the research topic Quantum Computing in the period 2014-2023

Table 48: Top 10 Micro-topics identified in Saudi Arabia research output in the research topic Quantum Computing in the period 2014-2023

Topic	Number of Saudi Arabia publications in the period 2014-2023
Quantum Computing research topic	659
Quantum Mechanics: Entanglement	279
Security, Encryption & Encoding: Image Encryption	48
Physical Chemistry: CCSD	33
Optical Chemistry: Hyperpolarizability	18
Quantum Mechanics: Superconducting Qubits	17
Corrosion & Deposition Chemistry: Corrosion	15
Security Systems: Random Oracle Model	10
Quantum Mechanics: Geometric Phase	8
Quantum Mechanics: Electromagnetically Induced Transparency	8
Deposition, Hardening & Coating: Diamond	6

4.2 Invention performance in the selected priority research topics

Saudia Arabia's applied research has more established sustained relative strength within the Economies of the Future priority technologies such as Semiconductors with 242 inventions (Figure 142).

Recently there has been high invention strength investment into technologies such as 3D printing, Net Zero Aviation and Cognitive Cities - Virtual Cities. AI in ICT - 473, Internet of Things - 168, Cloud Computing, and AGI - Privacy & Security Oriented technologies are more recent, relatively lower strength; however the volume of inventions exceeds all of technologies in this priority except for Semiconductors and 3D printing.

The recent high-volume investment in these areas suggests alignment with RDI missions.

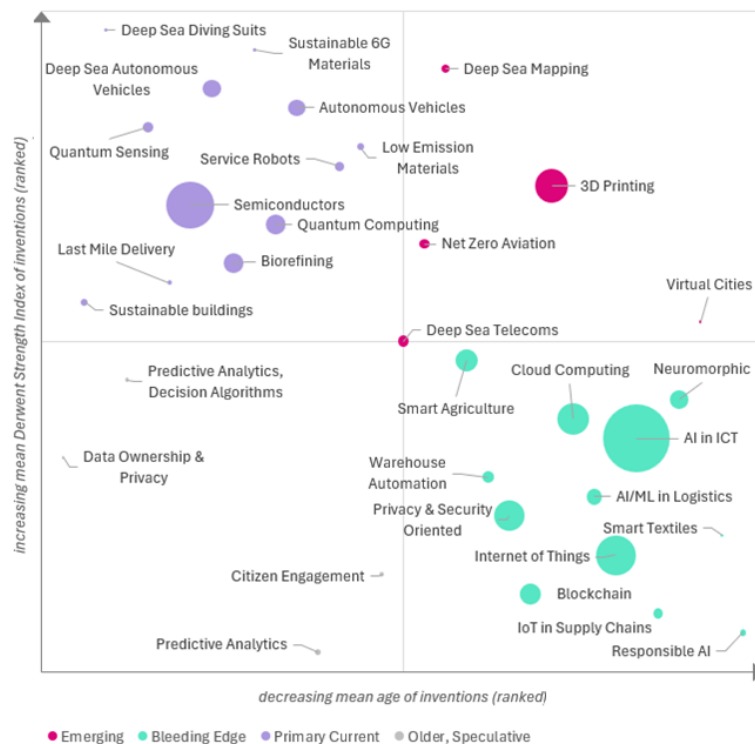


Figure 142: Technical dynamics model for the technologies within the Economies of the Future priority area from Saudi-based organizations

The Saudi Arabian analysis aligns with global trends in semiconductor technologies, both appearing as established high invention strength portfolios seen in Figure 143.

While the relative volumes of 242 compared to over 500K inventions globally significantly differ, the mean invention strength of 50 compared to 45 shows mid-range mean strength in Saudi Arabian semiconductor inventions. Cognitive City technologies are all found in the lower strength, more recent investment quadrant globally, than Air Quality.

Whereas Saudi Arabia has either high-strength, more established focus, or both across Citizen Engagement, Predictive Algorithms, Air Quality, Data Ownership, and Virtual City technologies. AI in ICT has aligned across Saudi Arabia compared to global trends, with this unique technology being a more recent lower-strength technology with a high relative number of inventions across both datasets.

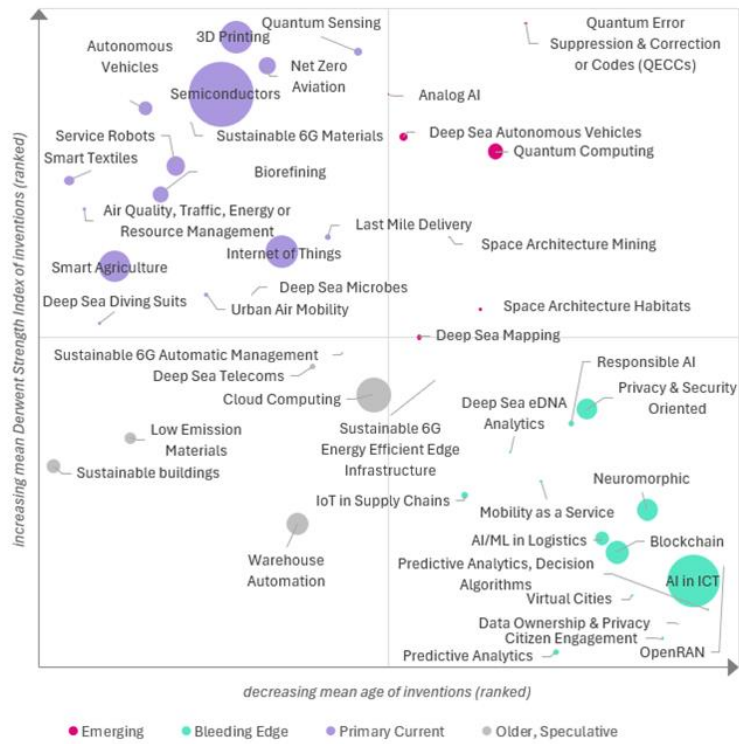


Figure 143: Technical dynamics model for the technologies within the Economies of the Future priority area from global organizations

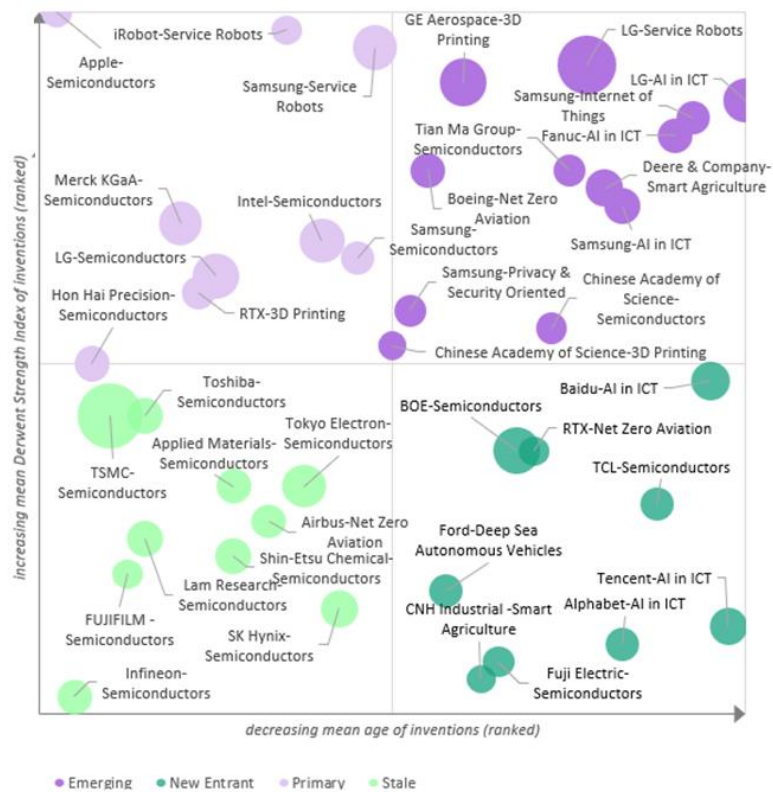


Figure 144: A view of the top forty global organizations with the strongest inventions awarded a score of 80+/100 on the Derwent Strength Index within the priority area of Economies of the Future

In the top left quadrant of Figure 144, established high-strength inventions are represented by Robot, Semiconductor, and 3D printing technologies from a mixture of Software, Medtech and Transport organizations. In the top right quadrant of the highest

strength, high-strength invention portfolio of high recency represents a larger variety of technologies: 3D Printing, Robots, AI in ICT, Semiconductors, Smart Agriculture, Net Zero Aviation and AGI - Privacy & Security Oriented.

Within the bottom left quadrant, semiconductor portfolios are present, the largest of which is owned by TSMC. The bottom right quadrant of new entrant technologies showcases recent high-strength portfolios; portfolios such as RTX's Net Zero Aviation or Baidu's AI in ICT could quickly move into the emerging portfolios by average high-strength inventions with a few higher-strength inventions.

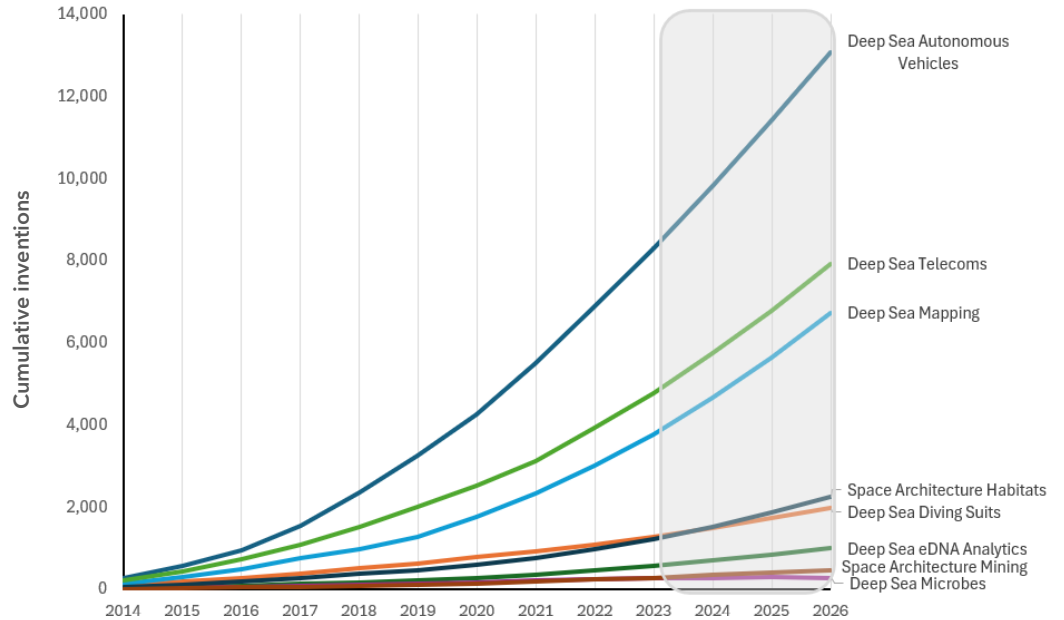


Figure 145: Cumulative inventions globally between 2014-2023 across Deep Sea and Space Architecture research topics within the Economies of the Future priority area

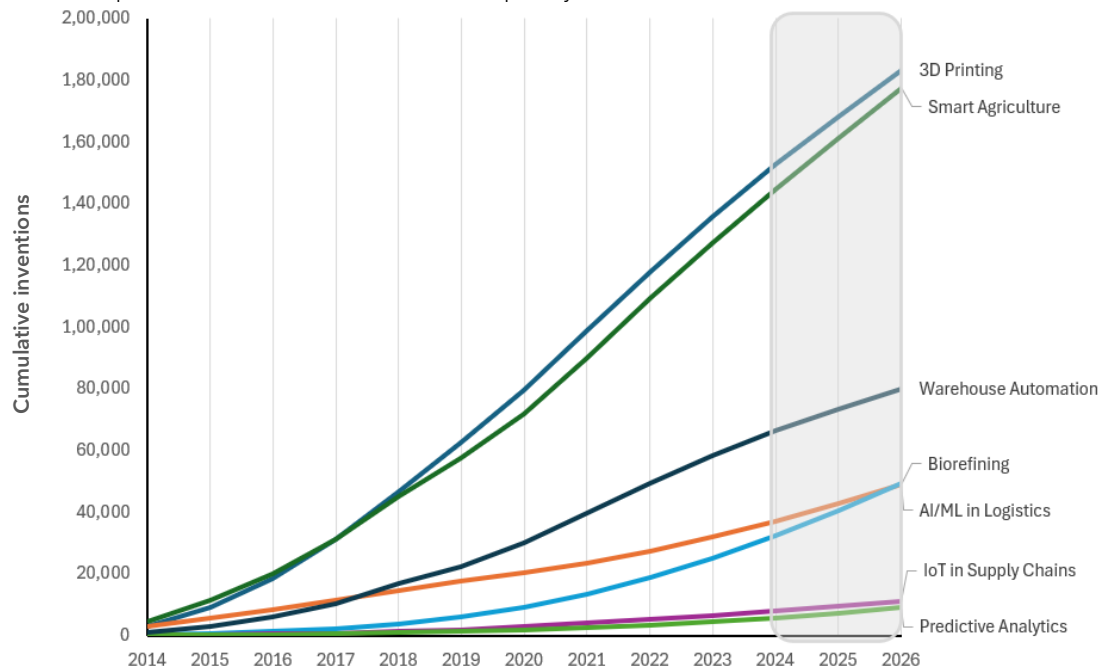


Figure 146: Cumulative inventions globally between 2014-2023 across 3D Printing, Bioeconomy and Logistics research topics within the Economies of the Future priority area

Deep Sea - Autonomous Vehicles, Telecoms, and Mapping technologies have the highest volume and growth rate trajectories out of all Space and Deep-Sea technologies within the Economies of the Future priority area. The three technologies are set to more than double their volumes between 2020-2026, as seen in Figure 145.

In Figure 146, 3D printing and Bioeconomy - Smart Agriculture have very aligned invention volumes and predicted growth trajectories, with invention volumes roughly tripling between 2019 and 2026. Logistics - AI/ML has a rapidly increasing growth rate, but it has started from a much lower level of inventions.

Service Robots and Net Zero Aviation have the highest volumes and growth rates of technologies, as shown in Figure 147. Urban Architecture - Sustainable buildings have experienced a recent plateauing of technology development, suggesting either their technology has matured, or it is not possible to progress further without other fundamental technologies.

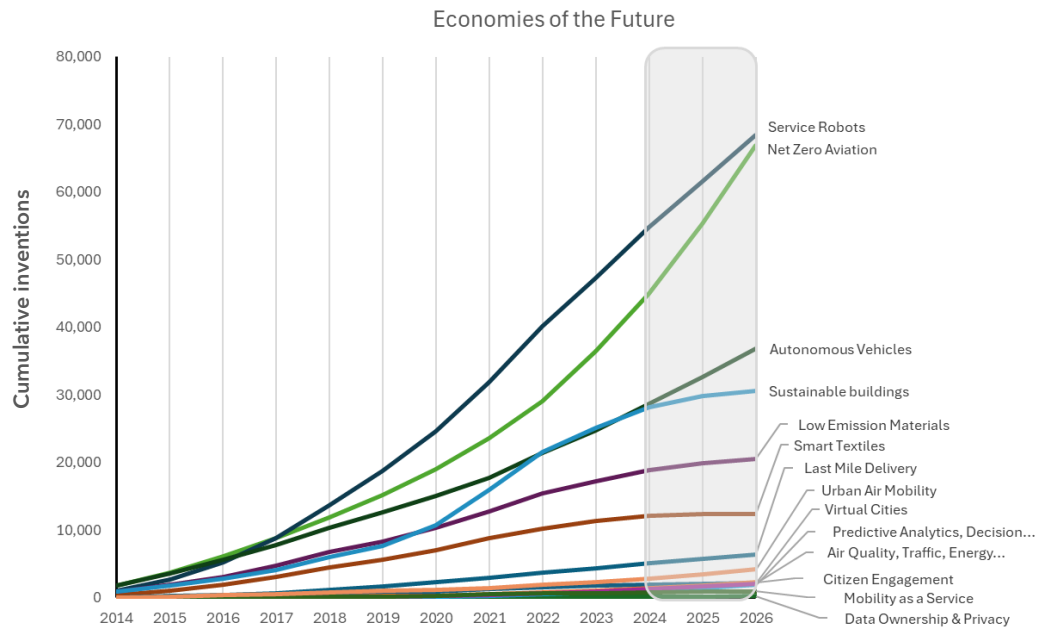


Figure 147: Cumulative inventions globally between 2014-2023 across Service Robots, Net Zero Aviation, Urban Architecture and Cognitive Cities research topics within the Economies of the Future priority area

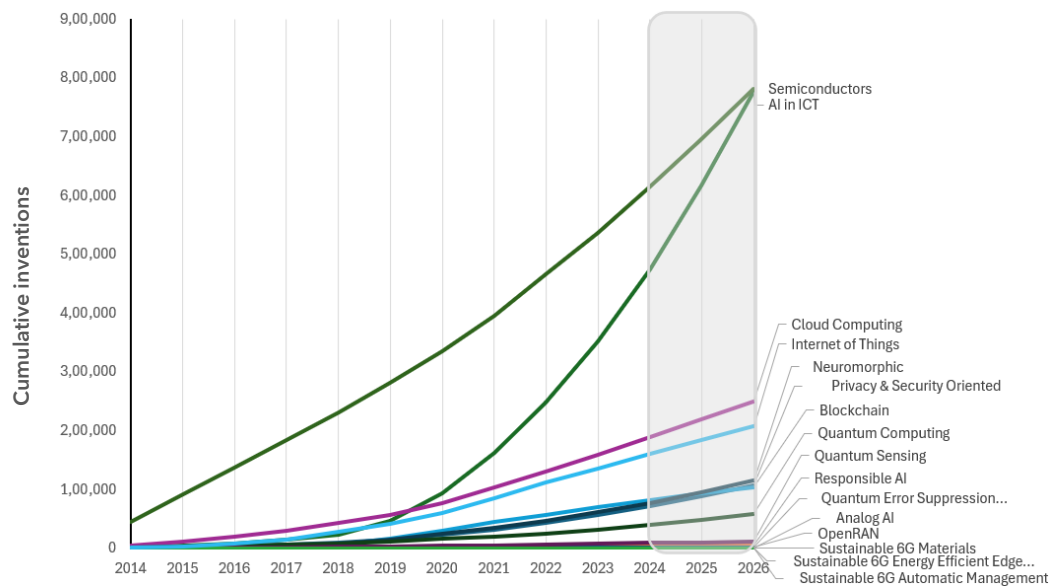


Figure 148: Cumulative inventions globally between 2014-2023 across Semiconductors, AI in ICT, Internet of Things and Sustainable 6 G-related research topics within the Economies of the Future priority area

In Figure 148, Semiconductors has the highest volume of inventions globally within the Economies of the Future technology priority area, however by 2027 AI in ICT is set to overtake Semiconductors and has been set on a rapid acceleration since 2019.

Technologies linked to AI in ICT, such as Cloud Computing and the Internet of Things, have more modest growth rates but are still steadily growing in recent years.

4.2.1 Air Quality, Traffic, Energy or Resource Management

In Figure 149, Mainland China is the leading source of Cognitive Cities - Air Quality, Traffic, Energy or Resource Management inventions between 2014 - 2024 producing 1,744 inventions. Followed by South Korea with 34 inventions, India with 26 inventions, US 15 inventions and Poland with five inventions.



Figure 149: Global distribution of inventions related to Air Quality, Traffic, Energy or Resource Management. The size of each bubble corresponds to the number of unique inventions published in that country or jurisdiction.

In Figure 150, State Grid Corp of China holds the highest strength largest recent invention portfolio globally in Air Quality, Traffic, Energy or Resource Management technologies with 13 inventions, followed by Chengdu Qinchuan IoT Technology with seven inventions, and Shanghai Urban Construction College with 5 inventions.

Terminus Beijing Technology holds 16 high-strength inventions with 16 inventions, Beijing Zhongke Huiju Technology with eight inventions and Wuhan Xilite Technology with five inventions.

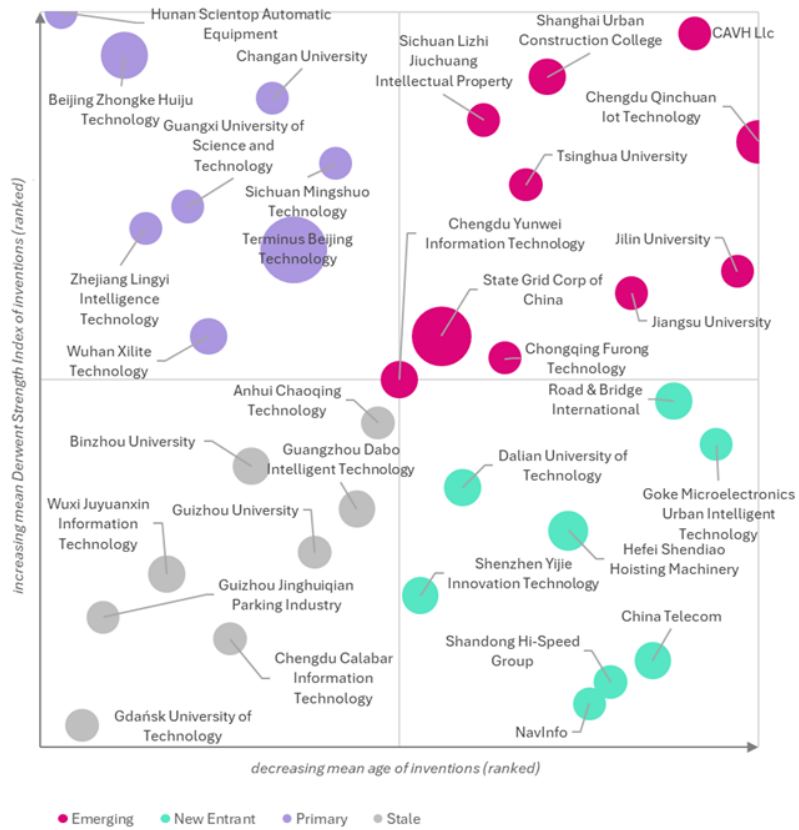


Figure 150: Commercial dynamics model for the top global patent assignees in the technology area of Air Quality, Traffic, Energy or Resource Management

4.2.2 Virtual Cities

In Figure 151, Mainland China was the leading source of cognitive cities – virtual cities inventions between 2014 – 2024, producing 776 inventions. Followed by the US with 92 inventions, South Korea with 47 inventions, India with 13 inventions and Australia with seven inventions.



Figure 151: Global distribution of inventions related to Virtual Cities. The size of each bubble corresponds to the number of unique inventions published in that country or jurisdiction.

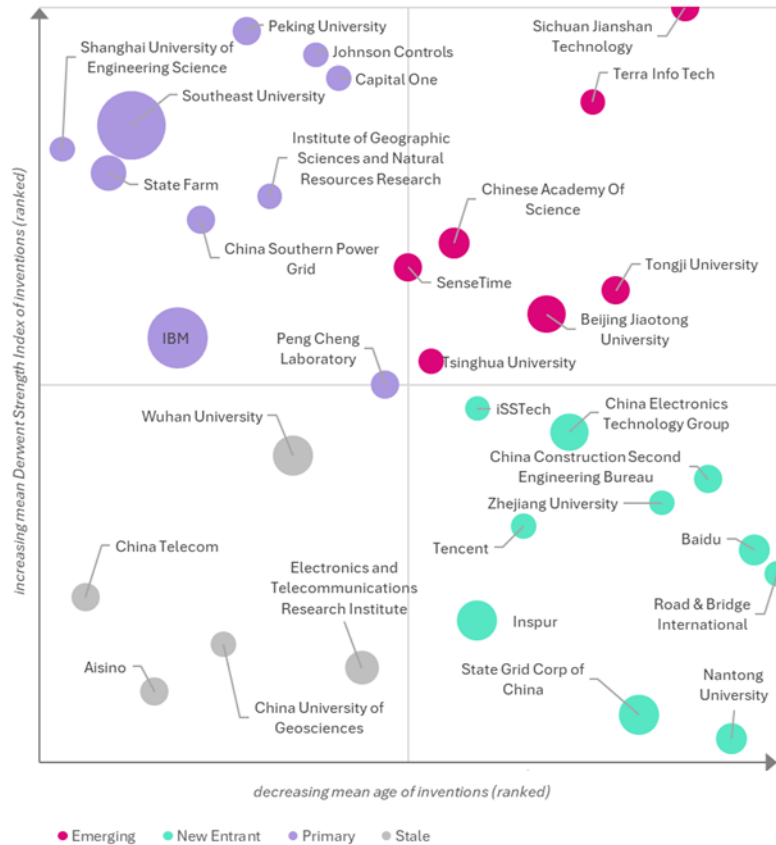


Figure 152: Commercial dynamics model for the top global patent assignees in the technology area of Virtual Cities

In Figure 152, the largest high-strength recent invention portfolios are held by Chinese Academia, such as Beijing Jiaotong University with nine inventions, Chinese Academy of Science with six inventions, and Tongji University with five inventions.

Whereas the high-strength more established invention portfolio contains corporations such as IBM with 23 inventions, State Farm with eight inventions, Capital One with four inventions, and Johnson Controls with four inventions.

4.2.3 Citizen Engagement

In Figure 153, Mainland China is the leading source of Cognitive Cities - Citizen Engagement inventions between 2014 - 2024 producing 977 inventions. Followed by India with 39 inventions, South Korea with 36 inventions, US with 13 inventions and Japan with five inventions.

In Figure 154, Chengdu Qinchuan IoT Technology holds the largest recent high-strength invention portfolio globally in Citizen Engagement technology with 27 inventions, followed by Ping An Insurance with eight inventions and Southeast University with seven inventions. Chinese Academy of Science has a more established high-strength portfolio of six inventions, and notably, Hitachi has three inventions.



Figure 153: Global distribution of inventions related to Citizen Engagement. The size of each bubble corresponds to the number of unique inventions published in that country or jurisdiction.

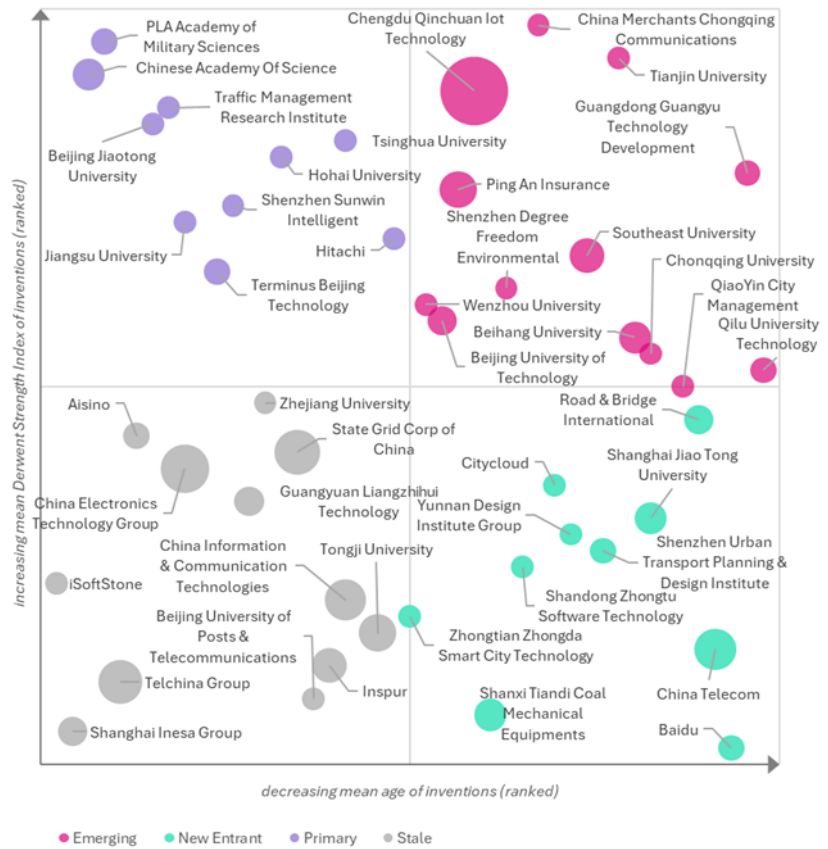


Figure 154: Commercial dynamics model for the top global patent assignees in the technology area of Citizen Engagement

4.2.4 Data Ownership & Privacy

In Figure 155, Mainland China is the leading source of Cognitive Cities - Data Ownership & Privacy between 2014 - 2024 producing 83 inventions. Followed by India with seven inventions, South Korea with six inventions, the US with three inventions and Saudi Arabia with one invention.



Figure 155: Global distribution of inventions related to Data Ownership & Privacy. The size of each bubble corresponds to the number of unique inventions published in that country or jurisdiction.

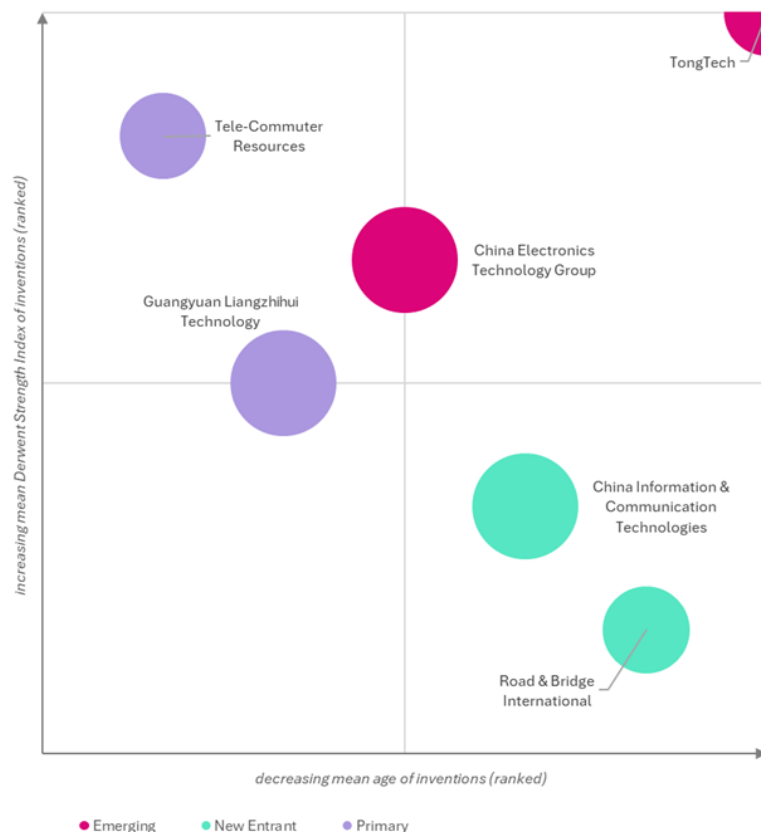


Figure 156: Commercial dynamics model for the top global patent assignees in the technology area of Data Ownership & Privacy

In Figure 156, China Electronics Technology Group has the largest, highest-strength invention portfolio globally in Data Ownership & Privacy with three inventions, followed by TongTech with two inventions. More established higher-strength

inventions are held by Guangyuan Liangzhihui Technology, which has three inventions, and Tele-Commuter Resources, which has two inventions.

4.2.5 Predictive Analytics, Decision Algorithms

In Figure 157, Mainland China was the leading source of predictive analytics and decision algorithms between 2014 and 2024, producing 659 inventions. Followed by India with 45 inventions, the US with 19 inventions, South Korea with 17 inventions, Japan with three inventions, Oman with three inventions and Saudi Arabia with two inventions.



Figure 157: Global distribution of inventions related to Predictive Analytics, Decision Algorithms. The size of each bubble corresponds to the number of unique inventions published in that country or jurisdiction.

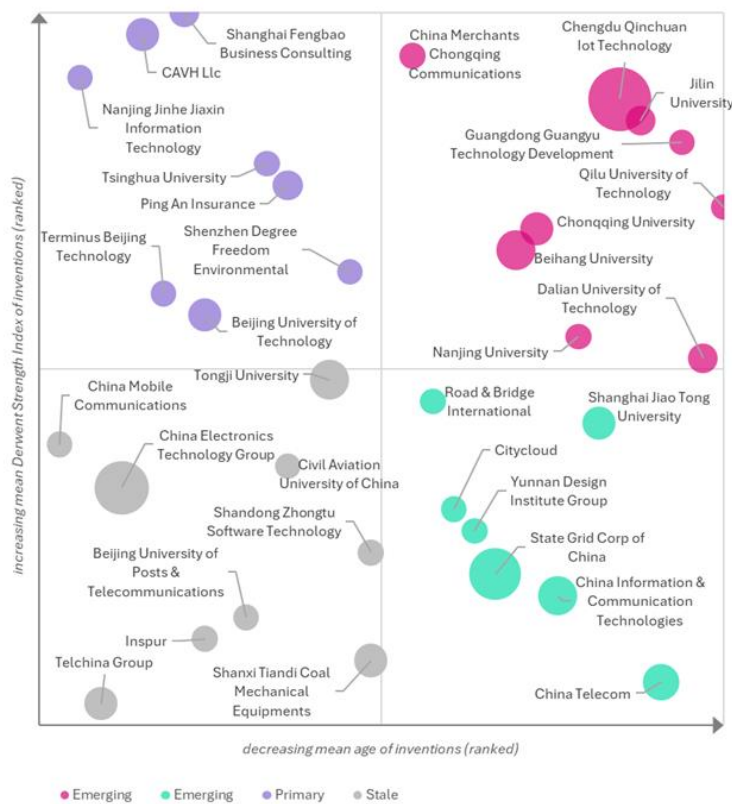


Figure 158: Commercial dynamics model for the top global patent assignees in the technology area Predictive Analytics, Decision Algorithms

In Figure 158, Chengdu Qinchuan IoT Technology holds the largest high-strength recent invention portfolio globally in Predictive Analytics and Decision Algorithms technology with 18 inventions, followed by Beihang University with seven inventions,

then Chongqing University with five inventions. Beijing University of Technology holds a more established invention portfolio of five inventions, CAVH LLC also holds five inventions and Ping An Insurance with four inventions.

4.2.6 Sustainable 6G Materials

In Figure 159, Mainland China is the leading source of Sustainable 6G Materials technologies between 2014 - 2024 producing 209 inventions. Followed by South Korea with 45 inventions, US with 39 inventions, Japan with 12 inventions and Canada with nine inventions.



Figure 159: Global distribution of inventions related to Sustainable 6G Materials. The size of each bubble corresponds to the number of unique inventions published in that country or jurisdiction.

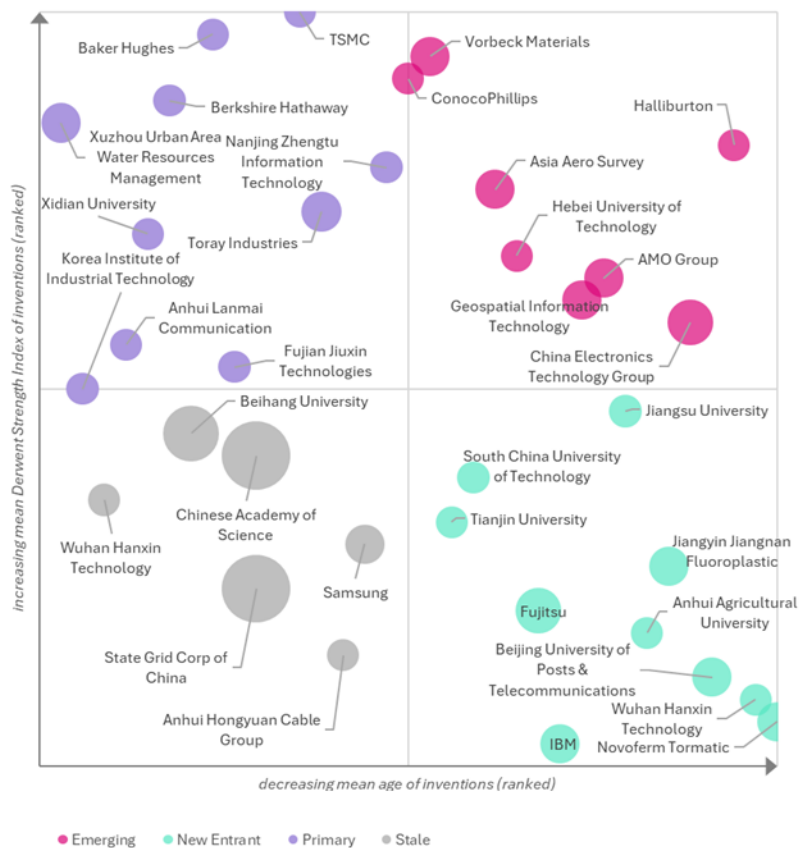


Figure 160: Commercial dynamics model for the top global patent assignees in the technology area of Sustainable 6G - Material

In Figure 160, China Electronics Technology Group holds the largest high-strength recent four inventions globally in Sustainable 6G Materials technology, AMO Group has three inventions, Vorbeck Materials has three inventions. Toray Industries has more established high-strength invention portfolio with three inventions, followed by Xuzhou Urban Area Water Resources Management with three inventions and TSMC with two inventions.

4.2.7 Sustainable 6G Automatic Management

In Figure 161, Mainland China is the leading source of Sustainable 6G Automatic Management technology between 2014 - 2024 producing 195 inventions. Followed by the US with five inventions, South Korea with five inventions, Taiwan with three inventions and Japan with one invention.



Figure 161: Global distribution of inventions related to Sustainable 6G Automatic Management. The size of each bubble corresponds to the number of unique inventions published in that country or jurisdiction.

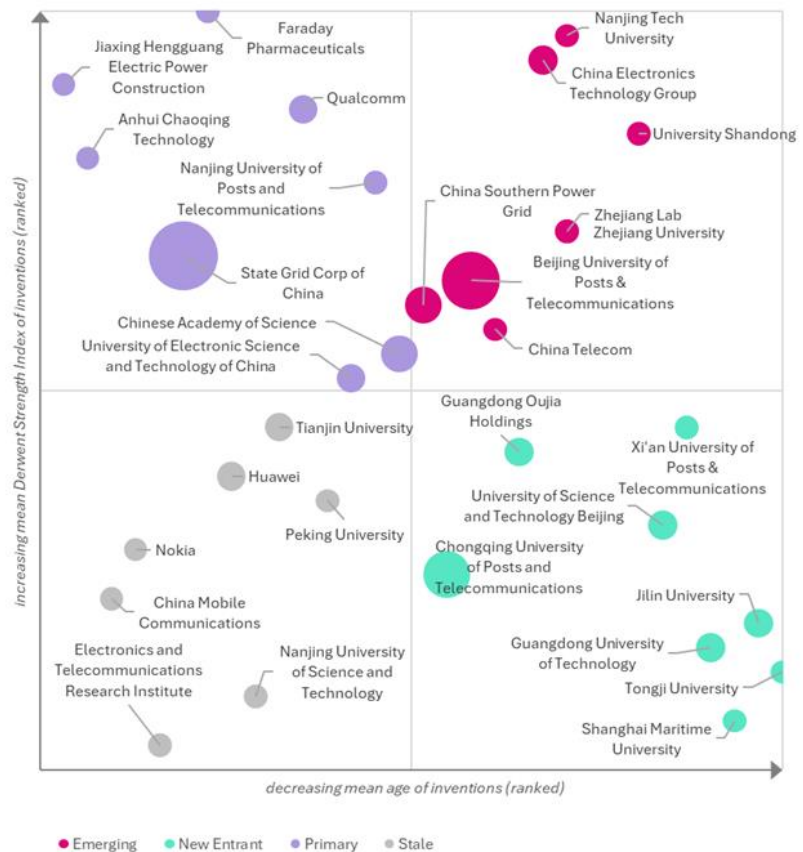


Figure 162: Commercial dynamics model for the top global patent assignees in the technology area of Sustainable 6G Automatic Management

In Figure 162, Beijing University of Posts & Telecommunications holds the largest number of recent high-strength inventions globally in Sustainable 6G Automatic Management technology with 12 inventions, followed by China Southern Power Grid with five inventions and China Electronics Technology Group with three inventions. State Grid Corp of China has 17 inventions with almost equal invention strength to Beijing University of Posts & Telecommunications: however, with shorter remaining years of protection, followed by the Chinese Academy of Science with five inventions. Notably, Qualcomm has three inventions, Huawei has three inventions, and Nokia has two inventions.

4.2.8 Sustainable 6G Energy Efficient Edge Infrastructure

In Figure 163, the United States is the leading source of Sustainable 6G Energy Efficient Edge Infrastructure technology inventions between 2014 - 2024, producing 42 inventions. Followed by Mainland China with 41 inventions, South Korea with ten inventions, Japan with ten inventions, and Sweden with five inventions.



Figure 163: Global distribution of inventions related to Sustainable 6G Energy Efficient Edge Infrastructure. The size of each bubble corresponds to the number of unique inventions published in that country or jurisdiction.

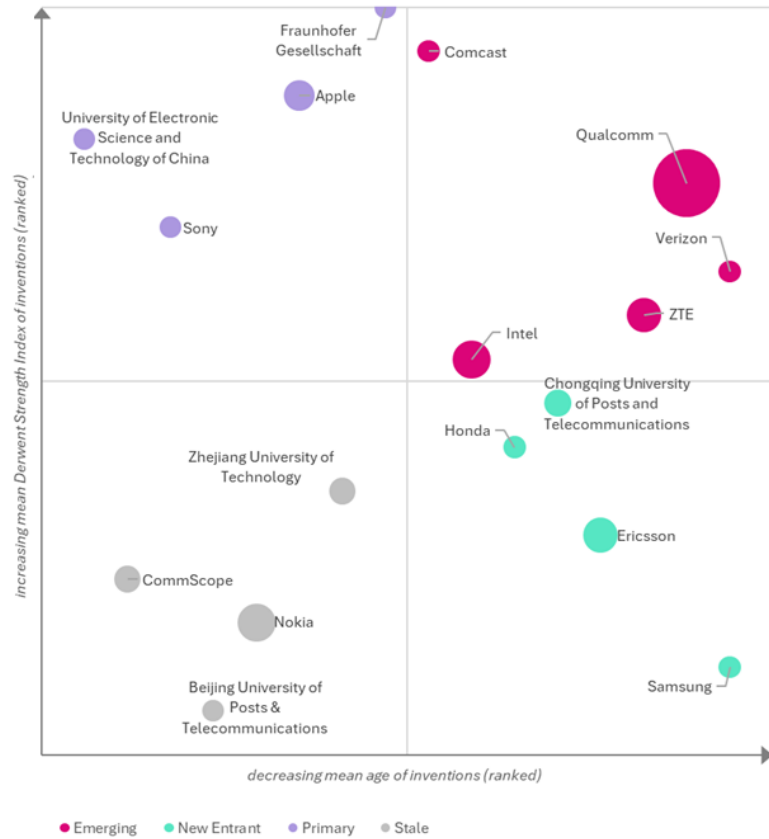


Figure 164: Commercial dynamics model for the top global patent assignees in the technology area of Sustainable 6G Energy Efficient Edge Infrastructure.

In Figure 164, Qualcomm holds the largest high-strength recent invention portfolio globally in Sustainable 6G Energy Efficient Edge Infrastructure technology, followed by Intel with six inventions with a mean invention strength score of 47.6, ZTE with five inventions, Verizon with two inventions and Comcast with two inventions. Apple holds four inventions with a mean invention strength score of 52.9, with slightly fewer remaining years than Qualcomm, followed by Sony with two inventions and Nokia with six inventions.

4.2.9 Autonomous Vehicles

In Figure 165, Mainland China is the leading source of Urban Architecture - Autonomous Vehicle technology inventions between 2014 - 2024 producing 13,471 inventions. Followed by Japan with 3,392 inventions, Germany with 2,916 inventions, US with 2,549 inventions, and South-Korea with 1,466 inventions.



Figure 165: Global distribution of inventions related to Autonomous Vehicles. The size of each bubble corresponds to the number of unique inventions published in that country or jurisdiction.

In Figure 166, Saudi Aramco has the highest strength largest invention portfolio from Saudi Arabia in Autonomous Vehicles, with 20 inventions with a mean invention strength score of 62.1, followed by King Abdullah University of Science and Technology with four inventions with an invention score of 63.5, Imam Abdulrahman Bin Faisal University with two inventions with an invention score of 59.5, KFUPM with five inventions with a mean invention strength score of 55.5, and Umm Al Qura University with four inventions with a mean invention score of 44.2.



Figure 166: Commercial dynamics model for the top patent assignees active in Saudi Arabia in the technology area of Autonomous Vehicles

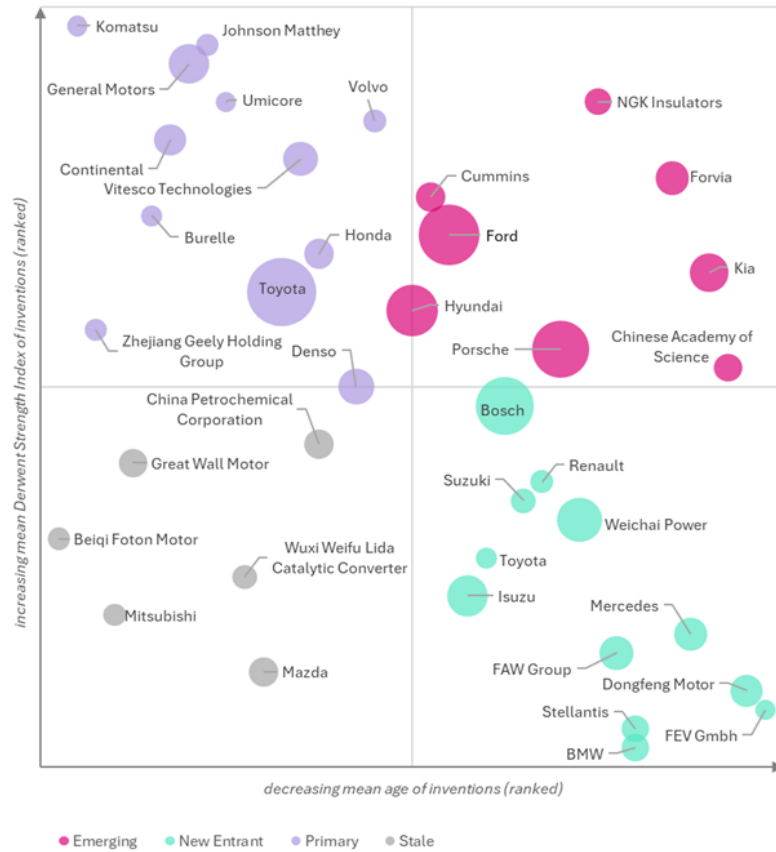


Figure 167: Commercial dynamics model for the top global patent assignees in the technology area of Autonomous Vehicles

In Figure 167, Ford holds the highest number of high-strength recent inventions globally in Autonomous Vehicles with 727 inventions, scoring 54.7 as a mean invention strength score, followed by Porsche with 631 inventions, Hyundai with 513 inventions, Kia with 284 inventions and Forvia with 221 inventions. Toyota holds 910 inventions with a mean invention score of 50 with slightly fewer remaining years of protection, followed by General Motors with 309 inventions.

4.2.10 Semiconductors

In Figure 168, Mainland China is the leading source of Semiconductors inventions globally between 2014-2023, with 279,321 inventions. Followed by Japan with 94,856 inventions, the United States with 72,919 inventions, South Korea with 60,385 inventions and Taiwan with 43,488 inventions.



Figure 168: Global distribution of inventions related to Semiconductors. The size of each bubble corresponds to the number of unique inventions published in that country or jurisdiction.

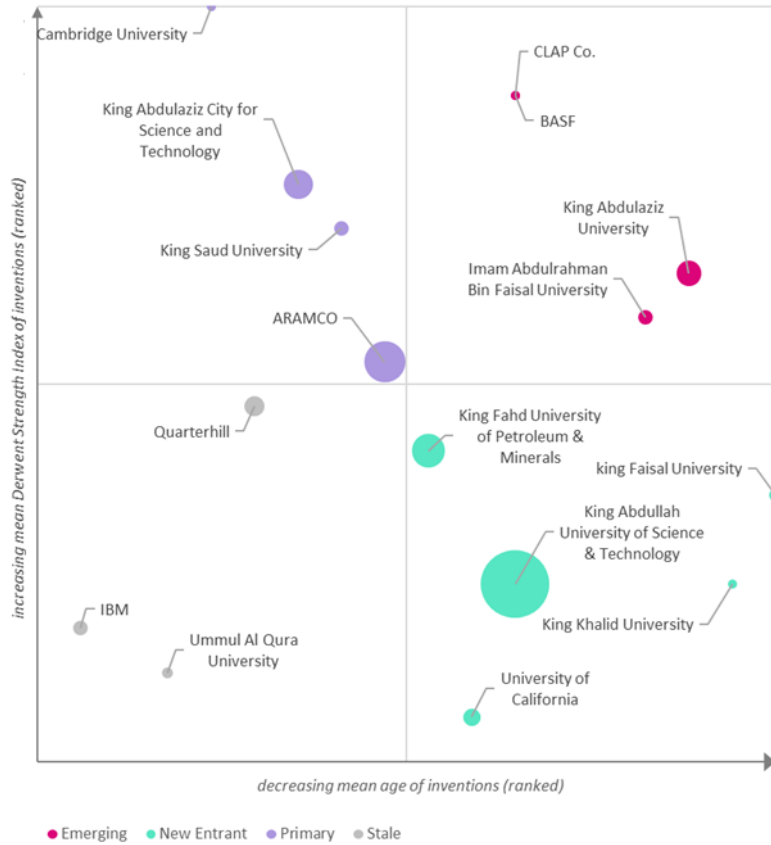


Figure 169: Commercial dynamics model for the top patent assignees active in Saudi Arabia in the technology area of Semiconductors

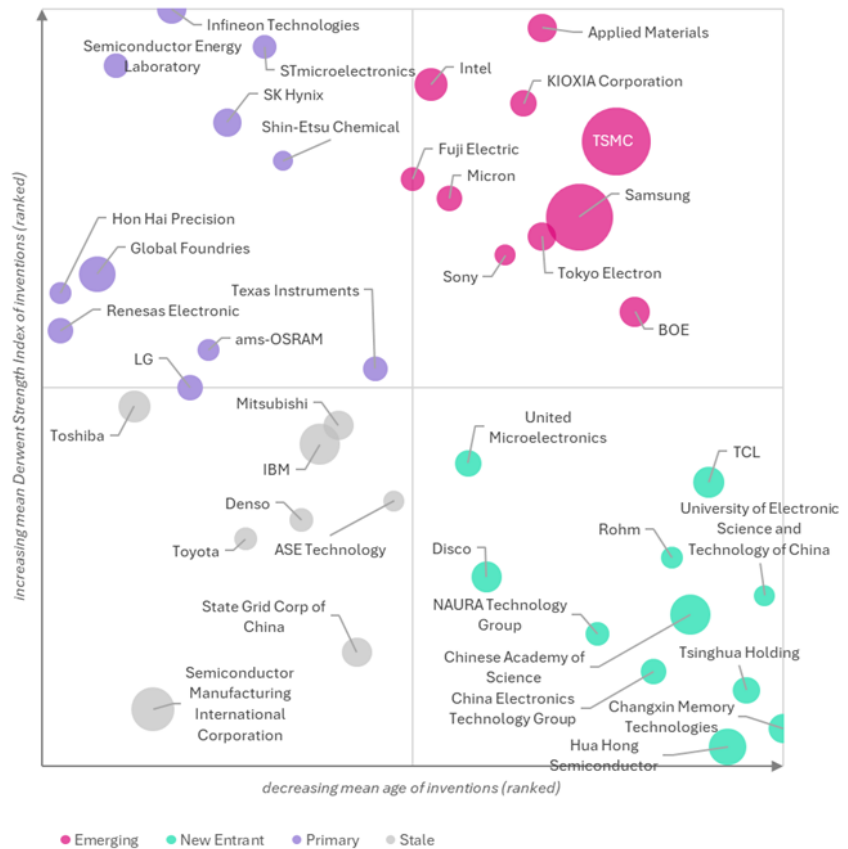


Figure 170: Commercial dynamics model for the top global patent assignees in the technology area of Semiconductors

In Figure 169, Saudi Aramco has the largest established high invention strength Semiconductors portfolio from Saudi Arabia, holding 39 inventions with a mean invention strength of 53.4, followed by KACST with 20 inventions with a mean invention strength score of 57.5, and King Saud University with five inventions with a mean invention score of 56.7. King Abdulaziz University, holding 15 inventions with an average strength score of 54.2, is found in the top right quadrant of more recent inventions. KAUST holds 109 inventions with a mean invention score of 48.5, and KFUPM has 26 inventions with a mean invention score of 52.

In Figure 170, TSMC holds the largest number of high-strength recent inventions globally with 20,572 inventions with a mean invention strength score of 51.8, followed by Samsung with 19,716 inventions and Intel with 4,825 inventions. Global Foundries is found within the top left quadrant of more established high-strength inventions, with 5,715 inventions, Infineon 3,677 inventions and SK Hynix 3,570 inventions.

4.2.11 OpenRAN

In Figure 171, the United States is the leading source of OpenRAN technology inventions between 2014 - 2024 producing 216 inventions. Followed by Mainland China with 98 inventions, India with 74 inventions, South Korea with 48 inventions and Japan with 43 inventions.



Figure 171: Global distribution of inventions related to OpenRAN. The size of each bubble corresponds to the number of unique inventions published in that country or jurisdiction.

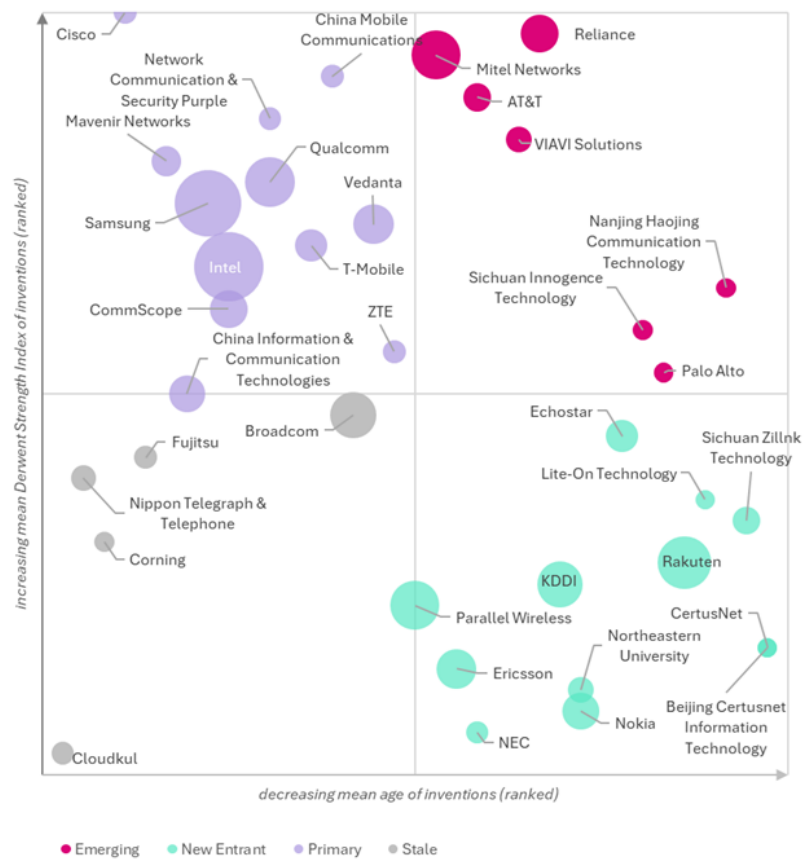


Figure 172: Commercial dynamics model for the top global patent assignees in the technology area of OpenRAN

In Figure 172, Mitel Networks holds the highest number of high-strength recent inventions in OpenRAN with 18 inventions, followed by Reliance with 11 inventions and

AT&T with six inventions. Intel is found within the top left quadrant for more established high-strength invention portfolios with 36 inventions, followed by Samsung with 34 inventions and Qualcomm with 19 inventions.

4.2.12 Urban Air Mobility

In Figure 173, Mainland China is the leading source of Urban Air Mobility technology inventions between 2014 - 2024, producing 1,470 inventions. Followed by the US with 312 inventions, South Korea with 184 inventions, Germany with 127 inventions and Japan with 116 inventions.



Figure 173: Global distribution of inventions related to Urban Air Mobility. The size of each bubble corresponds to the number of unique inventions published in that country or jurisdiction.

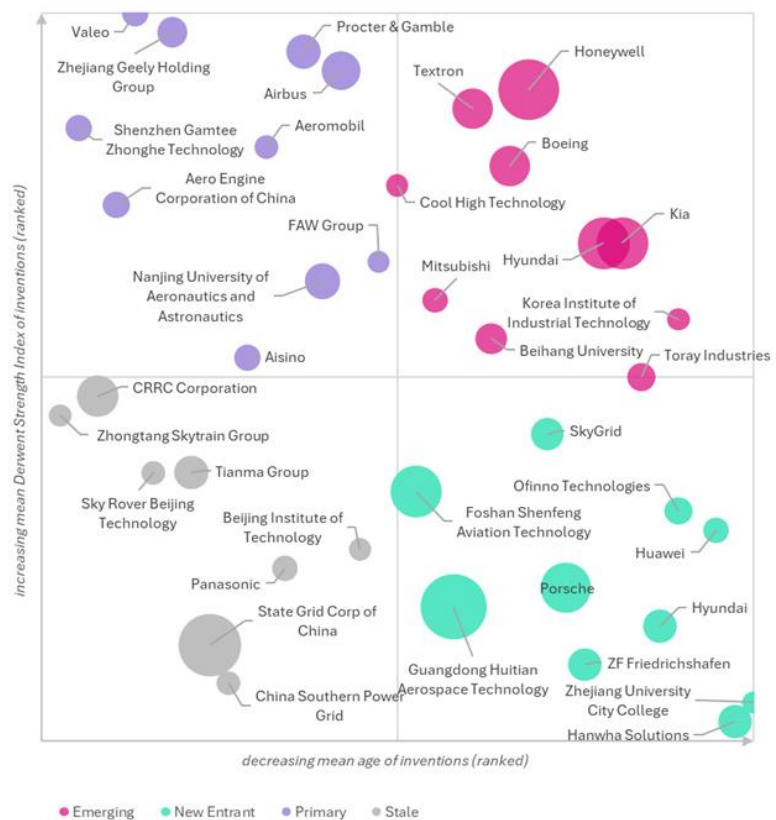


Figure 174: Commercial dynamics model for the top global patent assignees in the technology area of Urban Air Mobility

In Figure 174, Honeywell holds the largest high-strength recent invention portfolio globally in Urban Air Mobility with 52 inventions, followed by Hyundai and Kia with 38

inventions each and Boeing with 23 inventions. Within the top left quadrant for more established high-strength inventions, Airbus is found with 21 inventions, the Nanjing University of Aeronautics and Astronautics with 18 inventions, Procter & Gamble with 17 inventions, and Zhejiang Geely hold Group with 13 inventions.

4.2.13 Space Architecture Habitats

In Figure 175, Mainland China is the leading source of Space Architecture Habitats technology inventions between 2014 - 2024 producing 684 inventions. Followed by the US with 209 inventions, Russia with 101 inventions, Japan with 73 inventions and South Korea with 42 inventions.



Figure 175: Global distribution of inventions related to Space Architecture Habitats. The size of each bubble corresponds to the number of unique inventions published in that country or jurisdiction.

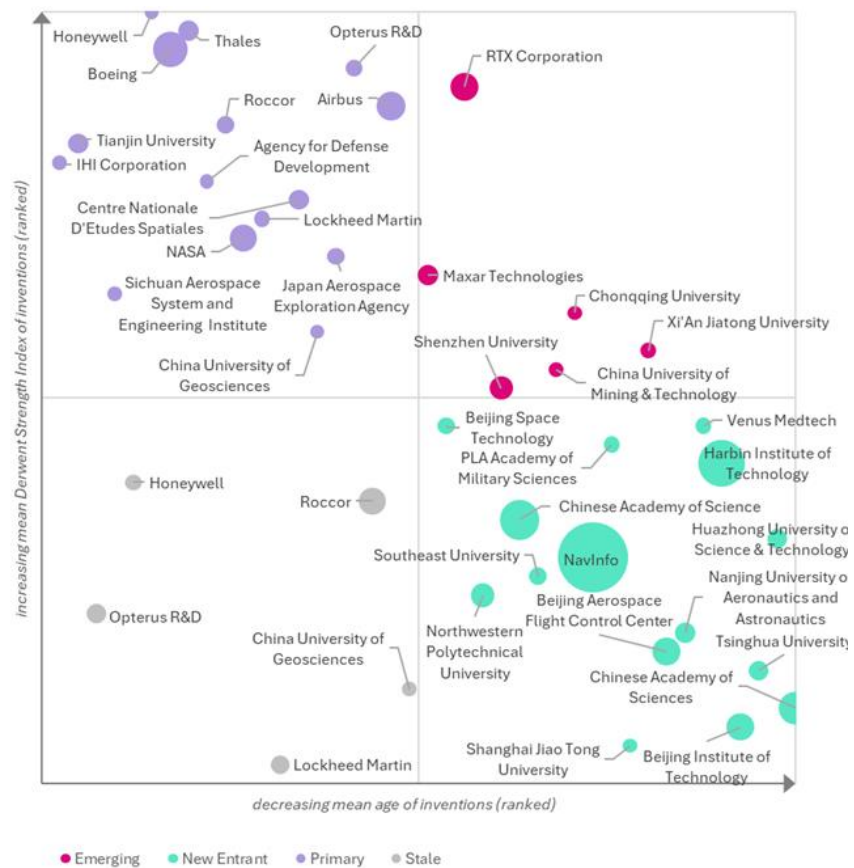


Figure 176: Commercial dynamics model for the top global patent assignees in the technology area of Space Architecture Habitats

In Figure 176, RTX Corporation holds the largest high-strength invention portfolio globally with 18 inventions in Space Architecture Habitats, followed by Shenzhen University with 13 inventions, and Maxar Technologies with ten inventions. Boeing, Airbus and NASA are found within the top left quadrant for high-strength, more established inventions, with 28, 19 and 17 inventions, respectively.

4.2.14 Space Architecture Mining

In Figure 177, Mainland China is the leading source of Space Architecture Mining technology inventions between 2014 - 2024 producing 127 inventions. Followed by the US with 71 inventions, Russia with 34 inventions, Japan with 12 inventions and Germany with ten inventions.



Figure 177: Global distribution of inventions related to Space Architecture Mining. The size of each bubble corresponds to the number of unique inventions published in that country or jurisdiction.

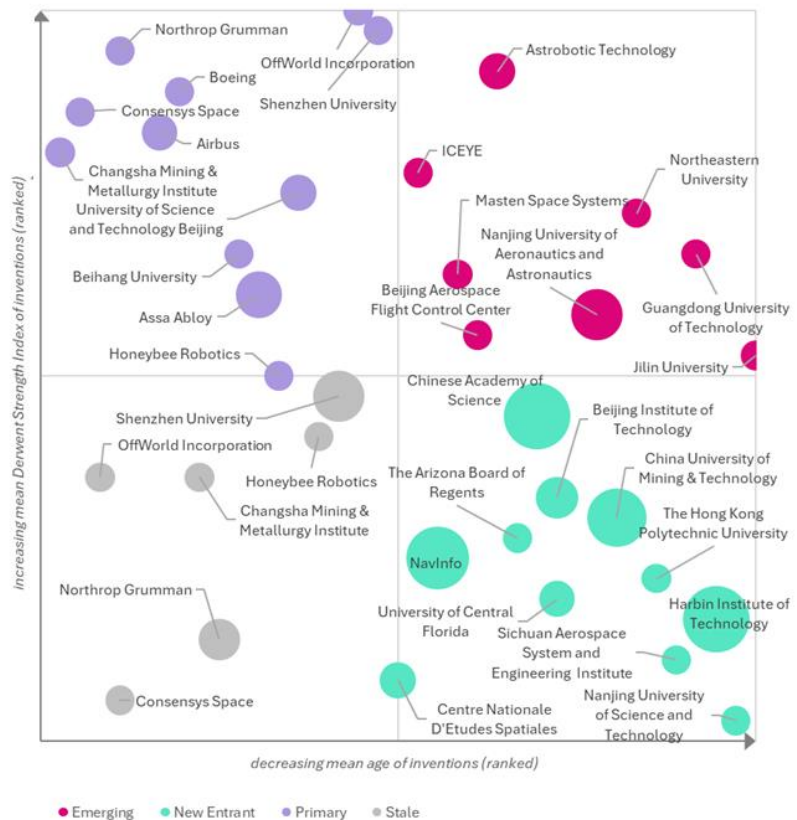


Figure 178: Commercial dynamics model for the top global patent assignees in the technology area of Space Architecture Mining

In Figure 178, the Nanjing University of Aeronautics and Astronautics holds the largest number of high-strength recent inventions globally for Space Architecture Mining, with six inventions, followed by Astrobotic Technology with three inventions and Guangdong University of Technology with two inventions. Assa Abloy and Airbus are found within the more established high-strength quadrant, with five and three inventions, respectively.

4.2.15 AI in ICT

In Figure 179, Mainland China is the leading source of AI in ICT technology inventions between 2014 - 2024 producing 233,723 inventions. Followed by the US with 56,710 inventions, South Korea with 25,721 inventions, India with 18,588 inventions and Germany with 6,017 inventions.



Figure 179: Global distribution of inventions related to AI in ICT. The size of each bubble corresponds to the number of unique inventions published in that country or jurisdiction.

In Figure 180, Saudi Aramco has the largest recent AI in ICT invention portfolio from Saudi Arabia, holding 175 inventions with a mean invention score of 45.6, followed by King Abdulaziz University with 11 inventions with a mean invention strength score of 57.1. KFUPM holds a more established high-strength 33 inventions, followed by King Saud University with two inventions with an invention score of 49.1

In Figure 181, Zhejiang University holds 2,713 inventions in the field of AI in ICT globally, they are found within the high-strength recent top right quadrant, alongside many Mainland China organizations. Conversely in the top left more established high-strength quadrant, there is much higher corporate representation. IBM holds 6,170 inventions, Baidu 4,695, Tencent 4,359, Alphabet 2,883, Samsung 2,559, and Microsoft 2,347.



Figure 180: Commercial dynamics model for the top patent assignees active in Saudi Arabia in the technology area of AI in ICT

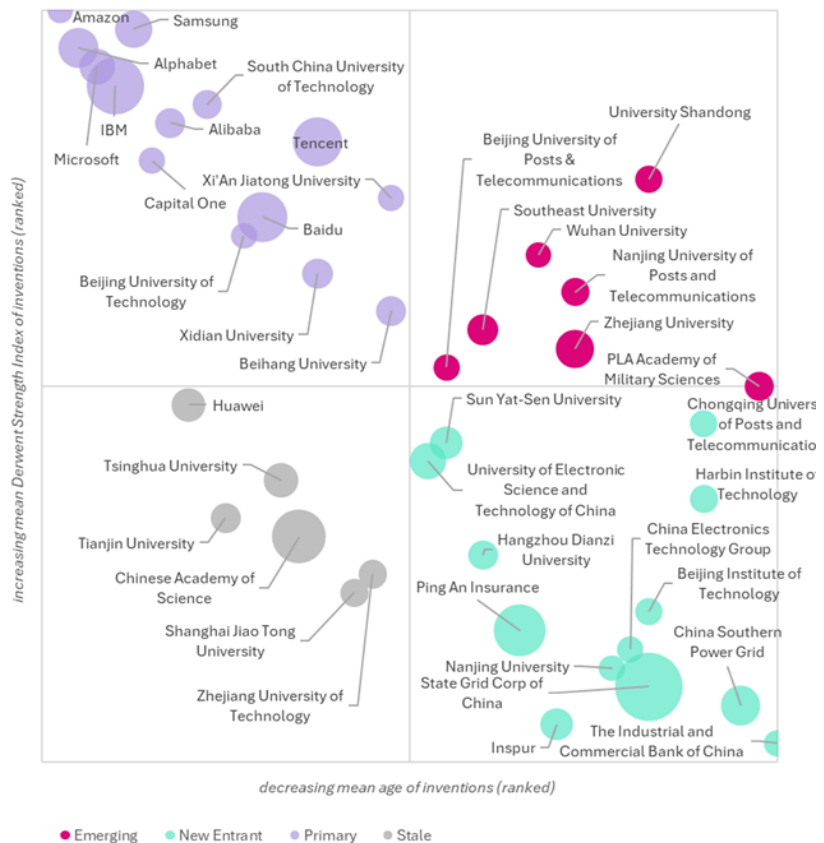


Figure 181: Commercial dynamics model for the top global patent assignees in the technology area of AI in ICT

4.2.16 Quantum Computing

In Figure 182, Mainland China is the leading source of Quantum Computing technology inventions between 2014 - 2024, and Mainland China is the leading source

of Quantum Computing technology inventions between 2014 - 2024, producing 20,265 inventions. Followed by the US with 5,430 inventions, Japan with 1,972 inventions, South Korea with 1,855 inventions and Germany with 877 inventions.



Figure 182: Global distribution of inventions related to Quantum Computing. The size of each bubble corresponds to the number of unique inventions published in that country or jurisdiction.

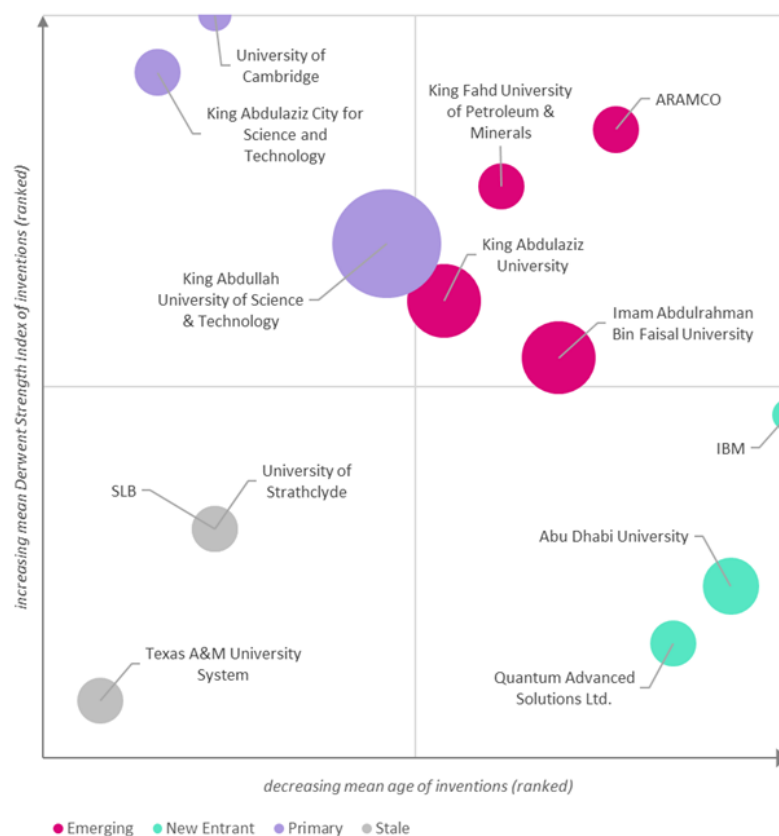


Figure 183: Commercial dynamics model for the top patent assignees active in Saudi Arabia in the technology area of Quantum Computing

In Figure 183, KAUST holds the largest established high-strength portfolio in Quantum Computing from Saudi Arabia with 11 inventions with a mean invention strength score of 55.5, followed by KACST with two inventions with a mean invention strength score of 67.4. King Abdulaziz University holds a high-strength, more recent portfolio of five inventions with a mean invention strength score of 54.7.

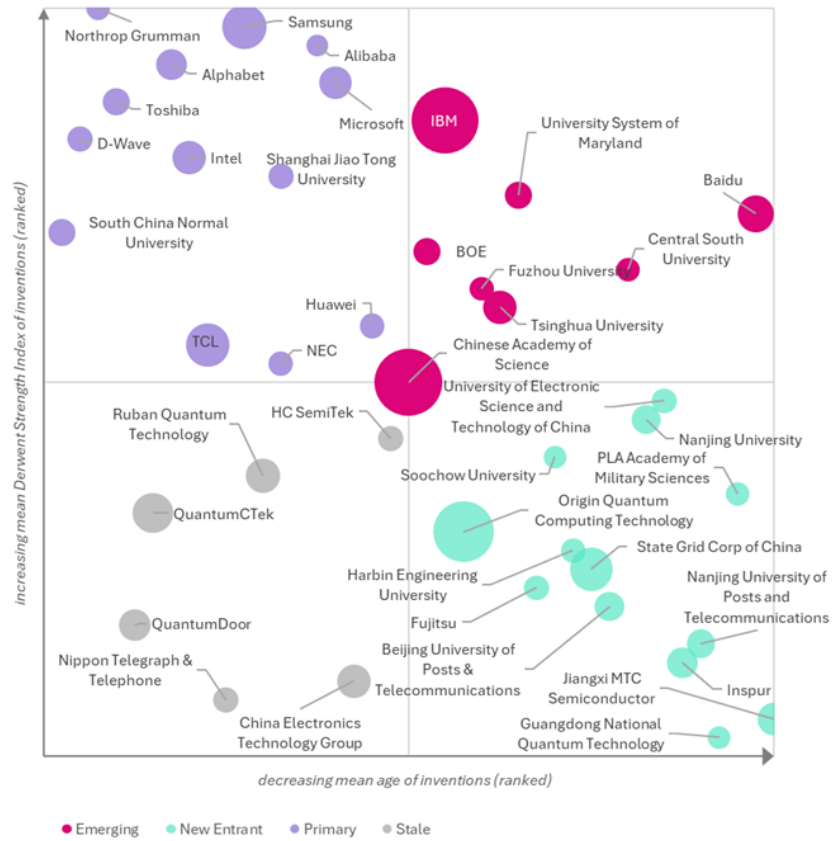


Figure 184: Commercial dynamics model for the top global patent assignees in the technology area of Quantum Computing

Chinese Academy of Science holds the largest number of recent high-strength inventions globally in the field of Quantum Computing, with 1,026 inventions, followed by IBM with 997 and Baidu with 301 (Figure 184). Samsung is found within the more established high-strength top left quadrant with 454 inventions, alongside TCL with 426 inventions, Intel with 253 inventions, Microsoft with 241 inventions, Alphabet with 209 inventions and Toshiba with 169 inventions.

5 Key findings within Economies of the Future



Drawing upon the insights from research and invention performance, Academic-Corporate Partnerships, and Technology Maturity evaluation for Saudi Arabian and global organizations, this section provides key findings tailored to the relative position of Saudi Arabia for each technology by using industry-leading metrics to provide the next steps. These findings will outline the potential of the technologies specifically for Saudi Arabia, where to invest, and ultimately whether more academic funding is required, further Academic-Corporate Partnerships, transfer of technology from academic to private entities, and potentially to continue the existing strategies.

Table 49: Economies of the Future research topic scorecard

				High	Medium	Low
	Saudi Arabia's research strength	Saudi Arabia's invention strength	Saudi Arabia's partnership strength	Saudi Arabia's research productivity	Technology maturity	Future predicted growth
AI in ICT	37393	15977	0.8%	1.9	4	10.9%
Air quality, traffic, energy or resource management	2208	0	0.8%	1.4	5	6.5%
Citizen engagement	244	71	0.0%	0.3	3	10.6%
Data ownership & privacy	1296	31	1.0%	1.9	3	0.0%
Predictive analytics, decision algorithms	2644	67	0.8%	2.1	2	11.3%
Virtual cities	131	36	0.0%	0.8	3	10.8%
OpenRAN	0	0	0.0%	0	3	12.5%
Quantum computing	735	1537	0.7%	1.1	5	9.4%
Semiconductors	16601	8054	1.6%	1.7	9	7.4%
Space architecture - Habitats	1368	0	1.4%	0.7	5	9.4%
Space architecture - Mining	419	0	1.6%	1	3	8.9%
Sustainable 6G - Automatic management	12	0	0.0%	0.6	4	6.2%
Sustainable 6G - Energy efficient edge infrastructure	10	0	0.0%	2.3	4	9.6%
Sustainable 6G - Materials	1665	71	3.5%	1.2	6	7.0%
Autonomous vehicles	820	1328	2.1%	0.8	7	7.7%
Urban Air Mobility	1789	0	0.6%	1.5	6	9.1%

The scorecard above contains factors analyzing Saudi Arabia's position per research topic; they are defined as:

- Research Strength:** Total number of Saudi Arabian research papers multiplied by CNCI. 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 publications with the same document type, year of publication and subject area.

- **Invention Strength:** Total number of Saudi Arabian inventions multiplied by DSI. A Clarivate metric of the strength and quality of a patented idea. Based on the impact of the invention on others (based on the frequency of downstream citation by the patent applications of third parties), the global footprint of patents granted (based on the % of world GDP covered by the patent asset), the investment level in the invention by the applicant (based on the number of patent jurisdictions in which the applicant sought protection) and the inventions rarity (based on the number of inventions in the global database that share the same technology mix).
- **Partnership Strength:** The mean partnership % for research papers and inventions in Saudi Arabia.
- **Research Productivity:** The productivity relative to global productivity is measured by the number of Saudi Arabia papers on a specific research topic divided by the number of global publications in the same research topic and period.
- **Technology Maturity:** Each of the research topics within the National Priority Areas has been mapped to individual Technology Maturity Index from 1 - least mature through 9 - most mature.
- **Future Predicted Growth:** CAGR predicted growth extrapolated from historic inventions level.

AI in ICT in Saudi Arabia has very high Research and Invention strength, the highest research strength across all RDIA priority technologies. The overall partnership level is relatively low at 0.8%, and medium-level research productivity is 1.9. There is a high predicted growth of 10.9% and a medium technology maturity of 4. With 21,983 research papers and 561 inventions, this balance is exactly as expected for a high growth, low technology maturity field. Saudi Arabian AI in ICT inventions is led by Saudi Aramco with 175 inventions, accompanied by King Abdulaziz University with 11 relatively strong inventions; KFUPM has 33 inventions of slightly older age. Given the strong research base led by King Abdulaziz University, followed by King Saud University and Prince Sattam Bin Abdulaziz University with 3799, 3367 and 1982 publications, respectively, it is recommended to further fund these academic local institutions. As AI in ICT is such a fast-moving field, and patentability difficulties of algorithms, software, and potential open-source models in AI, partnering with leading international corporations may deliver a significant boost to Saudi Arabia's AI innovation eco-system. Leading organizations in AI include Amazon, Samsung, Alphabet, IBM, Microsoft, Capital One, Alibaba, Baidu and Tencent; notably, LG has a small but very strong AI portfolio. Samsung, for example, has 88 inventions via an ACP with Seoul National University. Notable international academic institutions include the South China University of Technology, Xi'an Jiatong University, Beijing University of Technology, Xidian University and Beihang University, all with over 1,200 inventions within AI in ICT. It is predicted that AI in ICT could add \$0.28 billion to Saudi Arabia's economy if 1,667 inventions are protected in this field; the likely yield would be around six very strong inventions.

Quantum Computing has a low research strength derived from the volume of papers and CNCI, whereas it has a relatively high invention strength score for Saudi Arabia. ACP levels are low at 0.7%, research productivity mid-level at 1.1 and medium technology at 5, with medium predicted growth of 9.4%. There were 662 research papers compared to only 45 inventions. Considering the medium technology maturity, it is recommended to focus on early-stage academic research through local institutions such as established Quantum Computing researchers such as KAUST and KACST, alongside slightly newer King Abdulaziz University, Imam Abdulrahman Bin Faisal University, Saudi Aramco, and King Fahd University of Petroleum & Minerals. International collaborations with established innovators such as Samsung, Alibaba, Alphabet, Toshiba, Microsoft, D-Wave, Huawei, NEC, and Northrop Grumman. Newer high-strength innovators include IBM, Baidu, and BOE, alongside academic institutions such as Fuzhou University, Central South University, University System of

Maryland, Tsinghua University, and the largest innovator in the dataset, the Chinese Academy of Sciences, holding 1,026 inventions.

Semiconductors perform similarly to AI in ICT for Saudi Arabia, as a high research and invention strength technology, high technology maturity. Semiconductors have low predicted growth compared to other technologies; there are high invention levels globally. High ACP and research productivity are observed as well. Overall, over 11,000 semiconductor research papers have been published in the last 10 years, compared to only 254 inventions, which suggests a low translation of academic research into commercially applied research. Subsequently, it is recommended to focus on converting more research papers into inventions from King Saud University, followed by King Abdullah University of Science & Technology and King Abdulaziz University with 2,078, 2,051 and 1,848 publications with relatively high research paper output, and partners with corporations such as but not limited to TSMC, Samsung, Infineon, Applied Materials, STMicroelectronics, SK Hynix, Intel, KIOXIA Corporations, Fuji Electric, Micro, Sony, Global Foundries, Tokyo Electron, BOE, Hon Hai Precision, Semiconductor Energy Laboratory, ams-OSRAM, LG or Shin-Etsu Chemical. The local Saudi organizations with the highest semiconductor output are KAUST, Saudi Aramco, KACST, and more recently, King Abdulaziz University and Imam Abdulrahman Bin Faisal University have produced a relatively strong portfolio of 15 and 5 inventions, respectively. It is predicted that Semiconductors could add \$0.58 billion to Saudi Arabia's economy if 1,667 inventions are protected in this field, and if 1,667 inventions are protected in this field, the likely yield would be around 13 very strong inventions.

Sustainable 6G Automatic Management, Sustainable 6G Energy Efficient Edge Infrastructure and Sustainable 6G Materials represent a group of highly specialized technologies that operate in telecommunications, which is often led by a small group of very large telecommunications organizations. Automatic management and Energy Efficient Edge Infrastructure have low research strength compared to the medium research strength of Materials. Interestingly, 6G materials have high ACP levels, and 6G materials have high ACP levels and a strong invention strength; however, with no ACPs, both 6G - Automatic Management and Energy Efficient Edge Infrastructure have no inventions from Saudi Arabia. All three technologies have medium technology maturity and low to medium predicted growth. Saudi Aramco holds one invention in the field of 6G materials, as 6G development appears to not be a strategic initiative for Saudi Aramco; this technology may be more appropriate for organizations such as STC within Saudi Arabia or to fund local academic institutions, who have contributed to 6G material research publication apply the academic research to more commercial use cases. International organizations with significant invention portfolios in these 6G areas include Qualcomm, ZTE, Intel, Apple, Sony, Verizon, TSMC, Baker Hughes, ConocoPhillips, and Halliburton.

OpenRAN is a white space area for Saudi Arabia with no research papers of inventions from the Kingdom, notably OpenRAN has very low inventions levels globally, and has a technology maturity level of 3. It is a technology worth monitoring as it has high predicted invention level growth of 12.5%.

Cognitive Cities technologies span Air Quality, Traffic, Energy or Resource Management, Citizen Engagement, Data Ownership & Privacy, Predictive Analytics, Decision Algorithms and Virtual Cities in Saudi Arabia have medium research strength across Data Ownership & Privacy, Air Quality, Traffic, Energy or Resource Management and Predictive Analytics; however, there is low invention volume and strength, and ACPs across all five technologies within Cognitive Cities. These technologies align with Mission 4.3 Going beyond Smart Cities, establish 5 Cognitive Cities in Saudi Arabia by 2040. The low levels of inventions are to be expected due to the low technology maturity in all technologies apart from Air Quality, Traffic, Energy or Resource management, which is a medium-maturity technology. There is high research productivity in Data Ownership & Privacy and Predictive Analytics, Decision Algorithms. Overall, the invention levels are low compared to other technologies from Saudi Arabia, with Saudi Aramco owning one invention in each of Citizen Engagement, Predictive Analytics, Decision Algorithms and Virtual Cities. The importance of developing Cognitive Cities is very clear for

Saudi Arabia; the giga-project Neom showcases the capability to lead in cutting-edge technology, design and re-imaging how cities operate for decades into the future. It is recommended that the innovation created in these projects be captured and protected so that it can be re-purposed into future projects or commercialized into international territories. King Saud University and King Abdulaziz University are among the top 3 organizations in all these research topics. International organizations excelling in Cognitive City-related technology are notably populated with many academic institutions from Mainland China, further signaling the immaturity of these technologies. Large established organizations such as IBM, Johnson Controls, Capital One Sense time hold small portfolios in Virtual Cities, Hitachi, Ping An Insurance in Citizen Engagement, TongTech, Tele-Commuter Resources in Data Ownership & Privacy, and CAVH LLC, Ping AN Insurance, Chengdu Qinchuan IOT Technology in Predictive Analytics. The presence of numerous Mainland China corporations, Universities and public institutes showcases the aligned ambitions of Saudi Arabia and Mainland China to build future-proof cutting edge Cognitive Cities.

Space Architecture - Habitat and Mining technologies in Saudi Arabia linked to Mission 4.1 to Establish habitats on Mars by 2050, and 4.2 to Establish a permanent output on the Moon by 2040. Habitat technologies have a medium research volume and CNCI; while having no inventions, Mining technologies have a low research volume and CNCI, and also no inventions. There are high levels of research partnerships, no invention partnerships, medium technology maturity for Habitats and low maturity for Mining technologies. Research should be further funded at King Abdulaziz University, King Abdullah University of Science & Technology, and King Saud University to produce more papers. Globally, there are low levels of inventions in these two technologies; corporations with the largest and strongest portfolios for Habitat technology: Honeywell, Thales, Boeing, Airbus, NASA, and RTX Corporations - notably, these organizations have Space Aviation or Defence-related focuses, this explains their innovation relationship with hazardous environment. Within the Space - Mining technologies, Airbus and Boeing have small portfolios of 2-3 inventions, and Astrobotic holds three newer and stronger inventions.

Urban Architecture technologies relating to **Autonomous vehicles** and **Urban Air Mobility** have a complementary fit with the Cognitive City technologies and relate more to technologies flowing within the architecture and management of passenger transportation. While Autonomous vehicles have low research volume and CNCI combined with medium invention volume and strength, Urban Air Mobility has the reserve scores. This can be correlated to high collaboration and technology maturity for Autonomous vehicles, whereas Urban Air Mobility has low collaboration and medium technology maturity. Autonomous vehicles would benefit from further ACP to boost invention levels; inventions in Saudi Arabia have been generated by Saudi Aramco, KAUST, Imam Abdulrahman Bin Faisal University, KFUPM and Umm Al Qura University; these organizations hold between 4-20 inventions. International organizations in this field with both high volume and high-strength established portfolios include Komatsu, Johnson Matthey, General Motors, Continental, Vitesco, Volvo, Umicore, Honda, Toyota, Denso, Zhejiang Geely Holding Group, Burelle. Newer high-strength portfolios include NGK Insulators, Cummins, Ford, Hyundai, Porsche Automobile Holdings, Kia and Forvia. Ford, Porsche Automobile Holdings, Hyundai, and Toyota all hold over 500 inventions each and, therefore, could significantly boost Saudi Arabia's ACP-generated inventions and overall invention numbers.

In conclusion, Economies of the Future contains many diverse technologies, including the sixteen focussed on through the deep-dive section of this study. Only Semiconductors and Autonomous vehicles are high-maturity technologies; Semiconductors are an area of relatively high volume and strong inventions within Saudi Arabia- Saudi Arabia has recently established the National Semiconductor Hub - which plans to attract 50 semiconductor design companies to Saudi Arabia by 2030. AI in ICT is another large research and invention strength for Saudi Arabia; this is led by Saudi Aramco with 175 inventions; Saudi Aramco also has an academic-corporate partnership with KAUST, underpinned by the AI Hub at Saudi Aramco. Due to the size and speed at which AI technologies are moving globally, it is recommended that Saudi Arabian academic institutions and Saudi Aramco further partner with

international leaders in AI technologies and Mainland China Universities, many of which hold 1,000+ AI inventions each. The recent creation of the Saudi Authority for Data and Artificial Intelligence to set the national AI direction and oversee the implementation of artificial intelligence and data within the Kingdom. The combination of AI and Semiconductor technologies is evident from the industry leadership of international corporations such as but not limited to Nvidia, TSMC and Samsung. There is a significant opportunity and white space in the technology landscape for Saudi Arabia to lead the way with the further development of Cognitive city innovation which can be deployed into giga-projects such as Neom. Telecommunication technologies such as OpenRAN and Sustainable 6G technologies are not currently research or innovation strengths for Saudi Arabia, nonetheless, recently announced partnerships such as that between Ericsson and KAUST could accelerate the depth and capacity to produce technologies of the future.

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 for primary through tertiary education, we limit and define for the purposes of this study the tertiary sector only. However, note that 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. This study is specific to understanding the level of commercialization activity and the 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 by law to act as a legal person, distinct from the natural persons owning or operating within the entity. Corporate entities can enter contracts, own assets, and are subject to taxation while providing limited liability protection to their owners.

Innovation

Refers to 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 direction of creativity, technical knowledge, and information and can target the conversion of new and useful products and services. In this study, we focus on the definition of 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 publications surrounding the single invention/idea and, in turn, transforms the collection of multiple patent publications into metadata 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 at a specific time, using current prices without adjusting for inflation. Presented here in US dollars.

6.2 Patent related definitions

Patent

A patent is a legal instrument that grants an inventor exclusive rights to use, sell, or manufacture their invention for a limited period, typically 20 years, in exchange for public disclosure of the invention.

Patent Assignee

A patent assignee is the individual or entity that holds the ownership rights to a patent. This transfer of rights is typically formalized through a written contract or assignment agreement, which grants the assignee the exclusive rights to the patented invention, including the right to make, use, sell, or license the invention. The assignee assumes all associated rights and responsibilities from the original patent holder, known as the assignor. Typically, the assignment takes place because of employment contracts that require employees to assign intellectual property rights to their employer for creating an invention during their employment.

Patent Family

A patent family refers to a collection of patent applications or granted patents that are related to each other and cover the same or similar technical content. These related publications are typically filed in different countries,

originating from a single priority application or a set of priority applications. The concept of a patent family is instrumental in tracking the legal protection status of inventions globally and is recognized by various patent offices and databases. The family definition used in this study is specific to the Derwent World Patents Index™, which provides for a synonymous relationship between each family and an individual invention – e.g., one specific set of claims language (the section of a patent document detailing what is protected) in each legal jurisdiction in which protection has been sought.

Patent Jurisdiction, Patent-Issuing Authority

Refers to the legal authority granted to a country or region over the creation, use, and enforcement of patents within its territory. This includes the power to grant patents, determine their validity, and adjudicate disputes related to patent infringement. The jurisdiction is defined by the territorial scope within which the patent rights are applicable and enforceable, and it is typically the responsibility of national or regional patent offices to oversee these legal rights. Notably, patents are local rights that are only valid and have exclusivity within the jurisdiction of the patent office. There are multiple "regional" patent jurisdictions, such as the European Patent Convention or the Gulf Cooperation Council Patent Office.

Patentability

In order to be valid, a patent application needs to fully disclose an invention so that it can be understood by the average person with training in the technical field, and it must be novel (never seen in the public domain before), useful (typically, it must have a real-world use, and must actually work) and not be an obvious extension of previous technology (typically, simply combining multiple previous ideas together).

Technical maturity index (TMI)

A mathematical model that aggregates global scientific,

engineering, and technological structured disclosures (i.e., peer-reviewed scientific papers and patented inventions) alongside assertion of technology to empirically measure the maturity of a technology field, approach or use case. It can be used to assess differing fields and sectors alongside each other due to the normalization of measures incorporated into the model.

Technical readiness level (TRL)

A scale is used to estimate the maturity of a technology during the acquisition phase of a program. It provides a consistent and uniform discussion of technical maturity across different types of technologies. The scale ranges from 1 to 9, with 9 being the most mature technology. TRL assessments are critical in managing the progression of technology from conception to deployment. Originally created in the 1970s by NASA as a way of managing technical development readiness and safety for human spaceflight, the TRL system has been widely adopted by the International Standards Organization in 2013 as a qualitative measure of basic, through applied and then commercialized technology progression. In this study, TRL and TMI become synonymous - as the advanced measurement of global public science, research and technology assertion is captured and mathematically modeled so that it maps empirical measures of maturity onto (in relative terms) the structure of a TRL.

6.3 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, citation is a significant source of impact metadata, 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.

Citation Topics

Citation Topics are named document clusters based on cited and citing relationships between publications. 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 labeled 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 publications, topics are labeled 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 the Clarivate website.

Papers/publications/publications

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 are used exclusively to refer to substantive journal articles, reviews, and proceedings papers.

Researcher Affiliation

Researchers affiliated organization. A single researcher 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.

6.4 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 centers, 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, Sustainability and Essential Needs, Energy and Industrials, 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 and 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.

6.5 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.

Darts-ip™

Darts-ip is a comprehensive database and analytics platform that provides detailed information and insights on intellectual property (IP) litigation cases globally.

Derwent World Patents Index™

The Derwent World Patents Index (DWPI) is a comprehensive database that compiles patent applications and grants from 59 patent-issuing authorities worldwide. It provides abstracts in English, detailing the nature and use of inventions, and indexes them into technology categories for easy retrieval. DWPI also defines patent families, linking related patents globally around a Basic Patent (the first disclosure of the invention appearing in the database), facilitating the tracking of an invention's

protection status internationally as further applications or granted patents published in multiple patent jurisdictions.

6.6 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 publications 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 publications, for example, the collected works of an individual, institution or country/region, is the average of the CNCI values for all the publications 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 the global average.
- Values above 1 are considered above average.
- Values below 1 are considered below average.
- A CNCI value of 2 is considered twice the global average.

CNCI is an ideal indicator for benchmarking at all organizational levels (institution, region etc.). When dealing with small sets of publications, though, 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 the InCites website.

Growth and Average Growth

In this study, we visualize the evolution of the number of Web of Science publications for a certain entity and period. To quantify the change in the number of publications from one year to another, we use the growth. The growth is then the number of publications in the most recent year (Ny2) subtracted from the number of publications 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 is the arithmetic average of the growth from one year to another in that period. Sometimes, a considered entity does not have publications 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 publications with funding acknowledgment and the corresponding funding agencies.

Industry Collaboration

Papers that contain two or more Organizations with at least one Organization listing its organization type as corporate or global corporate. An industry collaborative publication is one that lists its organization type as "corporate" or "global corporate" for one or more of the co-author's affiliations. It's not possible to unify data for every affiliation of all publications in InCites; therefore, only unified entities have an organization type. There will be corporate affiliations that are not yet unified and without an organization type. As such, these affiliations will not identify as an industrial collaboration. Clarivate Analytics has made considerable efforts to identify the largest

corporations and unify them; however, these efforts tend to focus on large multinational corporations and may lead to regional bias.

International Collaboration

Papers that contain one or more international co-authors.

Emerging Trends

To investigate emerging trends globally and in Saudi Arabia in a research topic, we use the micro-topics as defined in the Citation Topics schema that is explained in the section **Citation Topics**.

To identify the emerging trends, we identify the top 20 micro-topics in the research topic in terms of the growth of the number of publications in the micro-topic from 2014 to 2023. We then rank the top 20 micro-topics in terms of difference in the share of citations from total citations in the research topic between 2014 and 2023. The growth in terms of publications identifies micro-topics within the research topic that have grown fastest within the considered period. The difference in citation share from the total citations in the research topic identifies micro-topics that have also grown their relative number of citations in the research topic, which reflects that these topics are also trending among the researchers active in the research topic.

Invention Strength

A Clarivate metric of the strength and quality of a patented idea. Based on the impact of the invention on others (based on the frequency of downstream citation by the patent applications of third parties), the global footprint of patents granted (based on the % of world GDP covered by the patent asset), the investment level in the invention by the applicant (based on the number of patent jurisdictions in which the applicant sought protection) and the inventions rarity (based on the number of inventions in the global database that share the same technology mi

هيئة تنمية البحث
والتطوير والابتكار
Research Development
and Innovation Authority

