

# Scientific and Technical Innovation in the UAE: A Capability-based Approach

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## **About the Growth Lab**

The Growth Lab's multidisciplinary team, led by Professor Ricardo Hausmann, pushes the frontiers of research on economic growth and development policy. The Growth Lab advances academic research on the nature of economic growth and conducts applied, place-based engagements that aim to understand context-specific growth processes, address key constraints, and identify promising opportunities. Key frameworks developed at the Growth Lab include Growth Diagnostics and Economic Complexity. Growth Diagnostics is a systematic methodology that aims to identify the most binding constraints to better growth outcomes, allowing policymakers to take the most impactful actions. Economic Complexity is a growing field of research that sees the economy as composed of distributed knowledge and productive capabilities that must be networked in order to be used in production and sees growth as the expansion of both the underlying knowledge and its uses. Through its research and teaching activities, the Growth Lab has become a global thought leader offering breakthrough ideas, methods, and tools that help policymakers, stakeholders, and scholars find ways to accelerate economic growth and expand opportunity across the world.

## **Acknowledgements**

This report was produced in the context of the ongoing collaboration between Harvard's Growth Lab and the Ministry of Economy of the United Arab Emirates (UAE), which aims to produce novel research-based inputs to inform an ambitious, forward-looking economic policy agenda. The goal of this collaboration is to provide rigorous research that can support the Ministry of Economy and related policy-making entities in their mission of promoting high-quality, sustainable growth and fostering structural transformation in the UAE.

## Contents

|                                                                                        |    |
|----------------------------------------------------------------------------------------|----|
| Executive Summary .....                                                                | 7  |
| Introduction .....                                                                     | 10 |
| 1. Innovation and its Importance for the UAE. ....                                     | 10 |
| 2. UAE's Performance in Innovation Activities .....                                    | 13 |
| 2.1 The Output of the R&D Sector .....                                                 | 13 |
| 2.2 UAE's Research Production Function.....                                            | 17 |
| 2.2.1 An Overview of the R&D Inputs.....                                               | 17 |
| 2.2.2 Understanding the UAE's Human Capital Innovation Capabilities .....              | 21 |
| 2.2.3 Understanding Expenditures and Investments in R&D .....                          | 29 |
| 2.3 The Productivity of the R&D Sector. ....                                           | 32 |
| 3. Leveraging UAE's Capabilities .....                                                 | 37 |
| 3.1 UAE's Capabilities in Fields, Technologies, and Industries .....                   | 37 |
| 3.1.1 Overview of Fields, Technologies, and Industries .....                           | 37 |
| III.1.2 Nearby Opportunities for the UAE .....                                         | 41 |
| 3.2 The Role of Foreign Firms and International Universities .....                     | 48 |
| Box 1: The Cases of Borouge and UPL Ltd.....                                           | 55 |
| 3.3 The Role of Scientific Collaboration .....                                         | 56 |
| 4. Ideas for Science & Innovation Policy.....                                          | 66 |
| 5. Conclusion .....                                                                    | 69 |
| References .....                                                                       | 70 |
| Appendix 1: Additional Descriptives .....                                              | 74 |
| Appendix 2: Density as a Predictor of Future Technological and Scientific Capabilities | 78 |

## List of Figures and Tables

### Figures

|                                                                                                             |    |
|-------------------------------------------------------------------------------------------------------------|----|
| Figure 1. Scientific Publications per Million People and GDP per Capita (2021) .....                        | 14 |
| Figure 2. Patents per Million People and GDP per Capita (2021) .....                                        | 15 |
| Figure 3. Scientific Works per Million People in GCC countries (2010-2021) .....                            | 16 |
| Figure 4. Patents per Million People and Top 1% Patents per Million People (2010-2021)<br>.....             | 17 |
| Figure 5. Global Innovation Index 2022: Input Score and Output Score .....                                  | 18 |
| Figure 6. Input Sub-Indexes: UAE vs. Peers .....                                                            | 19 |
| Figure 7. Human Capital and Research Sub-Indexes .....                                                      | 20 |
| Figure 8. Inbound Tertiary Students per Million People and GDP per Capita (2019).....                       | 21 |
| Figure 9. Advanced Studies and STEM Students per Thousand People and GDP per<br>Capita .....                | 22 |
| Figure 10. Workers in STEM Occupations per Thousand People and GDP per Capita<br>(2021) .....               | 23 |
| Figure 11. Full-Time Equivalent (FTE) Researchers and GDP per Capita (2021) .....                           | 24 |
| Figure 12. Share of FTE Researchers in Total Knowledge Workers .....                                        | 25 |
| Figure 13. FTE Researchers per Million People and GDP per Capita, by institutional sector<br>(2021) .....   | 26 |
| Figure 14. Research Employment Index, by Performance Sector (2018-2021) .....                               | 27 |
| Figure 15. Researchers in the Labor Force and Weighted R&D Intensity of Industry and<br>Exports .....       | 28 |
| Figure 16. Expenditures per Researcher and Researchers per Million People in the Labor<br>Force (2021)..... | 29 |
| Figure 17. Gross Expenditures in Research and Development, GDP per Capita (2021) 30                         |    |
| Figure 18. Research and Development Expenditures (2014-2021) .....                                          | 31 |
| Figure 19. Gross Expenditures in Research and Development, by Performance Sector                            | 32 |
| Figure 20. Researchers per Million People and Research Output.....                                          | 33 |
| Figure 21. Gross Expenditures in Research and Development (GERD) and Research<br>Output .....               | 34 |

|                                                                                                           |    |
|-----------------------------------------------------------------------------------------------------------|----|
| Figure 22. Productivity per Researcher and Expenditures per Researcher .....                              | 35 |
| Figure 23. UAE's Scientific Fields, sized by the number of works with more than 5 citations.<br>.....     | 38 |
| Figure 24. UAE's Technological Fields, sized by Patent Fractional Counts (2017-2022).<br>.....            | 39 |
| Figure 25. Industry of Patent Assignees, sized by Patent Fractional Counts (2017-2022)<br>.....           | 40 |
| Figure 26. Patent Production Intensity and Quality (2017-2022) .....                                      | 41 |
| Figure 27: UAE's Diversification into New Scientific Fields .....                                         | 42 |
| Figure 28. UAE's Diversification into new Technology Classes.....                                         | 43 |
| Figure 29. Global Trends and UAE's Opportunities. ....                                                    | 44 |
| Figure 30. Number of Patent Families where the Assignee is a Firm, by Ownership (1980-<br>2020) .....     | 50 |
| Figure 31. Scientific Productivity of UAE Institutions Over Time .....                                    | 50 |
| Figure 32. Agents that Introduced a Technology Sub-Class for the First Time (1970-2021)<br>.....          | 51 |
| Figure 33. Patent Families by Technology Cluster and Foreign Ownership Presence ...                       | 52 |
| Figure 34. Average Patent Asset Index, by Year of Filing .....                                            | 53 |
| Figure 35: UAE Institutions by Country of Parent Institution.....                                         | 54 |
| Figure 36. Median Distance from Capabilities to Other Technological Sub-Classes .....                     | 55 |
| Figure 37. Collaborations in Scientific Publications for UAE vs. USA .....                                | 58 |
| Figure 38: Collaborations in Scientific Fields for UAE, Adjusted by General Prevalence of<br>Works .....  | 59 |
| Figure 39: Co-authorships between UAE and Other Countries .....                                           | 61 |
| Figure 40: Residuals for UAE from Gravity Model of International Scientific Collaboration<br>Network..... | 62 |
| Figure 41: International Scientific Collaboration Network .....                                           | 63 |
| Figure 42: Degree Centrality Ranks in the International Scientific Collaboration Network.<br>.....        | 64 |

|                                                                                                         |    |
|---------------------------------------------------------------------------------------------------------|----|
| Figure 43: Betweenness Centrality Ranks in the International Scientific Collaboration Network.....      | 64 |
| Figure 44: Eigenvector Centrality Ranks in the International Scientific Collaboration Network.....      | 65 |
| Figure 45. Publications per Million People and GDP per Capita, Adjusted by Natural Resources Rent ..... | 74 |
| Figure 46. Patents per Million People and GDP per Capita, Adjusted by Natural Resources Rent .....      | 74 |
| Figure 47. Fastest Growing Technologies in the World.....                                               | 75 |
| Figure 48. Biggest Technologies in the World .....                                                      | 75 |
| Figure 49: Evolution of the International Scientific Collaboration Network.....                         | 77 |

## Tables

|                                                                                                                |    |
|----------------------------------------------------------------------------------------------------------------|----|
| Table 1: Sub-sample of Top Nearby Opportunities for the UAE in Patenting (Intensive Margin).....               | 46 |
| Table 2: Sub-sample of Top Nearby Opportunities for the UAE in Patenting (extensive margin).....               | 47 |
| Table 3: Sub-Sample of Top Nearby Opportunities for the UAE in Scientific Publications (intensive margin)..... | 48 |
| Table 4: Sub-Sample of Top Nearby Opportunities for the UAE in Scientific Publications (extensive margin)..... | 48 |
| Table 5: Gravity Model of International Scientific Collaboration Network.....                                  | 61 |
| Table 6: Institutions with Foreign Relationships Publishing in the UAE.....                                    | 76 |
| Table 7: Predicting growth in scientific publications using density.....                                       | 78 |
| Table 8: Predicting growth in patenting activity using density. ....                                           | 79 |

## Executive Summary

The success or failure of the United Arab Emirates' (UAE) mid- and long-term growth strategy will in large part be determined by innovation. The country aims to continue transitioning from its past focus on oil and gas, energy-intensive products and re-exporting services to a future economic model increasingly relying on high-value, knowledge-intensive goods and services. A successful transition will necessitate importing and adapting frontier foreign innovation, but also creating a world-class innovation ecosystem at home.

Part of this effort will entail developing further the country's Research and Development (R&D) capabilities. While significant catch-up is already visible, much remains to be done to bring the UAE's R&D output in line with the ambitions assigned by its leadership. The production of scientific publications and patents has been rapidly increasing over the past few years. However, the current level of scientific publications and international patenting activity remains below that of aspirational peers, such as Singapore and Norway, but also fellow Gulf Cooperation Council (GCC) countries, such as Qatar and Saudi Arabia.

One of the reasons may be simple: there are not enough researchers in the UAE. The proportion of researchers in the UAE's workforce is below what is expected for such an advanced economy. While the UAE has been successful at attracting foreign students and skilled workers, including in STEM fields which underpin R&D activities, this has not translated into a higher density of researchers in the labor force. Determining whether that results from low current demand for R&D skills due to the country's current economic structure or from difficulties in producing or attracting R&D talent is difficult, although both likely contribute to the issue.

Overall, R&D spending seems adequate. Contrary to researchers' headcount, the UAE's expenditures in R&D are close to what is expected level given the country's level of prosperity. These expenditures have in fact been rapidly increasing in the last few years, both in real terms and as a share of GDP, in line with the goals of the *National Innovation Strategy*. There are, however, less positive signs. R&D expenditures from the business sector (which includes State-Owned Enterprises) are, depending on the chosen metric, below or close to their expected level. The government's R&D spending is among the world's highest, while spending by the higher education sector is lower than most peers. Overall, this paints a picture of a government-led R&D push, which may prove less cost-efficient and less scalable than more diffuse, organic investments led by private and academic actors.

In fact, there is an increasing question of value for money. Although returns to R&D spending may not be immediate, some signals point to a mismatch between the level of

R&D investment and the current level of R&D output. Considering the researchers' headcount, the research output in patents and scientific publications is close to its expected value. However, looking at expenditures, the research output is well below what would be expected. In terms of research output per dollar spent, the UAE exhibits one of the lowest levels of R&D productivity in the world.

Increasing the return on the UAE's R&D investments may require unpacking the issue further and taking a closer look at the UAE's strengths and weaknesses by scientific or technological area. Since the early 2010s, the UAE's rapid growth in scientific publications was led by Computer Science and Medicine. The more modest growth in international patenting was powered by Biotechnology and Electronics & Telecommunication. However, growth was not confined to a handful of fields and the country has also strongly diversified its research output.

Considering the attractiveness of each research area as well as the existing R&D footprint of the UAE, we identify two types of opportunities. First, the country could double down on selected areas of strengths: in research areas that see high global growth and where the UAE already has a meaningful presence, local R&D output could be increased by building around actors which have a proven record of high-quality research in that area. Such areas of opportunity include for instance hydraulic and software engineering. A second approach could focus on attractive research areas that are globally growing, currently untapped but adjacent to existing UAE R&D capabilities. Those include for instance computational models or nuclear physics.

Foreign investment and international scientific collaboration are two prime channels to develop scientific capabilities in new areas. Foreign R&D by global players can foster collaboration and knowledge exchange, while also enhancing local innovation, as the UAE's experience shows. Historically, foreign firms were major contributors to UAE patenting efforts, while recently, local universities like Khalifa University have gained prominence as well. Despite not being the primary introducers of new technologies anymore, foreign firms and universities play a significant role in patenting in various technological clusters and provide valuable knowledge inputs, including in sectors where they support State-Owned Enterprises.

Beyond quantity, foreign actors can bring high-quality R&D. Patents by foreign entities are generally more valuable and globally influential, while the quality of local patents is uneven. Regarding scientific publications, the country of origin of academic institutions seems to matter for the quality of the research output. Local US-based institutions seem to produce especially high quality research, highlighting the value of well-chosen cross-border partnerships.

The UAE's record of scientific collaboration shows how they cross-border collaboration has been instrumental to some recent technological successes, while also pointing to areas for improvement. The UAE is already leveraging scientific collaboration as a key tool for innovation and acquiring scientific capabilities, particularly in AI and other STEM fields. The UAE's current collaborations are mainly focused on Computer Science, Environmental Science, and Materials Science, and are primarily with institutions from countries like the United States, the United Kingdom, China, India, Australia, and Saudi Arabia. This reflects, like for most other countries, a pattern of collaboration concentrating on countries with a large R&D sector and overall decreasing with geographical distance. When controlling for these factors, our analysis finds that the UAE may have major opportunities to expand collaboration with research institutions in certain countries including China, Germany, Spain, and Japan.

To develop further the UAE's innovation ecosystem in a significant, sustainable, and cost-effective manner, a range of public policies will be crucial. Strengthening the local R&D ecosystem will have to rely on increased R&D demand from economic actors, which ties back to a broader industrial policy agenda encouraging high-productivity diversification. However, innovation policy can help as well. Key strategies may include expanding the number of researchers by leveraging talented local and foreign STEM students. Introducing research activities in their curriculum through research assistantships or other schemes has been effective in other countries to foster career interest in research and increase scientific productivity. Programs focusing on attracting foreign "star researchers" has also proven effective to spur innovation in new areas and can be especially relevant as a complement to junior local talent. Sovereign Wealth Funds and SOEs can also play a role through targeted acquisitions and joint ventures for R&D growth, following a model that has already proven successful. The use of Free Zones has also proven effective in attracting R&D investments, particularly in AI and Computer Science and should be continued. Finally, it is essential to ensure that policymakers can rely on reliable data to guide policy. For instance, generating and making available firm-level indicators related to R&D expenditure composition or intangible capital stock will be essential for coordinated, effective innovation policy in the UAE.

## 1. Innovation and its Importance for the UAE.

**Technological progress and innovation allow us to understand the dynamics of economic growth and competitiveness.** This technological progress is shaped both by the number of ideas created in a society and its sophistication when connected to the economic system of a country. These ideas are created and shaped by the knowledge embodied in tools, codified in patents, and tacitly embedded in the brains of workers. Thus, the scientific and technological knowledge stemming from innovation activities can be understood as how an economy allows for the recombination of its local capabilities into new sets of products and production processes. The development of these scientific capabilities can potentially lead to future industrial competitiveness and economic prosperity (Hausmann et al., 2024b, 2024a).

**Measuring the level of innovation within an economy poses challenges, but patents filed internationally and scientific publications serve as useful, internationally comparable indicators.** In general, patenting and publishing are relatively uncommon for firms, as they prefer to engage in other forms of R&D, such as trademarks and trade secrets (Mezzanotti & Simcoe, 2023). This makes the measurement of R&D activities in the universe of firms in an economy especially challenging. However, publications and patents are especially concentrated in the firms that spend the most on Research and Development (R&D). At the same time, firms operating at the global productivity frontier demonstrate a higher propensity to patent while also being larger and more profitable (Saia et al., 2015). As these companies tend to concentrate most of the R&D expenditures, patents, and publications become useful proxies of the state of innovation of a country.

**Innovation and technological diffusion are key to sustained economic growth.** Strong innovation and technological diffusion increase productivity, both by developing new high-productivity activities and by enhancing the productivity of existing ones. The creation and adoption of new technologies by an economy are associated with higher economic growth in the future, especially through increased productivity growth (Comin & Mestieri, 2018). The UAE has managed to transform an economy built around oil extraction into an economy able to produce and export sophisticated services. Moving forward, a combination of innovation and technological adoption will be required as the country advances towards a new stage of development that spurs further economic growth.

**As the UAE enters different stages of development, the model of diversification changes from one based mainly in technological adoption to one based in pushing innovation at the frontier.** Economies introduce new export products, or “discoveries”, at lower levels of development and rely more on innovation after a high-income point where they become more specialized (Klinger & Lederman, 2006). The UAE has managed to diversify its export basket in recent decades and, as its leading firms get closer to the

global productivity frontier, continued R&D investment will allow it to keep adding innovative capabilities to the economy while retaining existing ones. An economy with a diversified set of innovative capabilities could potentially sustain non-oil economic growth while transitioning to a knowledge-based economy.

**Through technological adoption, the UAE can accumulate capabilities that can be recombined for economic production or shaped in different forms through innovation.** As the UAE moves forward in its current diversification path, the country will need a combination of technological adoption and innovation at the frontier. Technological adoption to capture the capabilities already created and available in other parts of the world. Innovation to recombine these capabilities and invent new processes, new services, and new products. The continued acquisition and diversification of these capabilities will allow the country to absorb existing ideas and generate spillovers to other sectors of the economy. This process of accumulation of related and unrelated knowledge would create the conditions for an ecosystem that can produce breakthrough innovation that has a more significant technological and economic impact.

**Economies are not limited to their local stock of knowledge but also benefit from incoming knowledge flows.** In this regard, the UAE finds itself in a privileged position to accumulate and create new knowledge. The country is currently undertaking efforts to sign trade agreements that could improve these linkages with other countries through investment attractions, while at the same time being able to attract a sizeable number of foreign researchers. The UAE will likely be able to attract related knowledge, but its diversity can potentially play a role in attracting and retaining unrelated knowledge bases. Moreover, these factors play a role and will continue to do so in how innovation in the country happens, as they are important elements of proximity.

**Different dimensions of proximity are key drivers of interactive learning and innovation, ranging from organizational to geographical aspects.** Bochsma (2005) outlines five different types of proximity that play a role in how innovation happens and how its intensity can be beneficial or detrimental to the output of a firm: cognitive, institutional, organizational, social, and geographical. Cognitive proximity allows for the assimilation of related ideas as previously discussed, while institutional proximity provides the formal and informal structure where the interactions happen and benefits from openness and stability. Related to migration and investment attraction policies, are organizational, social, and geographical proximity for which the innovation sector can benefit from current policies in the next few years.

**The attraction of researchers to the UAE could favor an environment where social and geographical proximity improves.** When researchers arrive in the UAE, they bring their knowledge and skills; as well as their social relationships with other researchers which favor the exchange of tacit knowledge which is more difficult to communicate. Once

in the country, the geographical proximity favors the interaction with other local researchers, creating social proximity, while also creating positive externalities, spillovers, and agglomeration effects in the local economy. Given the open labor market policies, the UAE is well-positioned to retain and attract key researchers from across the world, which can prove to be significant in increasing knowledge diversity and creation, as it will encourage local and international collaborations in patents and publications.

**Similarly, investment promotion policies aimed at attracting regional headquarters and campuses from international universities can foster organizational proximity.**

Organizational proximity is also closely linked to social and geographical proximity, as researchers attracted to these centers would create and foster the effects previously discussed. However, organizations provide an additional layer of proximity in which firms share and transfer knowledge across their international structure, reducing the transaction costs and uncertainty in the interactions and the transfer of complex knowledge. There is a geographical factor in the headquarters' attraction that relates to its interactions with other local firms that allow for spillovers and knowledge transfers with suppliers, customers, and partners. Organizational structures allow access to international networks that could be difficult to access otherwise, increasing the likelihood of collaborations and partnerships.

**Global Collaborative Patents (GCPs) tend to be strong innovations, typically exceeding those from the same firm that only uses local inventors.<sup>1</sup>** As different policies aimed at integrating UAE's researchers in global scientific networks are implemented to increase the knowledge diversity in the economy, there could also be a significant effect on the quality of the inventions in which they participate. Stronger patents and publications could lead to improvements in the productivity of certain sectors, as well as to technological breakthroughs. Typically, the first 10% of patents filed in a country and technology tend to have a global inventor on the team (Bahar et al., 2020). This highlights the importance of international networks in the development and retention of different technology classes and fields.

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<sup>1</sup> A patent is considered a GCP when at least one of the inventors resides in a country different from the rest of inventors.

## 2. UAE's Performance in Innovation Activities

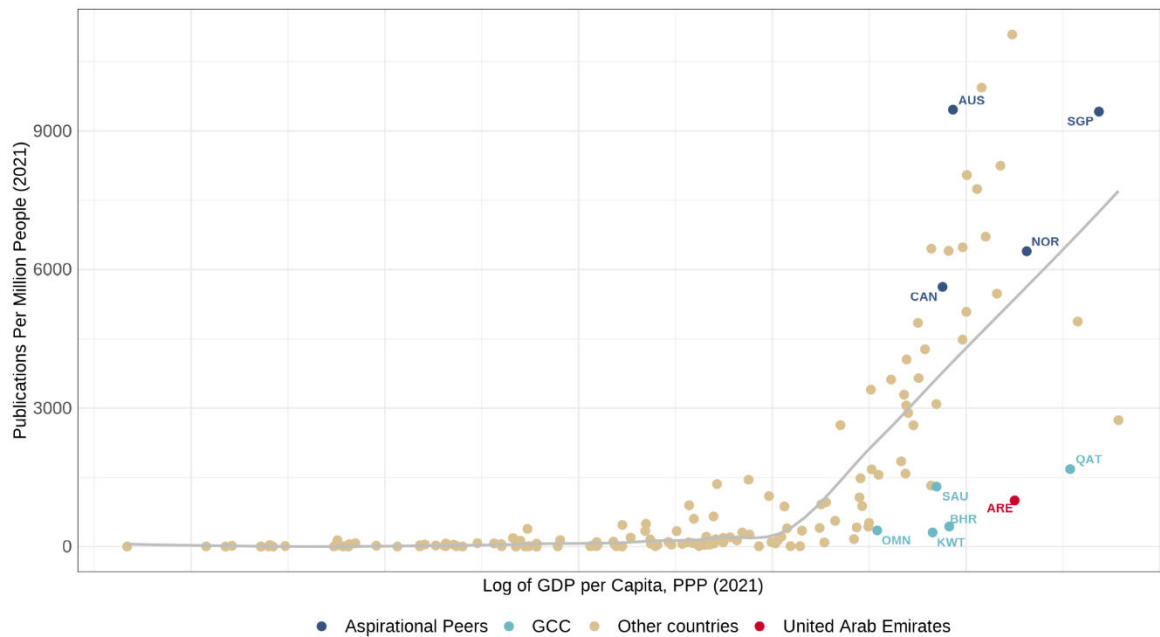
**Advancing science and technology innovation is a significant piece of the UAE's ongoing development process and a central piece of its strategies.** At the core of its Science, Technology, and Innovation policy there is a focus on increasing the involvement of the UAE in different advanced basic and applied research areas, such as space science, artificial intelligence, and alternative energy technology systems. Achieving UAE's goals will require a combination of understanding its current scientific capabilities and leveraging them to continue to grow its Research and Development Sector.

**Bridging the strategic goals set by the UAE and the current state of its R&D sector requires a diagnostic of its current capabilities in scientific production and the inputs required to advance it.** Scientific publications and patents are just part of the innovation process of firms, but they serve as meaningful indicators of the capabilities that are inside of an economy. This involves not only assessing the number of scientific publications and patents but also understanding the quality and impact of these contributions. Furthermore, identifying the specific areas where the UAE excels or lags in terms of innovation is crucial to outline how they can be leveraged and supported for further progress in the area.

### 2.1 The Output of the R&D Sector

**First, regarding scientific publications volume, it can be seen that it is below its expected level, given its GDP per Capita.** When compared with countries of similar levels of GDP per Capita, the UAE underperforms in its number of scientific publications. While the number of citable publications is similar to Saudi Arabia's number and higher than that of most of the GCC countries, it remains below Qatar and significantly below Aspirational Peers. The pattern remains when adjusting GDP per Capita by the natural resource rents. (see Figure 45 in Appendix 1).

Figure 1. Scientific Publications per Million People and GDP per Capita (2021)<sup>2</sup>

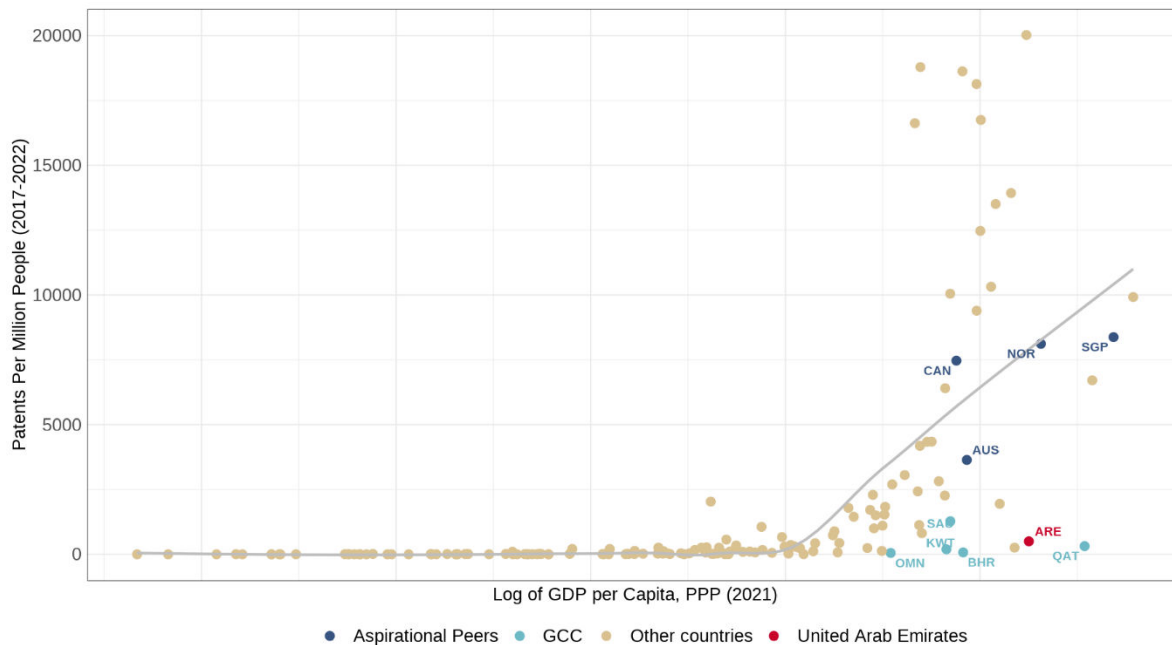


Source: OpenAlex; authors' calculations

**Similarly, patenting activity remains significantly below the levels of countries with similar levels of GDP per capita and below peers.** As in the case of publications, the UAE produces patents at a rate significantly below its aspiration peers, but it is close to the levels of its regional peers, such as Saudi Arabia and Qatar. Patent filings for the UAE and other GCC countries are similar to those of countries with much lower levels of income per capita, which highlights limitations in their scientific capabilities, as patents can be seen as an important feature of innovation. A similar pattern can be seen when adjusting for the patents by quality and the GDP per Capita by the size of the natural resources rent (see Figure 46 in Appendix 1).

<sup>2</sup> Only scientific works with more than 5 citations are included in the aggregations.

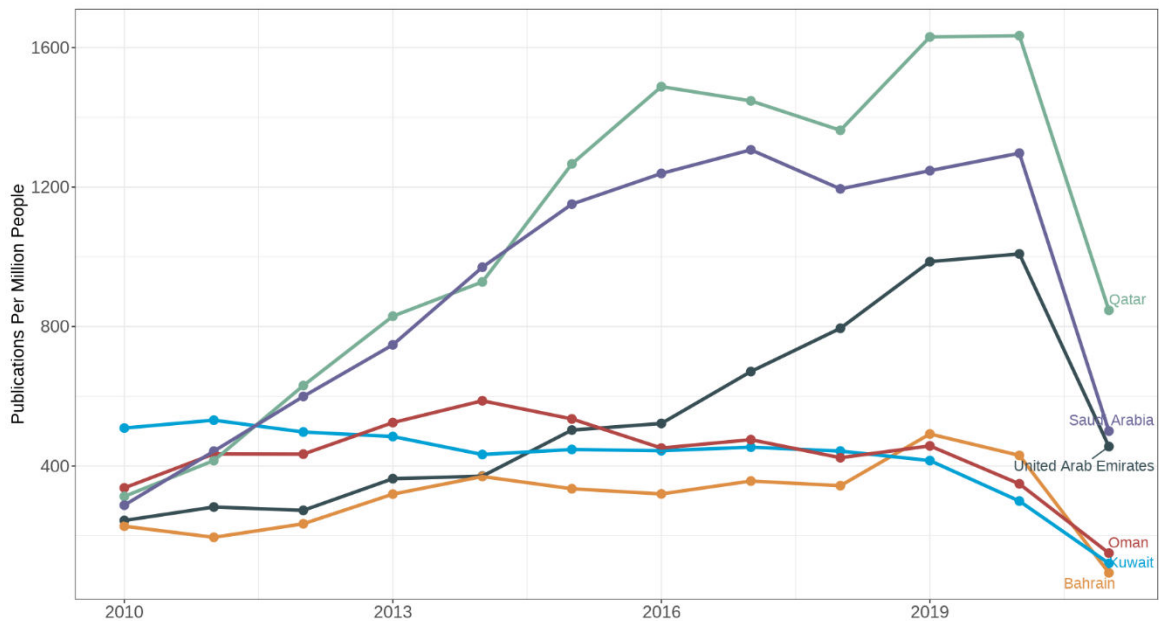
Figure 2. Patents per Million People and GDP per Capita (2021)<sup>3</sup>



**Despite the gap in the number of scientific publications, the number of scientific publications has been increasing rapidly in the last 5 years.** Driven by rapid increases in publications in Computer Science, Engineering, and Medicine, the UAE has been able to grow some research capabilities in fast-growing fields in the world. However, the growth since 2010 has not matched that of other major GCC economies such as Qatar and Saudi Arabia. All three countries started relatively similar levels in 2010 but Qatar (+523%) and Saudi Arabia (+351%) have widened the gap with the UAE (+314%) in the last few years. Bahrain, Kuwait, and Oman have diverged significantly from these groups of countries, especially when controlling for the quality of the publication using its citations.

<sup>3</sup> This graph excludes Korea's numbers.

Figure 3. Scientific Works per Million People in GCC countries (2010-2021)<sup>4</sup>



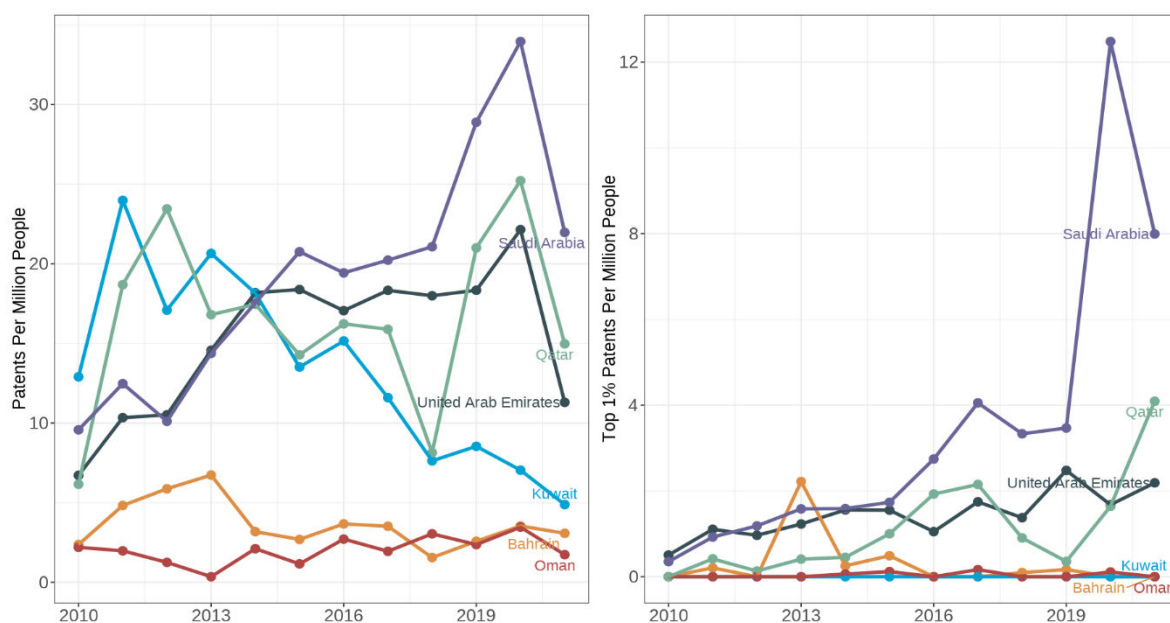
Source: OpenAlex; WDI; authors' calculations.

**While it experienced rapid growth in the number of patents between 2010 and 2014, patent creation stagnated until 2020.** From Figure 4, it is shown that the UAE's patenting activity growth between 2010 and 2014 is comparable to that of other GCC countries such as Qatar and Saudi Arabia. However, growth stagnated until 2020 while it continued in Saudi Arabia. This growth in the UAE, between 2010 and 2014, has come predominantly from technologies related to Physics and Human Necessities, especially in technology classes where there were no patents in the previous period. The growth in patents ranked in the top 1% of Competitive Impact<sup>5</sup> is significantly slower, which results in a significant gap between Saudi Arabia's and their own patenting that widens over time, while Qatar's quality patenting catches up by 2015.

<sup>4</sup> Number of scientific works for 2021 is incomplete in the snapshot utilized for this analysis.

<sup>5</sup> Competitive Impact is a measure created by PatentSight that involves the Market Coverage and the Technology Relevance of a patent.

Figure 4. Patents per Million People and Top 1% Patents per Million People (2010-2021)<sup>6</sup>



Source: PATSTAT; PatentSight; WDI; authors' calculations.

**UAE's underperformance in innovation activities could be a symptom of problems in its research production function or constraints for the demand for R&D activities inside the country.** Understanding the root of its underperformance requires a more in-depth dive into the inputs that go into R&D activities (Researchers and Expenditures in R&D), their dynamics, and an understanding of its current capabilities, and how to leverage them moving forward.

## 2.2 UAE's Research Production Function

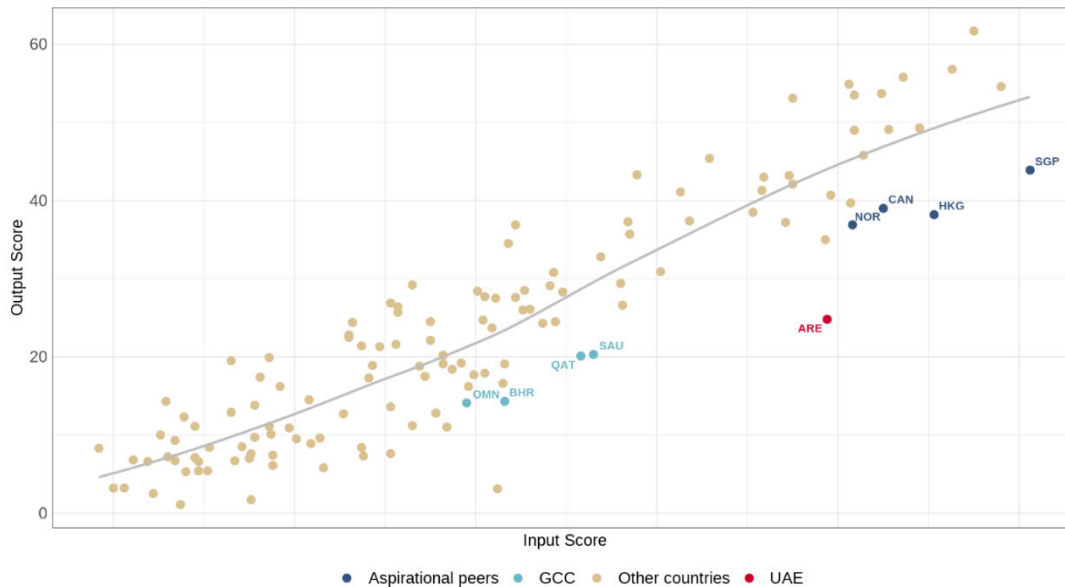
### 2.2.1 An Overview of the R&D Inputs

**At first sight, the Global Innovation Index (GII) shows relatively high endowments of inputs for innovation in the UAE, while its output performance has not matched the expected level given its inputs.** Its higher input score in the GII can be attributed to several index dimensions, especially those related to infrastructure, institutions, and human capital. In terms of output, the UAE remains on levels similar to those exhibited by other Gulf countries, such as Saudi Arabia or Qatar, but significantly below innovation hubs like Hong Kong or Singapore. The lower-than-expected knowledge output can be attributed to the number of quality publications, quality patents, trademarks, and industrial

<sup>6</sup> Number of patents for 2021 is incomplete in the snapshot utilized for this analysis.

designs, despite having a relatively high level of creative output, as aggregated in the Knowledge Output Sub-Index of the GII.

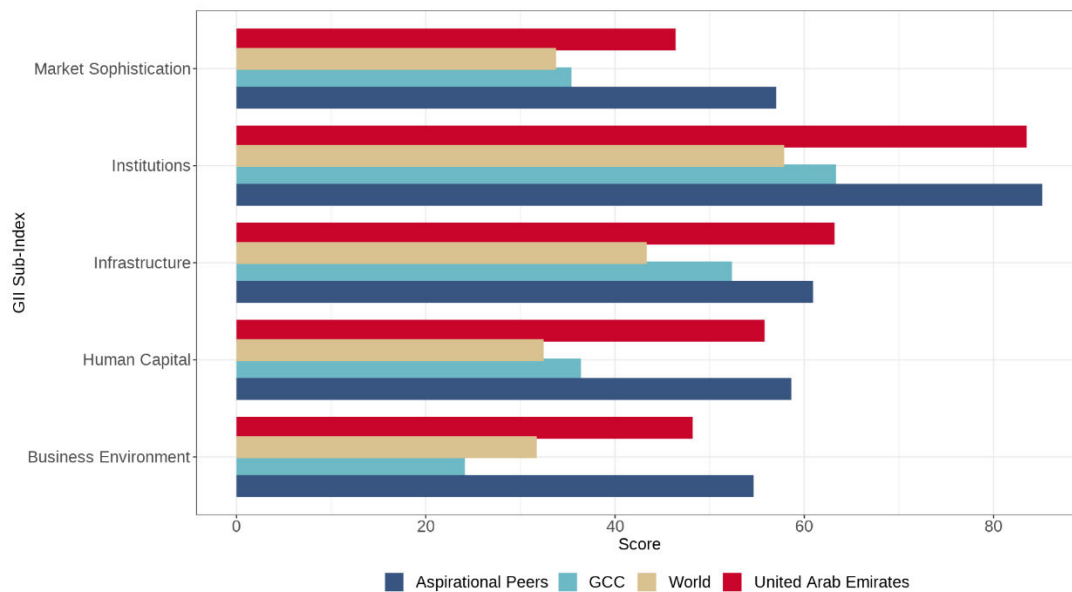
*Figure 5. Global Innovation Index 2022: Input Score and Output Score*



Source: Global Innovation Index Report 2023.

**UAE exhibits strong indicators in relevant inputs related to the support of the innovation ecosystem in the country.** While the levels in all sub-indexes are high relative to the world and to other GCC countries, the UAE is still below the average levels seen in aspirational peers such as Norway, Canada, and Singapore. The gap is larger in the market sophistication and the business environment indicators. UAE's endowment levels in these inputs put them on par with other countries with similar levels of GDP per Capita, when excluding natural-resource rich countries.

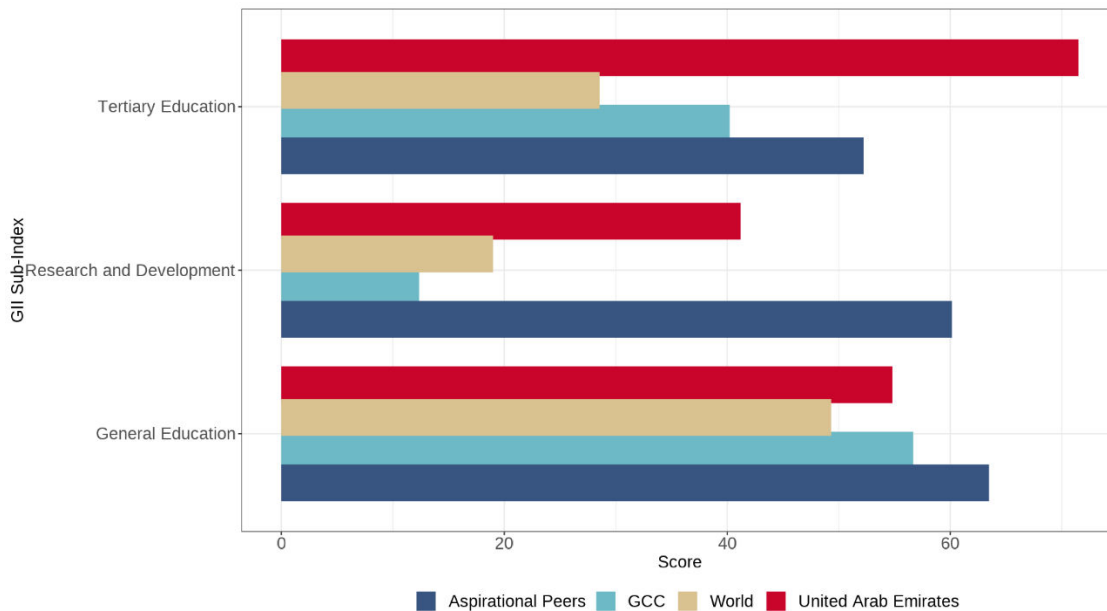
Figure 6. Input Sub-Indexes: UAE vs. Peers



Source: Global Innovation Index Report 2023; authors' calculations.

**Especially important for the innovation production process is the Human Capital and, specifically, its R&D capabilities where it trails behind its aspirational peers. The UAE's** results on General Education are slightly above average driven in part by weaknesses in its PISA scores and the relatively low levels of expenditures on Education with respect to GDP. These results could potentially explain the relatively low levels of tertiary enrollment by high school graduates in the UAE, which is compensated by the high number of foreign students incoming into UAE universities and the relatively high number of graduates in the sciences and engineering fields. In R&D, the UAE performs much better than the average and the GCC; however, there is a sizeable gap with aspirational peers such as Singapore which could explain the gap in research output compared to other countries with similar levels of GDP per capita.

Figure 7. Human Capital and Research Sub-Indexes



Source: Global Innovation Index Report 2023.

**At its core, R&D can be summarized as a production process where institutions and firms combine specific factors such as labor (researchers) and capital (proxied R&D expenditures) as inputs to produce output (patents and publications).** In OECD countries in the last 20 years, an increase of 1% in the overall number of researchers is associated with an accumulated increase in the number of publications of 2.07%, while it is not associated with any significant growth in patents in the 5 years after the increase. Similarly, an increase of 1% in real R&D expenditures is correlated with an increase in the number of publications of 3.07% and in the number of patents of 1.62%.

**Not only is the overall number of researchers important but the density of research human capital inputs in its economy plays a significant role in the output of the R&D sector.** Previous research has established a relationship between research human capital density (RHCD) and the production of patents and publications (Ayun, Haak and Ginther, 2023).<sup>7</sup> While increases in the overall number of researchers have had less significant effects on increases in the number of patents and publications, density is a significant factor in cross-country comparisons.

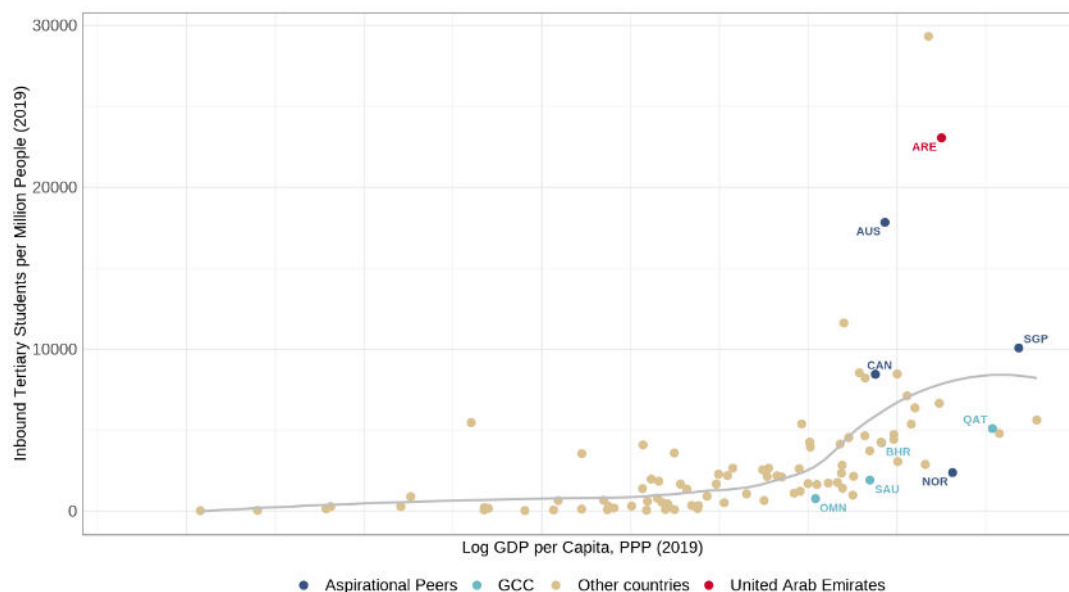
<sup>7</sup> Research Human Capital Density (RHCD) is the share of people dedicated to Research and Development per 1000 population ages 25-69. For the purpose of this report, it will be calculated using the total labor force in each country.

### 2.2.2 Understanding the UAE's Human Capital Innovation Capabilities

**As part of its National Innovation Strategy, the UAE has put special emphasis on educating, attracting, and retaining top talent in its economy.** Its overall strategy around human capital in Science, Technology, and Innovation, and Artificial Intelligence outlines policies around education and attraction of talent that include establishing the goal of having an economy, in which knowledge workers comprise around 40% of the workforce. The achievement of this goal involves a combination of policies surrounding Emiratization and the transfer of knowledge from foreign works to the local workforce, skills development in tertiary education, and global talent attraction policies, both for its labor force and as students for its higher education sector.

**An important source for future researchers comes from the students graduating from local universities, for which the UAE is a major attractor of foreign talent.** Even though the UAE does not list a university in the top-5 of the Arab region, it has managed to create a network of local and international universities that perform relatively well in the region on average. This ecosystem of universities has allowed the country to act as a major hub for foreign students looking for undergraduate and advanced degrees. In combination, the loosening of visa requirements for university students in 2018 expanded the pool of available talent for knowledge-intensive activities in the UAE (Figure 8).

*Figure 8. Inbound Tertiary Students per Million People and GDP per Capita (2019)*



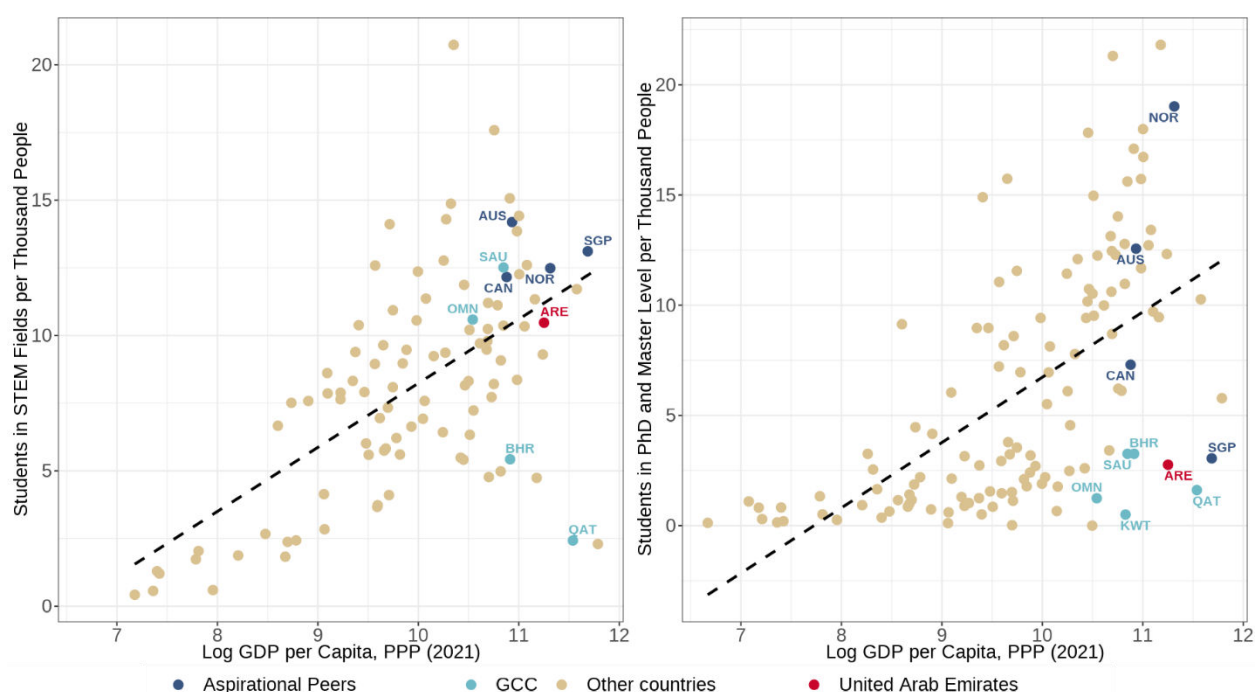
Source: WDI; UNESCO; authors' calculations.

**Even though the UAE has been able to attract students at very high rates to its higher education system, students pursuing advanced degrees and students in STEM fields remain close to peers.** UAE's success in attracting foreign students has not yet

21 | Scientific and Technical Innovation in the United Arab Emirates

translated into advanced studies, such as Master or PhD degrees. For instance, it is significantly below what is expected of a country with its level of development, but it is on par with its GCC peers and Singapore. In terms of attraction of STEM students, its rate is close to its expected level given its GDP per Capita and is comparable to many of its peers (Figure 9). These features of the UAE's higher education system can be explained by the significant number of students going to pursue undergraduate studies and the success in attracting students into other fields such as Business. Transforming the success of the student attraction to a pipeline of future researchers will require active policies that exposes the talent to research activities and translates the foreign talent in STEM fields into R&D workers.

*Figure 9. Advanced Studies and STEM Students per Thousand People and GDP per Capita*



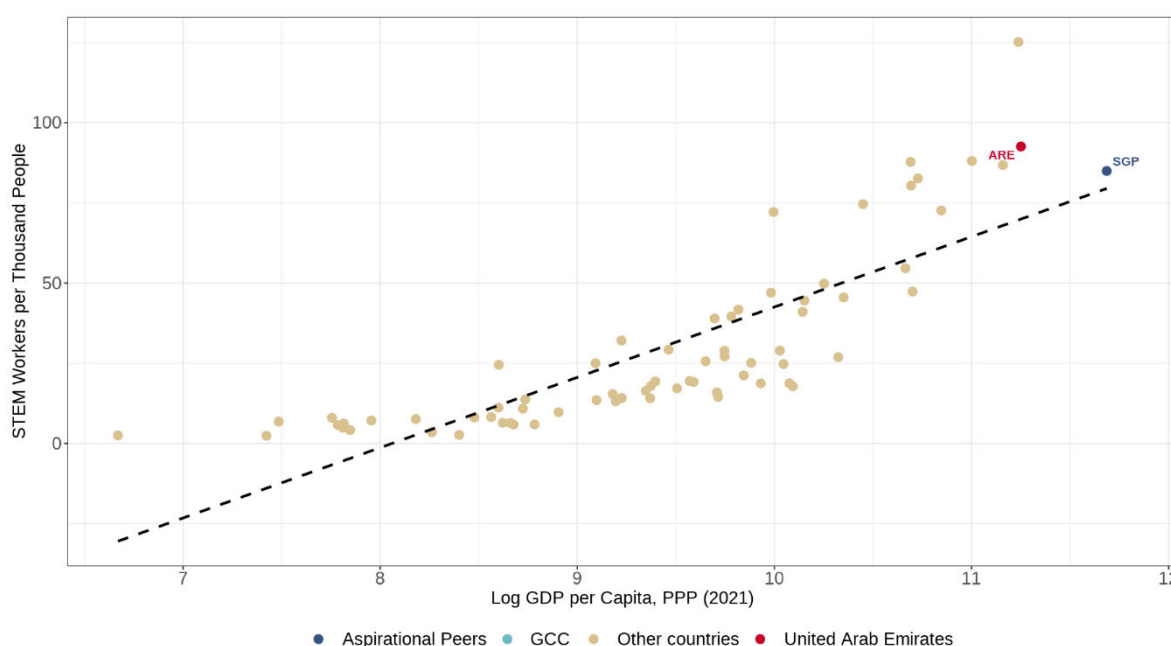
Source: UNESCO; WDI; authors' calculations.

**UAE's industries have been able to attract a significant number of workers to STEM occupations in its labor force.**<sup>8</sup> Although the data is not available for many countries in the world, it shows the UAE as one of the leading countries in attracting STEM workers, just behind countries like Switzerland and Singapore (Figure 10). These workers are concentrated in industries where the UAE has comparative advantages or where there has been significant growth in the last few years, such as Health Activities, Construction,

<sup>8</sup> Methodology to classify STEM workers includes IT specialists, engineers, systems technicians, managers, and other occupations (ILO, 2020).

and Computer programming activities which comprise more than 32% of all workers in STEM occupations. According to ILO (2022), more than 92% of workers in STEM occupations have tertiary degrees, and the growth has been concentrated in this segment of workers.

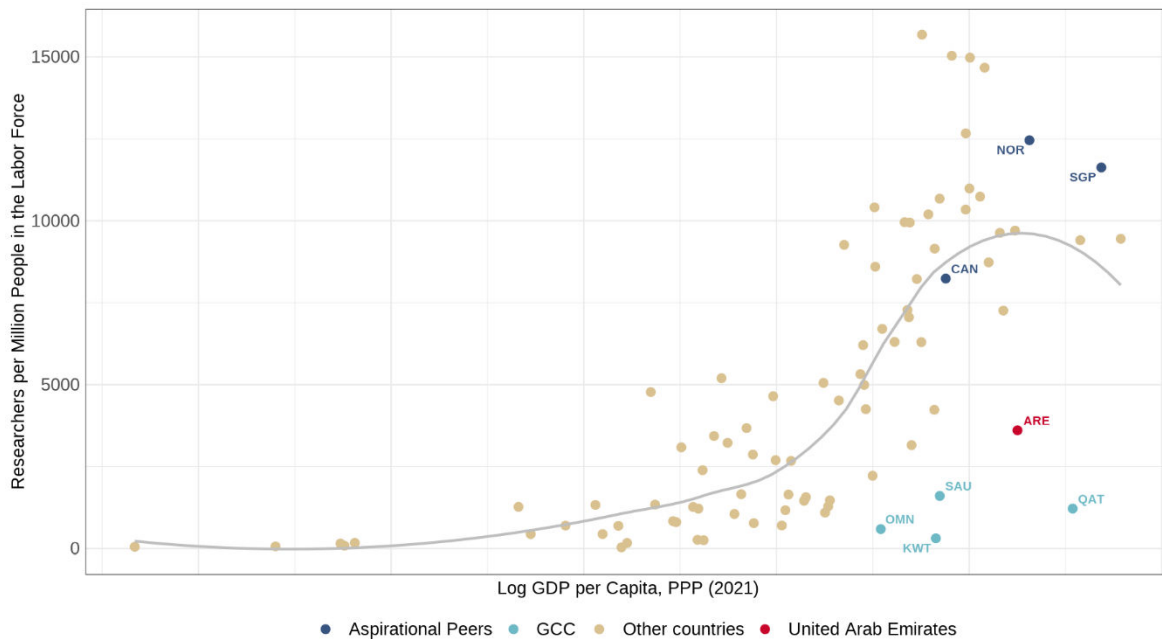
*Figure 10. Workers in STEM Occupations per Thousand People and GDP per Capita (2021)*



Source: ILO; WDI; authors' calculations.

**Despite the success of attracting international students to its universities and workers into STEM occupations, the number of researchers remains significantly below its aspirational peers and countries with similar levels of income.** Compared to other oil economies in the Gulf, the UAE has a higher prevalence of researchers in its population, but it is significantly below other peers. Its R&D ecosystem has been unable to translate its relatively open labor market, its success in attracting international students, and its relatively high number of graduates in sciences and engineering into a larger sector. As the output of innovation is dependent on its labor inputs, there is merit in deepening the analysis into the potential constraints that the growth in the number of researchers might be facing.

Figure 11. Full-Time Equivalent (FTE) Researchers and GDP per Capita (2021)

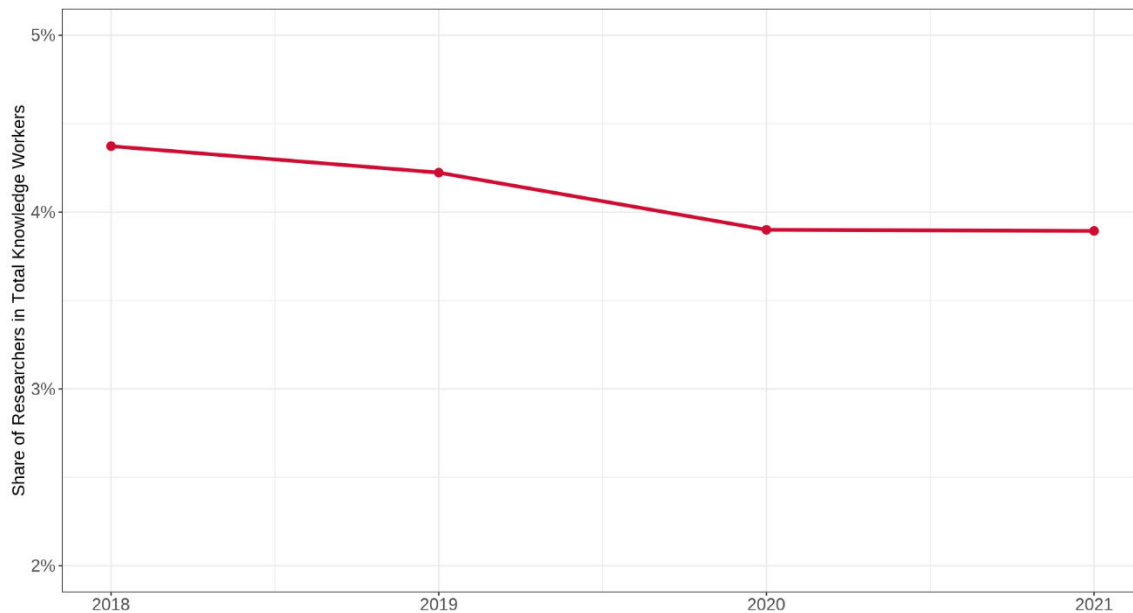


Source: UNESCO; WDI; authors' calculations.

**There has not been significant progress in closing the gap in the number of researchers since 2018.**<sup>9</sup> The increase in the number of available knowledge workers in the economy due to changes in the visa regime has led to significant growth in employment in high-skill occupations such as managers, professionals, and technicians. However, the number of FTE researchers dedicated to R&D has remained relatively stagnant since 2018. This has led to a decrease in the density of researchers in the labor force, which might be detrimental to the advancement of the sector and provide hints about potential constraints that are specific to the R&D sector and not to the employment of highly skilled workers in the UAE market, after the decrease caused by the COVID pandemic in 2022.

<sup>9</sup> According to UNESCO notes on UAE's data, there is a break in the series occurring in 2018 which limits the analysis of the evolution over time.

Figure 12. Share of FTE Researchers in Total Knowledge Workers<sup>10</sup>



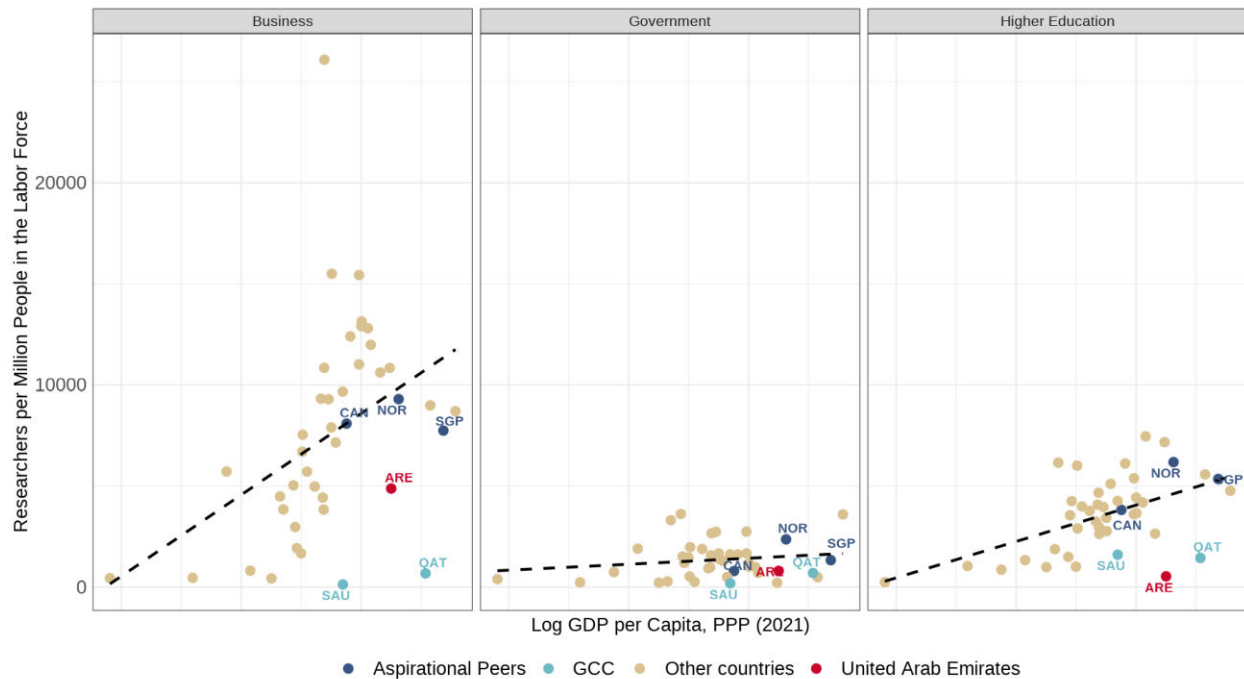
Source: FCSC; MOHRE

**The gap remains when compared by institutional sector to OECD countries and other selected countries<sup>11</sup>.** According to the data presented in Figure 13. FTE Researchers per Million People and GDP per Capita, by institutional sector (2021), the correlation between the density of researchers in government and the level of development of the country is weak. Here, the UAE performs better than the GCC and Canada. However, the correlation is stronger in the Business Sector and Higher Education Sector where the UAE is behind all its aspirational peers. Furthermore, the gap is noticeably larger in the Higher Education sector, where the UAE lags behind other GCC countries and has a sizeable gap with aspirational peers. Given that the UAE's universities are predominantly financed by the government, that state-owned enterprises (SOEs) lead business research, and that the government employs a substantial portion of researchers, it's crucial to investigate if there are barriers preventing the growth in researcher employment in the Higher Education sector.

<sup>10</sup> Figures of knowledge workers for 2020 are calculated interpolating values of 2019 and 2021.

<sup>11</sup> Other countries included are China, India, Saudi Arabia, Qatar, Russia, Singapore, Argentina, and UAE.

Figure 13. FTE Researchers per Million People and GDP per Capita, by institutional sector (2021)

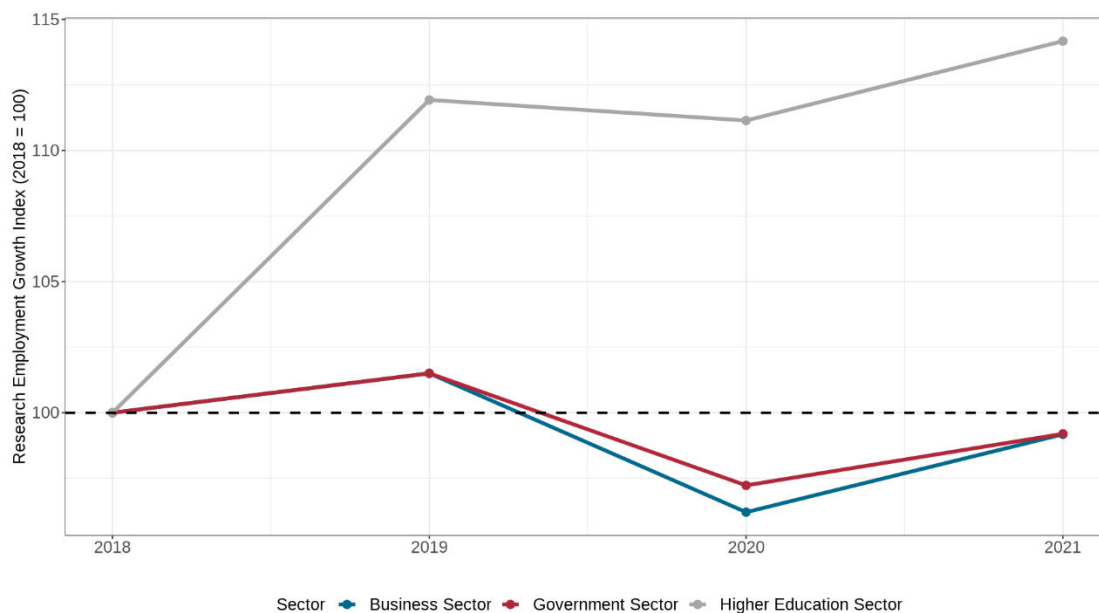


Source: FCSC (UAE); OECD; PSA (Qatar); GAS (Saudi Arabia); NITI Aayog (India)

**The decline in the number of researchers in the government sector and business caused by COVID-19 was partially offset by the strong growth that Higher Education has experienced since 2018.** While the dynamics of the growth in the number of researchers is mainly driven by the growth in the business sector, there has been significant growth coming from the Higher Education Sector in the last few years. Furthermore, in 2021, the Business Sector and the Government Sector were still below their research employment levels of 2019 when the Higher Education Sector already exhibited a 2% growth over its levels of 2019. Given the employment growth that occurred in 2022 in the UAE in the private sector, the research sector may have already recovered its 2019 levels<sup>12</sup>.

<sup>12</sup> At the time of this report there are no figures for researchers' employment in 2022 to compute the density of the researchers in the UAE economy.

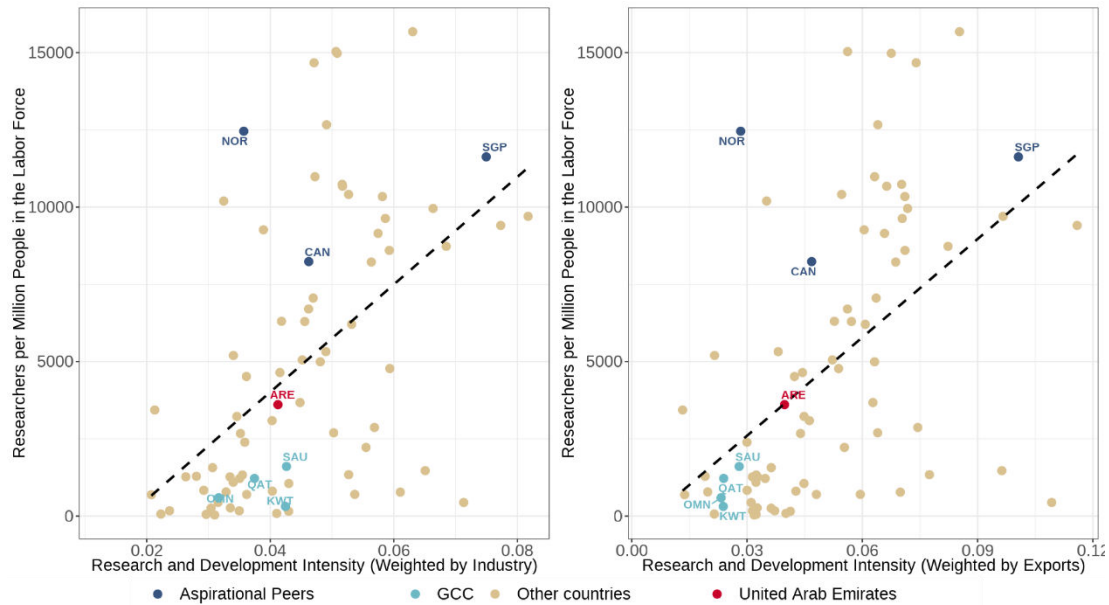
Figure 14. Research Employment Index, by Performance Sector (2018-2021)



Source: FCSC; authors' calculations.

**UAE's density of researchers is broadly in line with its expected value given the R&D intensity of its exports and its industrial composition, suggesting that corresponds with the demand of its industries.** Using the intensity of R&D assets at the industry level in the US, the UAE is below the levels of R&D intensity that its aspirational peers exhibit but is significantly more R&D intensive than the countries of the GCC. When comparing it with the density of researchers in the labor force, there is a positive relationship which suggests that this might be determined by factors such as the demand for R&D labor in the industries of a country. Specifically in the case of the UAE, the density of the researchers seems to be at the level expected from its industrial composition.

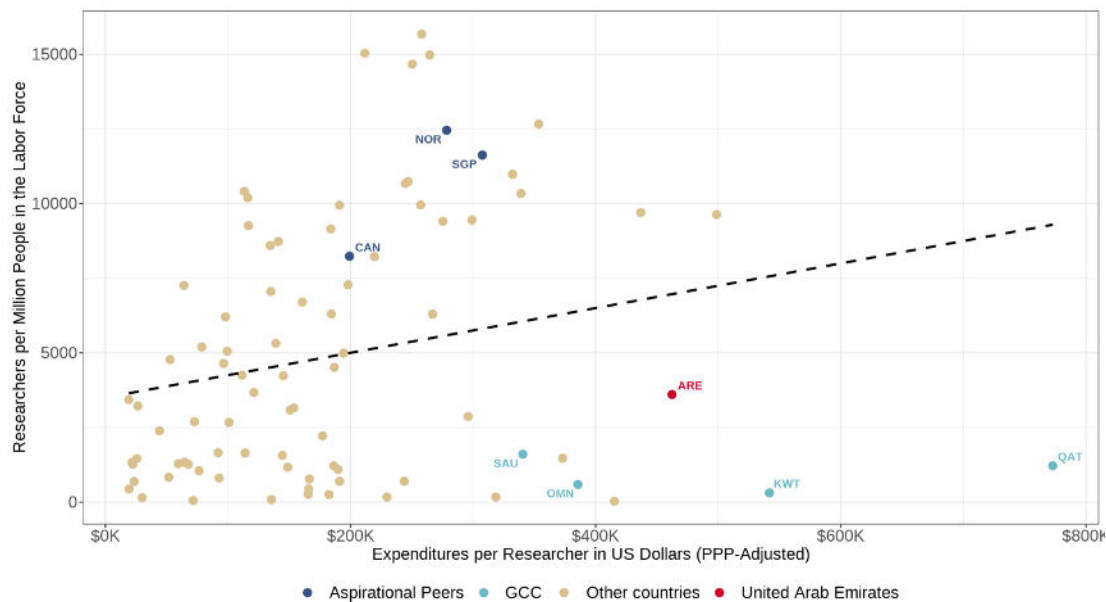
*Figure 15. Researchers in the Labor Force and Weighted R&D Intensity of Industry and Exports*



Source: COMPUSTAT; UNESCO; authors' calculations.

**However, the level of expenditures per researcher might be suggestive of a higher premium being paid for researchers or of a higher capital intensity of the R&D process in the UAE.** Excluding the GCC area, there is a correlation between an increased agglomeration of researchers and the expenditures per research that businesses, academia, and government dedicate to their activities. In the case of the GCC, expenditures per researcher are among the highest in the world which suggests either an increase premium paid for researchers to locate in the UAE or significant capital investments that overpass the current presence of researchers in its R&D Sector. In the case of the UAE, State-led demand and investments following its strategies on innovation activities could be leading to both outcomes in which there are increased efforts to incentivize top researchers to relocate to the UAE, while also increasing efforts to provide improved investments for physical capital for R&D activities, such as in the case of the Borouge Innovation Center which opened in Abu Dhabi in 2015 as part of a joint venture between Borealis and ADNOC.

Figure 16. Expenditures per Researcher and Researchers per Million People in the Labor Force (2021)



Source: UNESCO; WDI; authors' calculations.

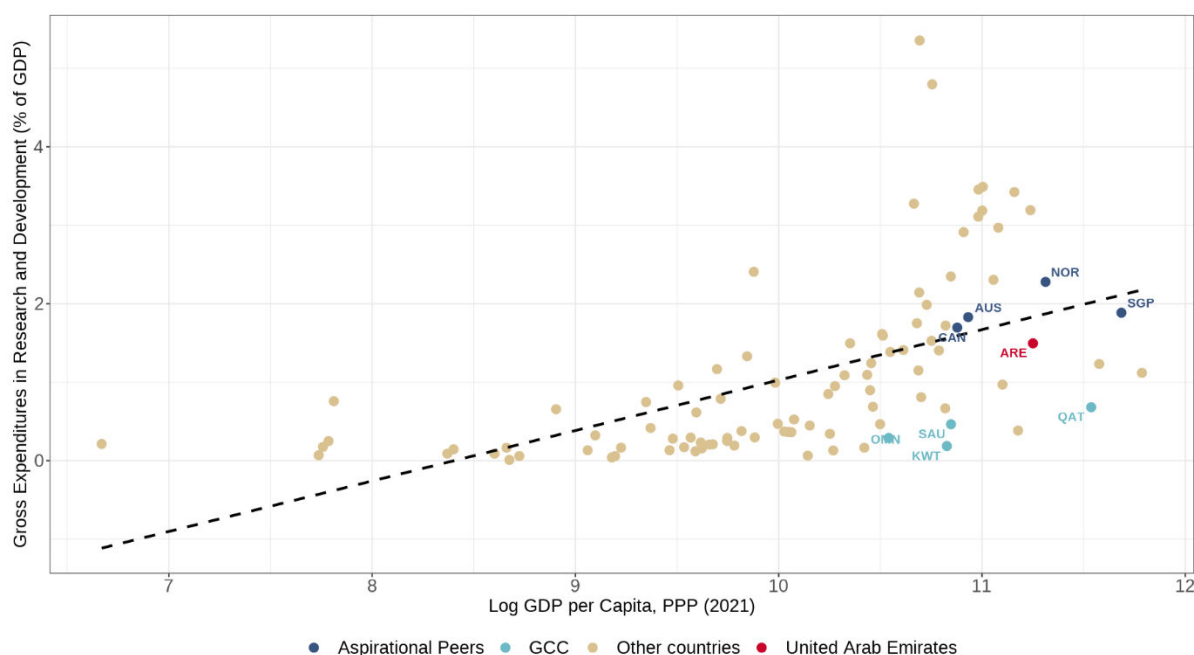
**Achieving the goals of the National Innovation Strategy and the National Advanced Sciences Agenda 2031 will require incremental attraction and training of researchers to add capabilities to its current R&D sector.** The current rate of growth of R&D personnel in all the institutional sectors might hinder the advancements in the UAE, as the country continues to invest significantly in the sector. The success in attracting international students and skilled workers in the last few years provides both a pipeline and a blueprint to ensure that the increased demand for R&D is met with sufficient research skills in the labor market, as the R&D sector continues building upon its current set of capabilities.

### 2.2.3 Understanding Expenditures and Investments in R&D

**In its framework to support basic and applied scientific research, the UAE establishes that it will provide enough government funding for these activities and envisions an increase in industry funding.** The R&D Governance Policy Framework forecasts an increase in industry R&D spending to AED 57 billion in 2031, which would represent an increase of 338% from its 2021 levels and would represent 1.9% of GDP of the AED 3 trillion GDP goal for that year. That level of industry expenditures would be comparable to top R&D performers such as Germany and the United Kingdom, which would provide a significant opportunity for breakthrough innovations in the Emirates but will also require enough capacity to absorb the resources and translate them into quality research.

**UAE levels of R&D Gross Expenditures are close to the level that is expected at its level of GDP per Capita.** While it is still behind aspirational peers in this regard, its current levels are significantly above those of other countries in the Gulf. At these levels of expenditures in R&D, it is unlikely that there are currently constraints in the availability of funds for this purpose. However, it is important to evaluate questions surrounding the efficiency of these expenditures and the current capacity of the economy to absorb them and translate them into research output.

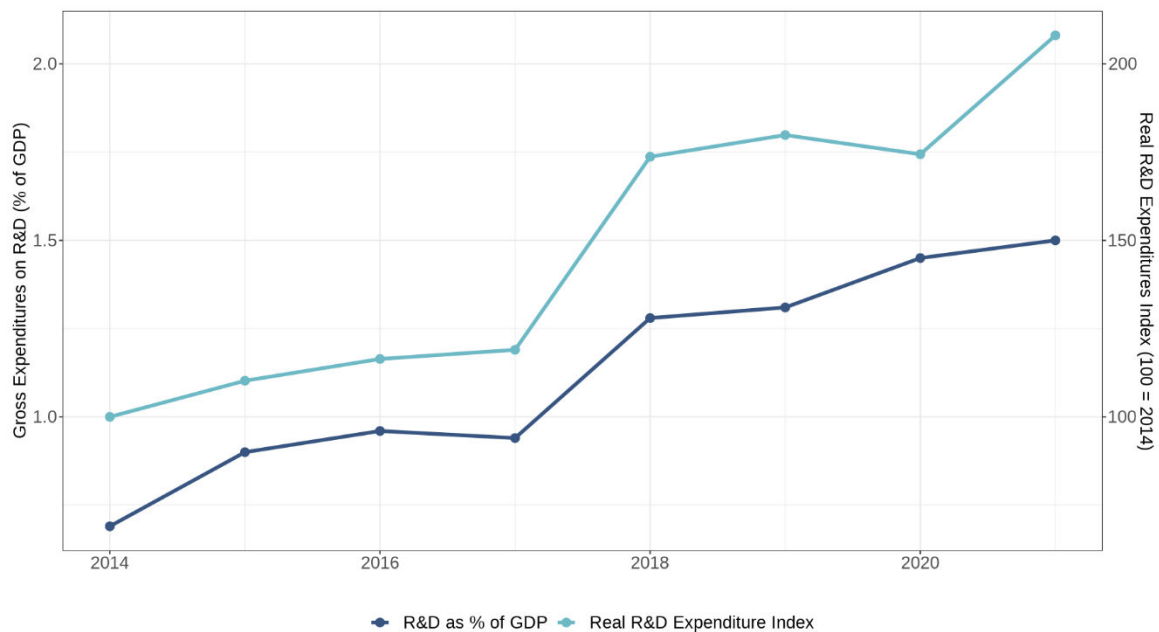
*Figure 17. Gross Expenditures in Research and Development, GDP per Capita (2021)*



Source: UNESCO; WDI.

**The different R&D strategies adopted have led to a substantial increase in the funding available for R&D activities.** Since 2014, total real expenditures in R&D activities have grown 108% (Figure 18), while the share of GDP has risen from 0.69% to 1.5% of GDP. These accelerated growth in the availability of funding for R&D could be surpassing the UAE's current available capabilities, which highlights the need for an in-depth diagnostic of the available innovation capabilities and skills that support knowledge generation and absorption. While the growth of R&D expenditures has come from all performance sectors, there are significant differences in the level that deserve a close look.

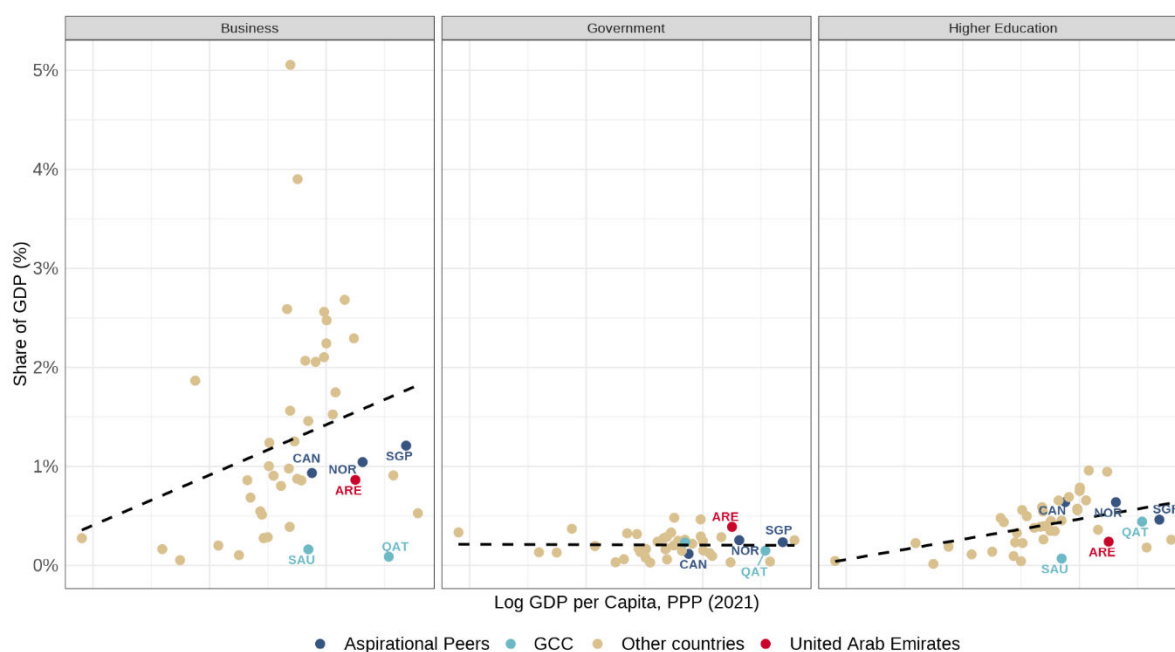
Figure 18. Research and Development Expenditures (2014-2021)



Source: FCSC; WDI; authors' calculations.

**Despite growth in R&D spending in the last few years, a significant gap remains in Business R&D expenditures, which are being covered by the Government Sector (Figure 21).** While the Business Sector remains the most significant sector in terms of spending for R&D activities in almost all countries, its level remains below what is expected for a country of UAE's level of development, albeit close to its aspirational peers. Similar to the case of researchers, the Higher Education expenditures are among the lowest of its peers just above Saudi Arabia. The UAE's ability to maintain R&D expenditures at a level expected by its GDP per capita is a result of its government's hefty investments in R&D, surpassing those of most OECD nations. Since government investments in R&D are not the results of a market-based equilibrium where firms decide to locate their R&D activities in the country, there is a risk of not achieving increased research output at the scale of its expenditures. This risk is primarily due to the potential disconnect between the R&D capital and the required complementary skills and knowledge to augment the productivity of the sector.

Figure 19. Gross Expenditures in Research and Development<sup>13</sup>, by Performance Sector



Source: FCSC (UAE); OECD; PSA (Qatar); GAS (Saudi Arabia); NITI Aayog (India)

**The Federal Government, the Emirates, and its SOEs are very likely the most significant source of funding for R&D expenditures.** Even though there is no official data released about the sources of funding, it can be extrapolated from the structure of the Emirati economy that the State is a significant player in the innovation ecosystem. State funding for R&D activities not only flows from the Government Sector but also from the different State-Owned Enterprises (SOEs), such as ADNOC and DP World, and publicly owned universities, such as UAE University and Khalifa University. Given this and the economic structure of the UAE, it is important to analyze the current set of capabilities of the UAE and the overall productivity of the researchers for the level of expenditures that they are currently receiving.

## 2.3 The Productivity of the R&D Sector.

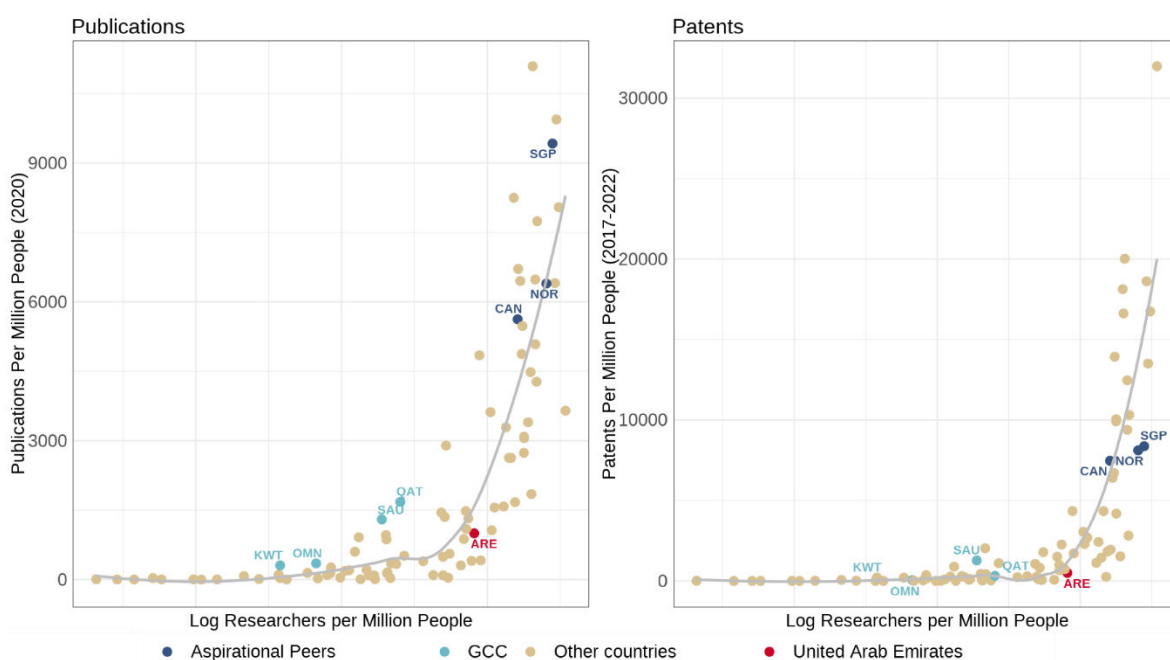
**The productivity of the inputs going into the production of patents and scientific works will provide a more in-depth understanding of the status of the sector.** This comparison serves as a key metric to evaluate the efficiency and effectiveness of R&D investments. High productivity in R&D implies that the resources, including human capital and financial investments, are being utilized effectively to generate valuable intellectual property and scientific advancements. Conversely, low productivity might indicate inefficiencies or misallocation of resources, signaling a need for strategic reallocation or

<sup>13</sup> Last available year for each country.

policy intervention to address the cause of these inefficiencies, additional to relative low-density of researchers.

**Researchers' productivity is in line with the expected production of patents and publications, which would imply the need for more researchers to increase output.** Despite being in different parts of the productivity curve, as shown in Figure 20, their research output is close to its expected level given the number of researchers that the UAE has in its economy. This implies that the UAE would need to increase its density of researchers in the economy, which also requires an understanding of whether there is a constraint in the current growth of researchers, if this is a market-based outcome where firms prefer not to locate their R&D capabilities in the UAE, or if there might be a further increase in the productivity of researchers in the medium-term.

*Figure 20. Researchers per Million People and Research Output*

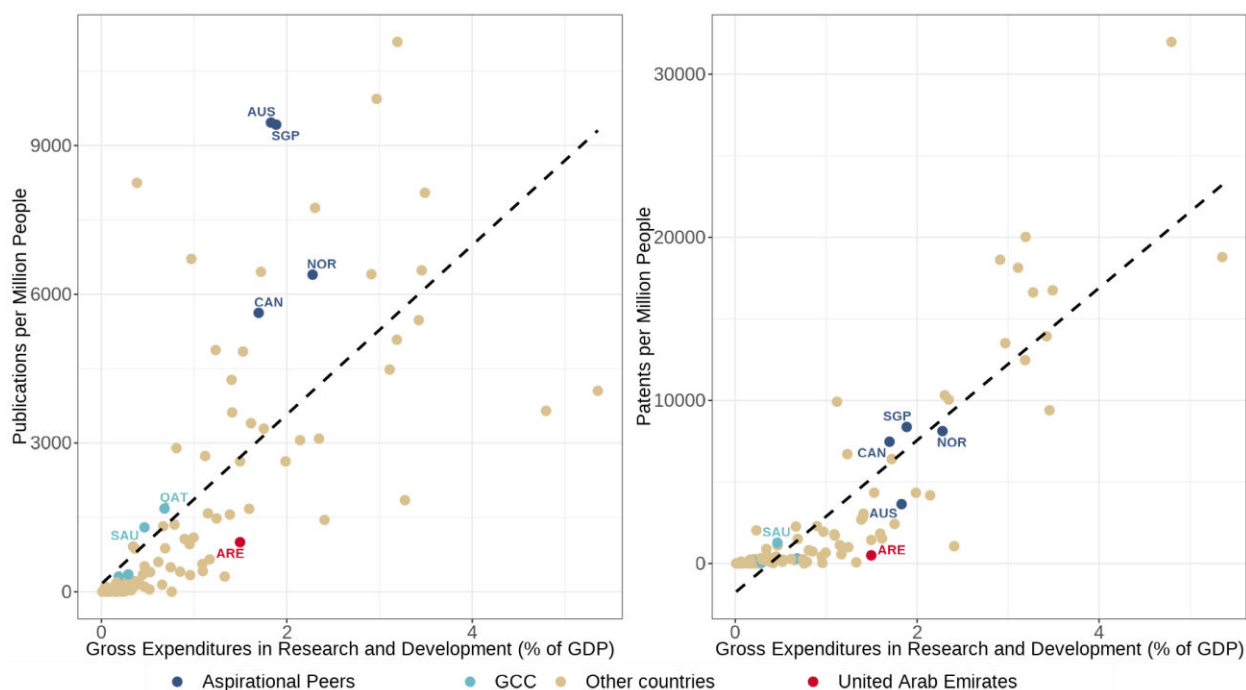


Source: UNESCO; WDI; OpenAlex; PATSTAT

**The UAE is below its expected output of patents and publications given its current level of expenditures.** This finding has two potential implications: (i) the UAE has been spending above its current capabilities to absorb its R&D expenditures, in which case the expenditures are not market-driven but funded by the State, and (ii) expenditures today might result in increased output in the future, provided that the UAE is able to attract and develop innovation capabilities as it has done in the last few years. The performance and the dynamics stemming from this are determined by the recent changes in Gross R&D

Expenditures by the UAE, the source of this funding for expenditures, and the sectors performing and spending it.

*Figure 21. Gross Expenditures in Research and Development (GERD) and Research Output*

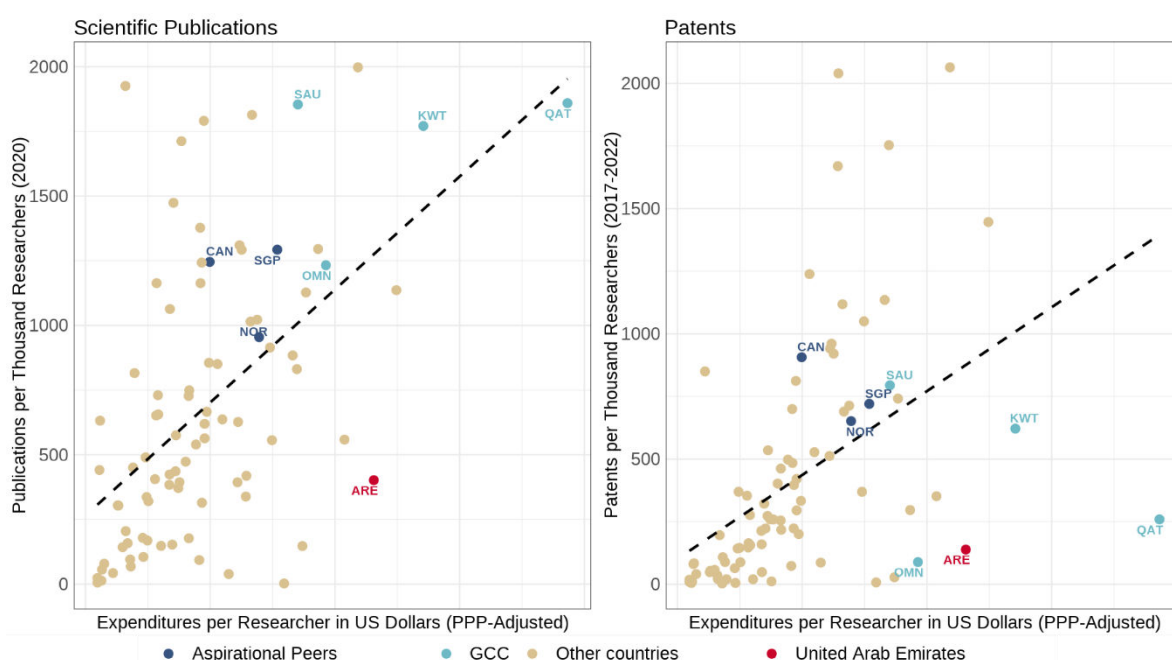


Source: UNESCO; OpenAlex; PATSTAT; WDI; authors' calculations.

**The mismatch between the level of expenditures, the number of researchers and the research output might be pointing to different constraints.** The level of expenditures that the UAE currently has is on level with its level of development but there are significant gaps in the number of researchers and the research output that they are generating. Productivity levels of researchers suggest that the innovation ecosystem and the R&D sector are working on par with what its economy is demanding; however, growing to the level of research output that an economy of its size should have will require attracting more researchers and significantly increasing their productivity. Understanding the dynamics of its research production function becomes central to unlocking the UAE's capabilities in the innovation sector.

**The productivity per researcher in the UAE is an outlier when controlled by the size of the expenditures per researcher.** In the case of scientific publications, the UAE's productivity is below aspirational peers and countries from the GCC, while also spending considerably more per researcher than most of them. In the case of patents, the productivity is on par with Oman's while also spending considerably more than them and it is an outlier when compared to peers like Saudi Arabia, Singapore, and Norway. Although higher spending can boost research output in the medium-term, current evidence suggests issues in R&D productivity that are not being addressed by increasing R&D expenditures, especially through the Government sector.

*Figure 22. Productivity per Researcher and Expenditures per Researcher*



Source: PATSTAT; Open Alex; UNESCO; FCSC; authors' calculations.

**UAE's low returns to the scale of its R&D Expenditures point towards constraints in its Research production function which can be a result of the absence of some innovation capabilities.** As has been acknowledged in the literature, the emergence of technological specializations and the appearance of technological breakthroughs is largely driven by the recombination of capabilities and skills to create new knowledge. The United Arab Emirates (UAE) aims to transform into a knowledge-based economy, moving away from its reliance on oil. Achieving this goal, as outlined in the UAE's National Innovation Strategy, necessitates a focused approach to enhancing its technological capabilities. By progressively building on its existing technology base, the UAE can significantly boost its research productivity. This enhancement in technology and

research will not only increase the chances of generating groundbreaking patents but also firmly establish the UAE as a hub of innovation and knowledge.

### 3. Leveraging UAE's Capabilities

#### 3.1 UAE's Capabilities in Fields, Technologies, and Industries

**UAE's R&D sector features a blend of relative low density of researchers, high expenditures per researcher, and relative low productivity per dollar invested.** Its significant investment in research and development, as reflected in the high expenditures per researcher and per patent/scientific publication, makes it an outlier compared to many other countries. Its demand for research-skills and the growth in different STEM occupations underscores the importance of adopting an incremental approach to targeting specific technology sub-class that maximize research output and unlock UAE's research capabilities in the future.

**An incremental approach facilitates a nuanced exploration of technological relatedness and unrelatedness, key to fostering innovation.** The emergence of breakthrough technologies often relies on a blend of related and unrelated technological fields (Boschma et al., 2023). By focusing incrementally on sub-classes where existing technological strengths are combined with new, unrelated technologies, the UAE can create an environment conducive to innovation. This approach aligns with the understanding that technological breakthroughs frequently occur at the intersection of different fields. Targeting technologies through migration and investment attraction policies and targeted investments in infrastructure might increase the likelihood of the appearances of breakthrough technologies.

**UAE's investments in R&D and the infrastructure to support it have the potential to boost its innovation output but only if the capabilities are available in its ecosystem.** Without the supporting capabilities and the conditions to boost certain technologies in the near term, there is a risk that these investments end up hindering innovation, as research has shown that local mismatch between R&D and labor can persistently affect it and prevent further spillovers (Crescenzi, 2021). Foreign firms, scientific international collaborations, and scientific migration can potentially play a role in this process, as they act as channels for knowledge diffusion which could turn into increased scientific and technological capabilities.

##### 3.1.1 Overview of Fields, Technologies, and Industries

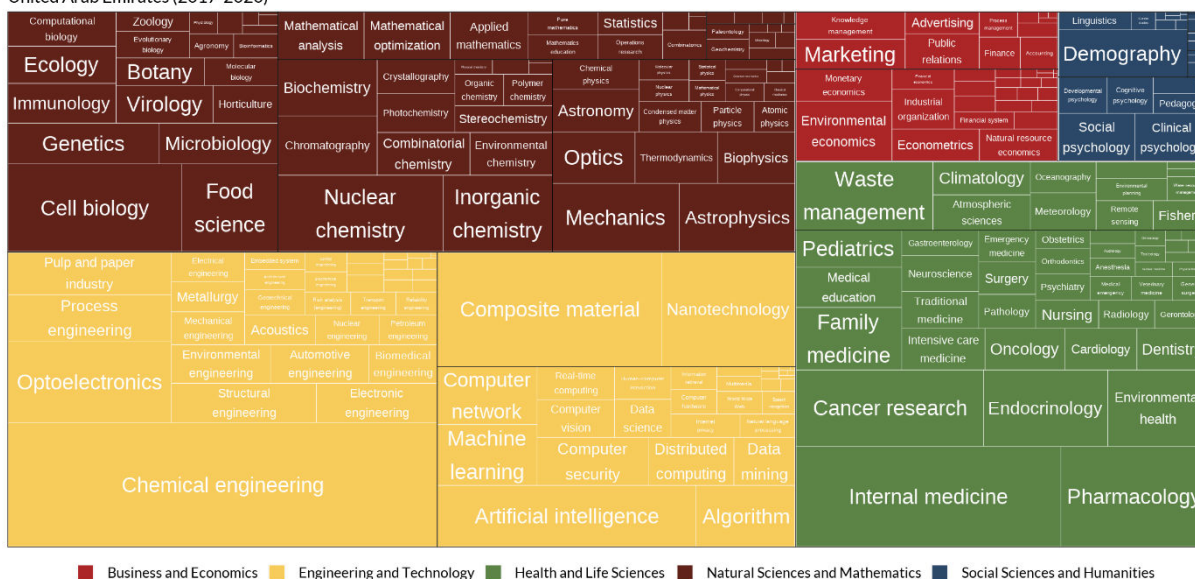
**UAE's current research capabilities on scientific publications are mainly focused on Medicine, Materials Sciences, Engineering and Computer Science.** The UAE does publish in a range of other scientific fields as well, as indicated by Figure 23. There is a noticeable concentration of scientific publications in fields related to Energy and STEM fields such as Artificial Intelligence, which not only reflects the nation's strategic priorities but also its response to global trends and challenges. The strong emphasis on technology-

37 | Scientific and Technical Innovation in the United Arab Emirates

driven sectors such as Artificial Intelligence suggests an alignment with global economic shifts towards emerging technologies. Researchers in the UAE seem to be publishing in basic sciences such as Biology and Chemistry as well as applied fields like Engineering and Health Sciences, indicating a balanced scientific ecosystem that can support both basic research and its application to real-world problems.

*Figure 23. UAE's Scientific Fields, sized by the number of works with more than 5 citations.*

Scientific Works per Field  
United Arab Emirates (2017-2020)



Source: OpenAlex; authors' calculations.

**UAE's production of patents is concentrated in technology clusters such as Information, Telecommunication and Constructions.**<sup>14</sup> While the number of patents per year has remained relatively stagnant in the last few years, it has managed to diversify into a wide range of technological subclasses mainly dominated by clusters in Electronics and Telecommunication, and Physical Sciences. The advancement of scientific publications in fields related to computer science has been accompanied by the increase in patents around Artificial Intelligence technologies (G06) and Informational Technologies (G16). Additionally, UAE inventors not only have patented technologies in areas close to their comparative advantages (chemicals, oil, and aluminum) but have also created technologies in agriculture, healthcare, and green energies.

<sup>14</sup> The technology cluster of each technology sub-class is defined as the largest technology cluster in 2022 for that specific sub-class, as computed by PatentSight.

<sup>15</sup> This analysis uses the assignees of the patents for aggregation purposes.

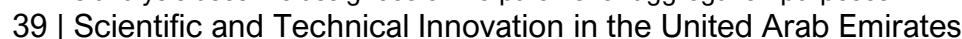
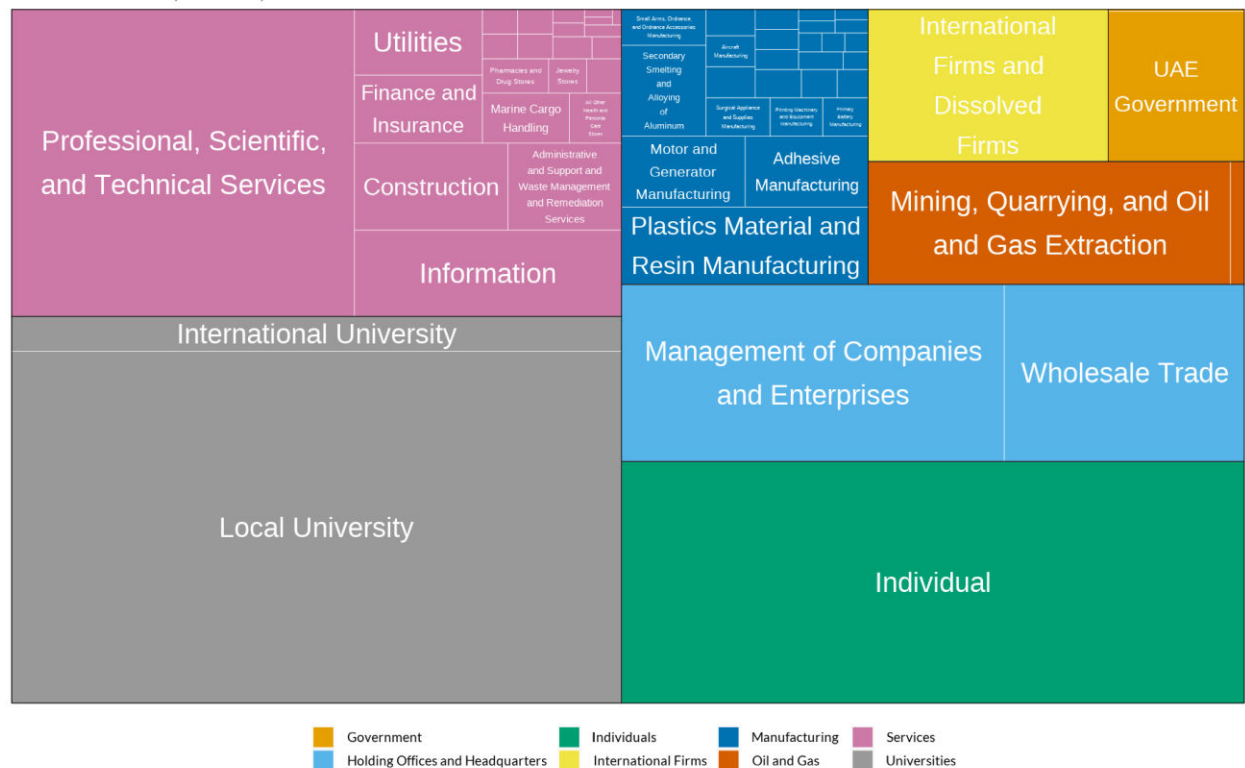


Figure 25. Industry of Patent Assignees, sized by Patent Fractional Counts (2017-2022)

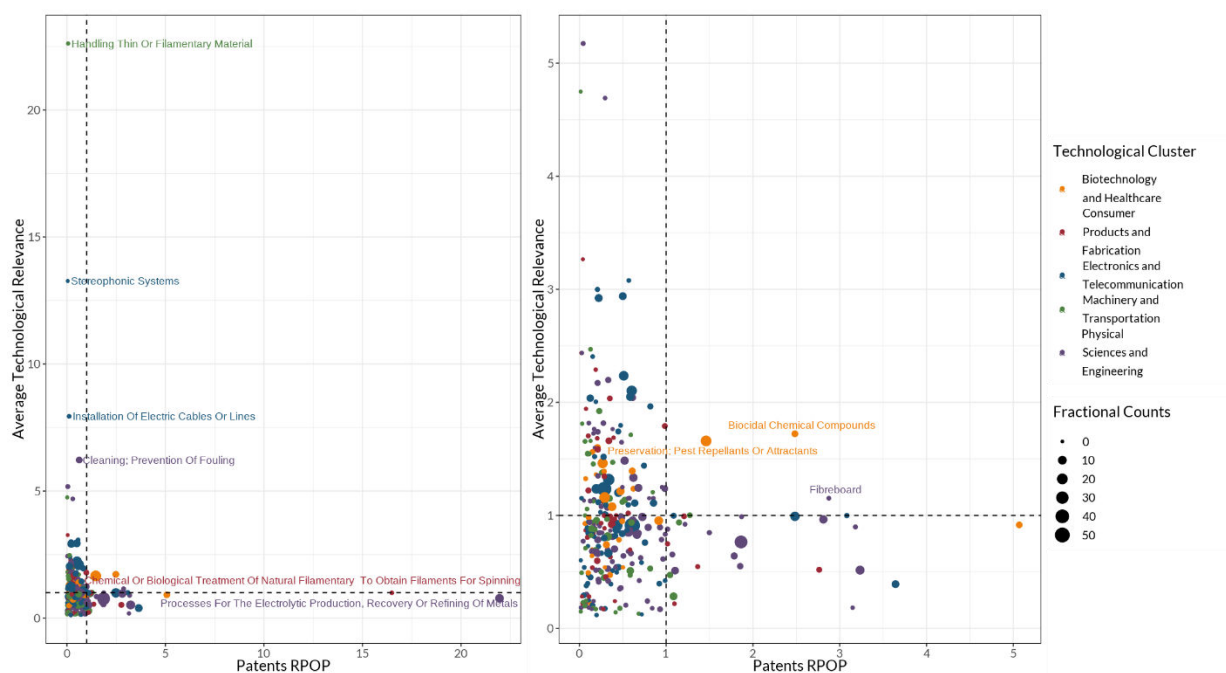
Patent Fractional Counts per Industry  
United Arab Emirates (2017-2022)



Source: PATSTAT; National Economic Registry (NER); authors' calculations.

**Inventors in the UAE participate in a significant number of technology classes, at an above-average quality but at a lower frequency than expected for the country's population size which highlights opportunities in the intensive margin.** The UAE has been able to produce more than its expected share of patents at a higher quality in just two technology classes: two related to agriculture and one to sciences and engineering. There is also a significant number of technologies that are produced at higher rates, but at a below-average quality which might benefit from policies that increase their quality, through a combination of policies highlighting local and international collaborations and star researchers' attraction. Finally, a larger number of technologies is produced with above-average quality, which is suggestive of the presence of capabilities to innovate in them. Putting in place policies that encourage local spillovers could prove beneficial to the overall capabilities of the UAE.

Figure 26. Patent Production Intensity and Quality<sup>16</sup> (2017-2022)



Source: PATSTAT; PatentSight; authors' calculations.

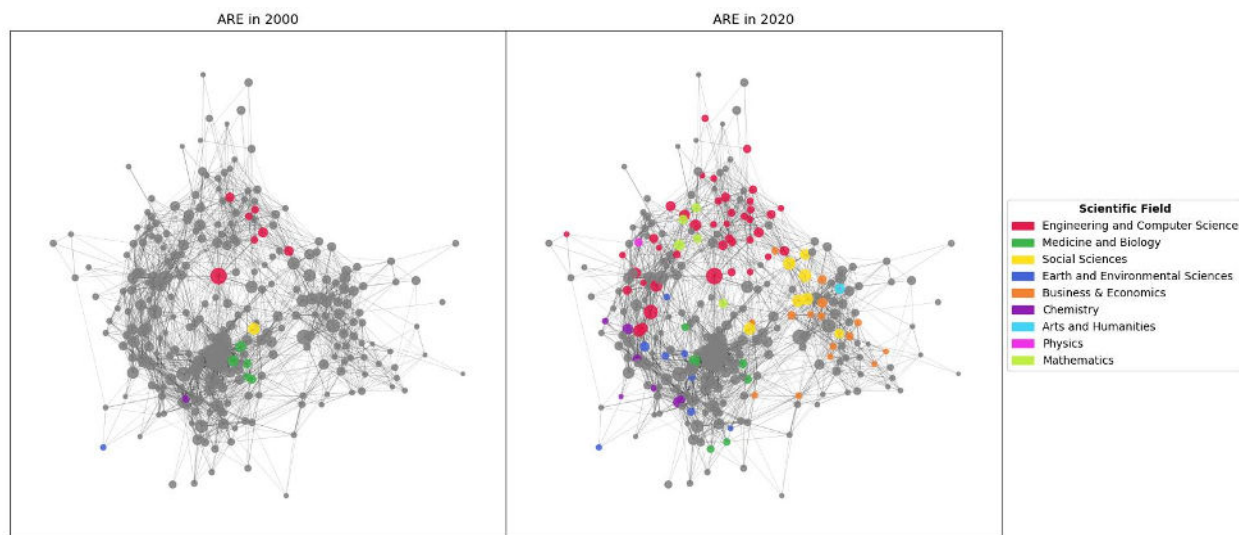
### III.1.2 Nearby Opportunities for the UAE

**The UAE has exhibited marked diversification into sophisticated scientific fields over the period 2000-2020.** In 2000, the UAE's research landscape was relatively sparse, with a modest presence in a few fields within Engineering and Computer Science, and Medicine and Biology. By 2020, there has been a significant shift, not only in the volume but in the variety of scientific disciplines, indicating an expansion into most Engineering and Computer Science fields, and some Social Sciences, Earth and Environmental Sciences, and Mathematics. This diversification is indicative of the UAE's growing capabilities in scientific publishing, reflecting an investment in a broader range of knowledge sectors. The "scientific field space" in the figure illustrates relationships between scientific fields. Each circle is a scientific field, sized by the size of that field overall in the world in terms of number of publications. This graph only considers scientific publications with at least 5 citations, to limit noise from low-impact publications. If a field is overrepresented in the UAE compared to the expected number of high-impact publications based on the country's size (RpCA or RPOP), it is colored. Grey circles nearby colored circles indicate scientific fields that are "nearby" - opportunities for diversification that are attainable given the set of capabilities already present. This figure

<sup>16</sup> On the left, all unfiltered observations. On the right, zoom-in to RPOP < 6 and Technological Relevance < 6

shows us how we can use an economic complexity perspective to guide policy recommendations for diversification in scientific fields. We will use this approach later in this section to document nearby opportunities for diversification for the UAE in scientific publishing and patenting. The increase in clusters associated with advanced scientific fields suggests an emerging sophisticated innovation ecosystem in the UAE.

*Figure 27: UAE's Diversification into New Scientific Fields*

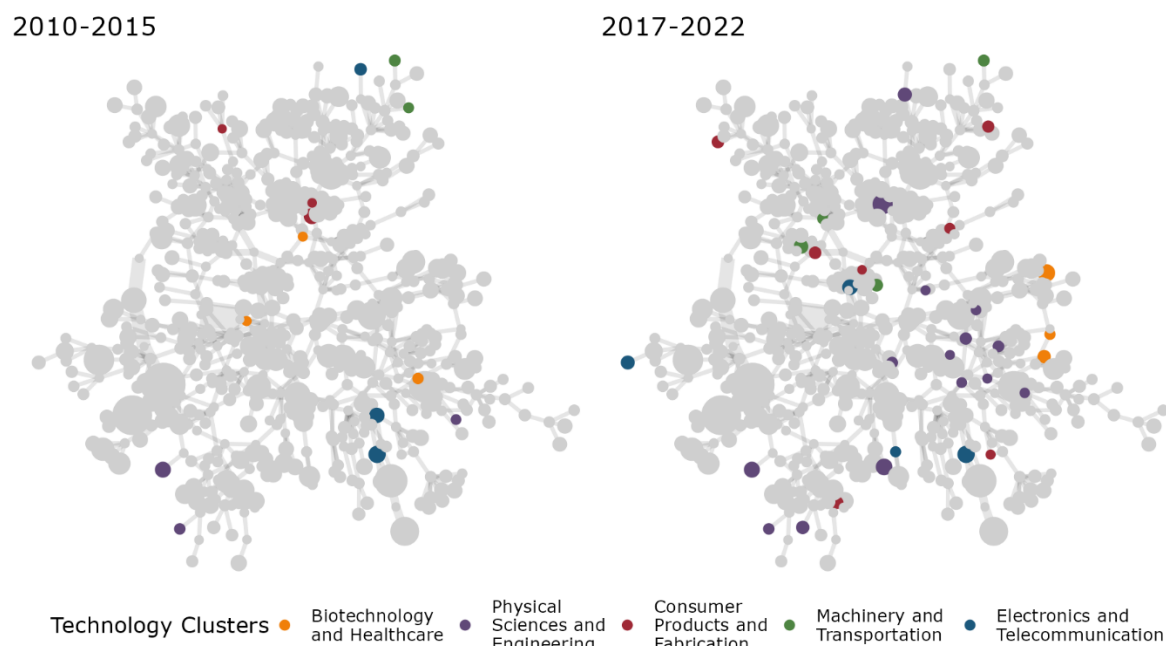


Source: OpenAlex; authors' calculations.

**Relative to 2010-2015, the UAE has diversified into more technology classes, but the pattern is modest in comparison to the dramatic diversification in scientific publications, suggesting a nuanced trajectory of innovation advancement.** The period from 2010-2015 shows a sparse picture, with some minimal activity in sectors such as Biotechnology and Healthcare, and Physical Sciences and Engineering. Subsequent years demonstrate an expansion into new technology clusters like Consumer Products and Fabrication, and Electronics and Telecommunication. This suggests a deliberate effort to transition from an oil-centric economy to one that is innovation-driven, although the scale of activity remains relatively conservative compared to the significant diversification seen in scientific publishing. It suggests that while the UAE has successfully cultivated a stronger scientific research base, the translation of this research into patented technologies has been more conservative. This contrast highlights a potential gap between research outputs and their commercial application, emphasizing the need for policies that not only foster research but also enhance the capacity for innovation commercialization. Strengthening the link between research institutions and industry, providing support for the patenting process, enhancing intellectual property rights

regulations, and incentivizing patenting-centric R&D, could further enhance patenting activity in the UAE.

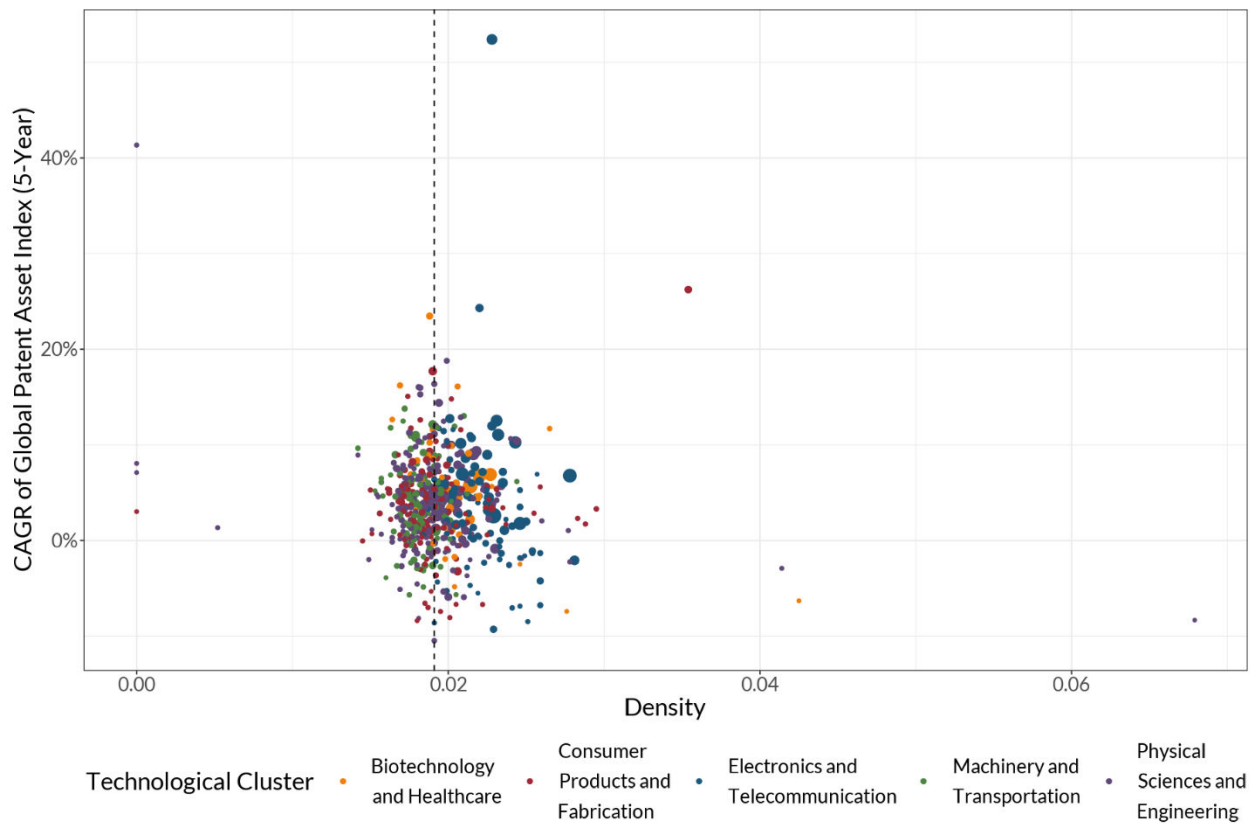
*Figure 28. UAE's Diversification into new Technology Classes.*



Source: PATSTAT; authors' calculations.

**While there is a weak relationship between the UAE's current technological capabilities and global growth rates, there are opportunities in some technological trends.** The UAE's current technological capabilities, as measured by density in various technology classes, shows a small positive correlation with the global growth rates of these sectors, as measured by the Compound Annual Growth Rate (CAGR) of the global patent asset index. For policymakers, this highlights the potential for a strategic realignment of priorities to focus on increasing innovation capabilities in technology classes not only where global CAGR is high but also in areas where the UAE can realistically build competitive advantage (low density) and can contribute to the UAE's overall innovation priorities. The UAE's current technology portfolio seems diverse, but not fully aligned with global growth trends. However, there are opportunities in technological clusters around healthcare and biotechnology, as well as opportunities in Electronics and Telecommunication.

Figure 29. Global Trends and UAE's Opportunities.



Source: PATSTAT; PatentSight; authors' calculations.

**Capabilities around various scientific fields and technology classes, as measured by the "density" around those areas, are predictive of future growth in those areas (Table 7, Appendix 2).** We define density as the capability overlap between what capabilities a country has and what capabilities are needed for a scientific field to be present in that country. The regressions presented in the table illustrate a positive association between the density of scientific fields and the subsequent growth in these areas, suggesting that fields with a higher concentration of existing capabilities are likely to see continued progress. This is true across the globe and within the UAE, suggesting that investment in areas of existing expertise (intensive margin) and areas adjacent to existing expertise (extensive margin) may yield significant growth. Notably, the "Growth %" column in the regression indicates that as the density of a scientific field increases, so does the intensive margin growth—meaning there is an increase in the depth and value of existing knowledge within that field. Similarly, the 'Appearance' and 'Disappearance' columns reflect the extensive margin, representing the emergence and phasing out of new scientific fields or technologies. The robustness of these results across different specifications confirms the reliability of density as a predictive measure of future growth.

This lends support to the idea of "related diversification" - that is, the expansion of capabilities into areas that are adjacent to existing strengths is more likely than into areas that are further away in the scientific field / technology spaces. These findings underscore the potential for the UAE to leverage its existing strengths in scientific research and innovation as a strategy for sustained development of its innovation portfolio.

**While globally density remains a significant indicator of patenting growth, this result is not statistically significant when considering just the UAE (Table 8, Appendix 2).**

This lack of a clear relationship between UAE's patenting density and growth could be attributed to either a genuine lack of correlation between the two within the nation or to the relatively small number of noisy observations specific to the UAE's patenting activity. The noise in this data is exacerbated by the UAE's recent and rapid increase in patent filings across diverse technology classes from a previously low baseline. Hence, these initial findings suggest that while scientific publications may benefit from bolstering existing areas of expertise, the relationship between current patenting concentrations and future innovation is less clear.

**The UAE has a high concentration of current patenting capabilities in technology classes such as 'Mechanical Driven Clocks or Watches' and 'Waveguides', although these are not the fastest-growing technology classes globally.** To ensure sustainable innovation growth, the UAE must foster its existing capabilities while also adapting to the dynamic global market trends. The table provides a detailed assessment of various technology classes where the UAE has existing capabilities, alongside the corresponding global growth rates in patenting. The modest overlap between the UAE's capabilities and the global growth rates in these areas suggests that while the UAE has built a base in certain technologies, it has not yet aligned its strengths with the fastest-growing global sectors. This requires a nuanced understanding of both the domestic innovation ecosystem and needs as well as the international technological frontier.

**Table 1: Sub-sample of Top Nearby Opportunities for the UAE in Patenting (Intensive Margin)**

**Opportunities for Intensification**

United Arab Emirates (2020 - 2022)

| IPC TECHNOLOGY SUBCLASS                                           | TECHNOLOGICAL CLUSTER             | PATENT ASSET INDEX* | PATENT RCA (POPULATION-ADJUSTED) | DENSITY (IHS) | GLOBAL CAGR (5-YEARS) | GLOBAL CAGR (10-YEARS) |
|-------------------------------------------------------------------|-----------------------------------|---------------------|----------------------------------|---------------|-----------------------|------------------------|
| Installations For Collecting, Or Distributing Water               | Physical Sciences and Engineering | 12,261              | 2.49                             | 0.03          | <b>8.8%</b>           | 7.3%                   |
| Mechanically-Driven Clocks Or Watches                             | Electronics and Telecommunication | 13,886              | 1.68                             | 0.02          | <b>3.9%</b>           | 4.8%                   |
| Waveguides                                                        | Electronics and Telecommunication | 28,374              | 2.21                             | 0.02          | <b>4.6%</b>           | 3.3%                   |
| Laboratory Apparatus                                              | Electronics and Telecommunication | 55,140              | 1.44                             | 0.02          | <b>7.0%</b>           | 5.6%                   |
| Control Or Regulating Systems In General                          | Electronics and Telecommunication | 201,518             | 1.13                             | 0.02          | <b>8.6%</b>           | 8.9%                   |
| Treatment Of Water, Waste Water, Sewage, Or Sludge                | Physical Sciences and Engineering | 147,192             | 1.13                             | 0.02          | <b>7.9%</b>           | 7.8%                   |
| Hydraulic Engineering                                             | Physical Sciences and Engineering | 22,993              | 2.66                             | 0.02          | <b>9.0%</b>           | 7.1%                   |
| Refrigeration Systems                                             | Physical Sciences and Engineering | 74,447              | 1.14                             | 0.02          | <b>4.5%</b>           | 4.7%                   |
| Organic Fertilisers; Fertilisers From Waste Or Refuse             | Physical Sciences and Engineering | 14,466              | 1.87                             | 0.02          | <b>5.0%</b>           | 8.9%                   |
| Measuring Temperature                                             | Electronics and Telecommunication | 39,985              | 1.48                             | 0.02          | <b>8.5%</b>           | 7.5%                   |
| Generating Or Transmitting Mechanical Vibrations                  | Physical Sciences and Engineering | 14,184              | 1.41                             | 0.02          | <b>4.4%</b>           | 4.6%                   |
| Blasting                                                          | Physical Sciences and Engineering | 4,349               | 3.35                             | 0.02          | <b>12.5%</b>          | 8.5%                   |
| Generation Of Electric Power By Conversion Of Infra-Red Radiation | Electronics and Telecommunication | 30,570              | 1.65                             | 0.02          | <b>11.4%</b>          | 16.7%                  |
| Mountings For Smallarms Or Ordnance                               | Physical Sciences and Engineering | 9,087               | 5.14                             | 0.02          | <b>4.9%</b>           | 5.2%                   |
| Solar Heat Collectors                                             | Physical Sciences and Engineering | 13,560              | 2.41                             | 0.02          | <b>6.2%</b>           | 4.0%                   |

\*Patent Asset Index is a measured computed by PatentSight which normalizes citations by technology class, age, and office and multiplies it by the Market Coverage at the patent level. Then, they were aggregated at the Technology Subclass level.

**Nearby innovation opportunities on the extensive margin are mostly in the "Electronics and Telecommunication" cluster, with a few exceptions.** The UAE has strong existing patent assets in the Electronics and Telecommunication cluster, albeit with varying global growth rates. While the UAE has made strides in diversifying its technological portfolio, there is a need to strategize its innovation focus towards globally expanding sectors that are adjacent to the UAE's current capabilities. The density measure in these tables provides insight into the UAE's proximity to these fields considering the capabilities overlap, and thus the ease with which the country can diversify its innovation portfolio into these fields.

**Table 2: Sub-sample of Top Nearby Opportunities for the UAE in Patenting (extensive margin)**

**Opportunities for Diversification**

United Arab Emirates (2020 - 2022)

| IPC TECHNOLOGY SUBCLASS                                                 | TECHNOLOGICAL CLUSTER             | PATENT ASSET INDEX* | PATENT RCA (POPULATION-ADJUSTED) | DENSITY (IHS) | GLOBAL CAGR (5-YEARS) | GLOBAL CAGR (10-YEARS) |
|-------------------------------------------------------------------------|-----------------------------------|---------------------|----------------------------------|---------------|-----------------------|------------------------|
| Additive Manufacturing                                                  | Consumer Products and Fabrication | 75,231              | 0.44                             | 0.04          | 26.2%                 | 46.1%                  |
| Transmission Of Digital Information                                     | Electronics and Telecommunication | 973,181             | 0.29                             | 0.03          | 5.1%                  | 5.3%                   |
| Wireless Communication Networks                                         | Electronics and Telecommunication | 704,636             | 0.23                             | 0.03          | 6.8%                  | 7.4%                   |
| Electric Digital Data Processing                                        | Electronics and Telecommunication | 1,787,167           | 0.37                             | 0.03          | 5.3%                  | 5.4%                   |
| Speech Analysis Or Synthesis; Speech Recognition                        | Physical Sciences and Engineering | 108,481             | 0.12                             | 0.02          | 10.4%                 | 7.7%                   |
| Data Processing Systems Adapted For Administrative, Or Similar Purposes | Electronics and Telecommunication | 491,332             | 0.84                             | 0.02          | 10.3%                 | 8.5%                   |
| Measuring Electric Variables                                            | Electronics and Telecommunication | 238,802             | 0.19                             | 0.02          | 6.0%                  | 5.5%                   |
| Antennas                                                                | Electronics and Telecommunication | 103,377             | 0.51                             | 0.02          | 7.2%                  | 5.6%                   |
| Specific Uses Or Applications Of Nanostructures                         | Physical Sciences and Engineering | 91,052              | 0.87                             | 0.02          | 5.7%                  | 7.7%                   |
| Recognition Of Data                                                     | Electronics and Telecommunication | 465,965             | 0.51                             | 0.02          | 11.1%                 | 7.9%                   |
| Image Data Processing Or Generation                                     | Electronics and Telecommunication | 442,536             | 0.18                             | 0.02          | 12.5%                 | 8.9%                   |
| Radio Direction-Finding                                                 | Electronics and Telecommunication | 195,868             | 0.50                             | 0.02          | 12.0%                 | 8.9%                   |
| Computer Systems Based On Specific Computational Models                 | Electronics and Telecommunication | 314,461             | 0.62                             | 0.02          | 52.4%                 | 32.6%                  |
| Diagnosis; Surgery                                                      | Biotechnology and Healthcare      | 588,561             | 0.32                             | 0.02          | 6.9%                  | 5.6%                   |
| Printed Circuits                                                        | Electronics and Telecommunication | 264,436             | 0.05                             | 0.02          | 4.5%                  | 3.6%                   |

\*Patent Asset Index is a measure computed by PatentSight which normalizes citations by technology class, age, and office and multiplies it by the Market Coverage at the patent level. Then, they were aggregated at the Technology Subclass level.

**The UAE's strengths in scientific publishing are mostly in Engineering and Technology, whereas its adjacent opportunities on the extensive margin are mostly in other fields such as the natural sciences, health sciences, social sciences, and business and economics.** Some of the adjacent opportunities have high global growth rates, indicating that the UAE is well-poised to capitalize on these opportunities. Conversely, fields such as 'Construction Engineering' and 'Economic Policy', where the UAE has a higher number of scientific publications and patent densities, show moderate global growth rates. Based on these insights, the UAE can prioritize investment in scientific research and development in high-growth areas aligned with its needs, while continuing to nurture the fields where it already has a strong set of capabilities. This approach will not only align with global trends but also capitalize on the foundational strengths within the UAE's existing innovation ecosystem.

**Table 3: Sub-Sample of Top Nearby Opportunities for the UAE in Scientific Publications (intensive margin)**

| Opportunities for Intensification |                                  |                                   |               |                 |                       |                        |
|-----------------------------------|----------------------------------|-----------------------------------|---------------|-----------------|-----------------------|------------------------|
| United Arab Emirates (2020)       |                                  |                                   |               |                 |                       |                        |
| SCIENTIFIC FIELD                  | SCIENTIFIC FIELD CATEGORY        | NUMBER OF SCIENTIFIC PUBLICATIONS | DENSITY (IHS) | PUBLICATION RCA | GLOBAL CAGR (5-YEARS) | GLOBAL CAGR (10-YEARS) |
| Traditional medicine              | Health and Life Sciences         | 99,831                            | 0.88          | 1.34            | 15.8%                 | 14.5%                  |
| Programming language              | Engineering and Technology       | 577,754                           | 0.85          | 1.30            | 10.5%                 | 8.9%                   |
| Pulp and paper industry           | Engineering and Technology       | 84,997                            | 0.84          | 1.53            | 16.9%                 | 17.5%                  |
| Operating system                  | Engineering and Technology       | 551,968                           | 0.84          | 1.88            | 12.9%                 | 11.2%                  |
| Computer engineering              | Engineering and Technology       | 10,714                            | 0.83          | 1.28            | 25.2%                 | 15.7%                  |
| Software engineering              | Engineering and Technology       | 47,338                            | 0.83          | 2.76            | 10.5%                 | 6.9%                   |
| Engineering drawing               | Engineering and Technology       | 16,543                            | 0.83          | 1.33            | 13.8%                 | 12.6%                  |
| Computer architecture             | Engineering and Technology       | 13,673                            | 0.82          | 2.68            | 7.6%                  | 5.1%                   |
| Financial economics               | Business and Economics           | 31,806                            | 0.82          | 4.69            | 9.0%                  | 6.9%                   |
| Theoretical computer science      | Engineering and Technology       | 68,433                            | 0.82          | 1.23            | 13.5%                 | 10.0%                  |
| Combinatorics                     | Natural Sciences and Mathematics | 162,571                           | 0.82          | 1.36            | 7.1%                  | 8.4%                   |
| Macroeconomics                    | Business and Economics           | 237,770                           | 0.82          | 1.55            | 12.9%                 | 13.5%                  |
| Automotive engineering            | Engineering and Technology       | 71,922                            | 0.82          | 2.19            | 13.8%                 | 14.2%                  |
| Engineering management            | Engineering and Technology       | 15,500                            | 0.82          | 3.01            | 16.6%                 | 11.1%                  |
| Civil engineering                 | Engineering and Technology       | 67,927                            | 0.81          | 1.82            | 17.1%                 | 17.3%                  |

**Table 4: Sub-Sample of Top Nearby Opportunities for the UAE in Scientific Publications (extensive margin)**

| Opportunities for Diversification |                                  |                                   |               |                 |                       |                        |
|-----------------------------------|----------------------------------|-----------------------------------|---------------|-----------------|-----------------------|------------------------|
| United Arab Emirates (2020)       |                                  |                                   |               |                 |                       |                        |
| SCIENTIFIC FIELD                  | SCIENTIFIC FIELD CATEGORY        | NUMBER OF SCIENTIFIC PUBLICATIONS | DENSITY (IHS) | PUBLICATION RCA | GLOBAL CAGR (5-YEARS) | GLOBAL CAGR (10-YEARS) |
| Fishery                           | Health and Life Sciences         | 142,917                           | 0.82          | 0.51            | 12.7%                 | 10.5%                  |
| Mineralogy                        | Natural Sciences and Mathematics | 99,768                            | 0.78          | 0.98            | 9.4%                  | 9.4%                   |
| Economic policy                   | Business and Economics           | 14,389                            | 0.78          | 0.13            | 14.2%                 | 10.4%                  |
| Regional science                  | Natural Sciences and Mathematics | 16,562                            | 0.76          | 0.88            | 20.7%                 | 16.9%                  |
| Gender studies                    | Social Sciences and Humanities   | 35,016                            | 0.75          | 0.63            | 16.9%                 | 13.0%                  |
| Nuclear physics                   | Natural Sciences and Mathematics | 265,947                           | 0.75          | 0.47            | 4.3%                  | 8.5%                   |
| Soil science                      | Health and Life Sciences         | 114,003                           | 0.74          | 0.55            | 15.4%                 | 13.8%                  |
| Neoclassical economics            | Business and Economics           | 3,743                             | 0.73          | 0.73            | 10.8%                 | 7.7%                   |
| Polymer chemistry                 | Natural Sciences and Mathematics | 175,635                           | 0.71          | 0.67            | 4.5%                  | 6.8%                   |
| Audiology                         | Health and Life Sciences         | 109,655                           | 0.70          | 0.38            | 8.2%                  | 10.2%                  |
| Classics                          | Social Sciences and Humanities   | 2,262                             | 0.70          | 0.40            | 8.4%                  | 5.0%                   |
| Environmental resource management | Health and Life Sciences         | 94,739                            | 0.69          | 0.80            | 17.6%                 | 18.0%                  |
| Computational science             | Engineering and Technology       | 12,791                            | 0.68          | 0.14            | 8.6%                  | 8.9%                   |
| Environmental ethics              | Social Sciences and Humanities   | 10,526                            | 0.66          | 0.78            | 17.9%                 | 14.1%                  |
| Cognitive science                 | Social Sciences and Humanities   | 17,451                            | 0.66          | 0.63            | 10.6%                 | 9.7%                   |

## 3.2 The Role of Foreign Firms and International Universities

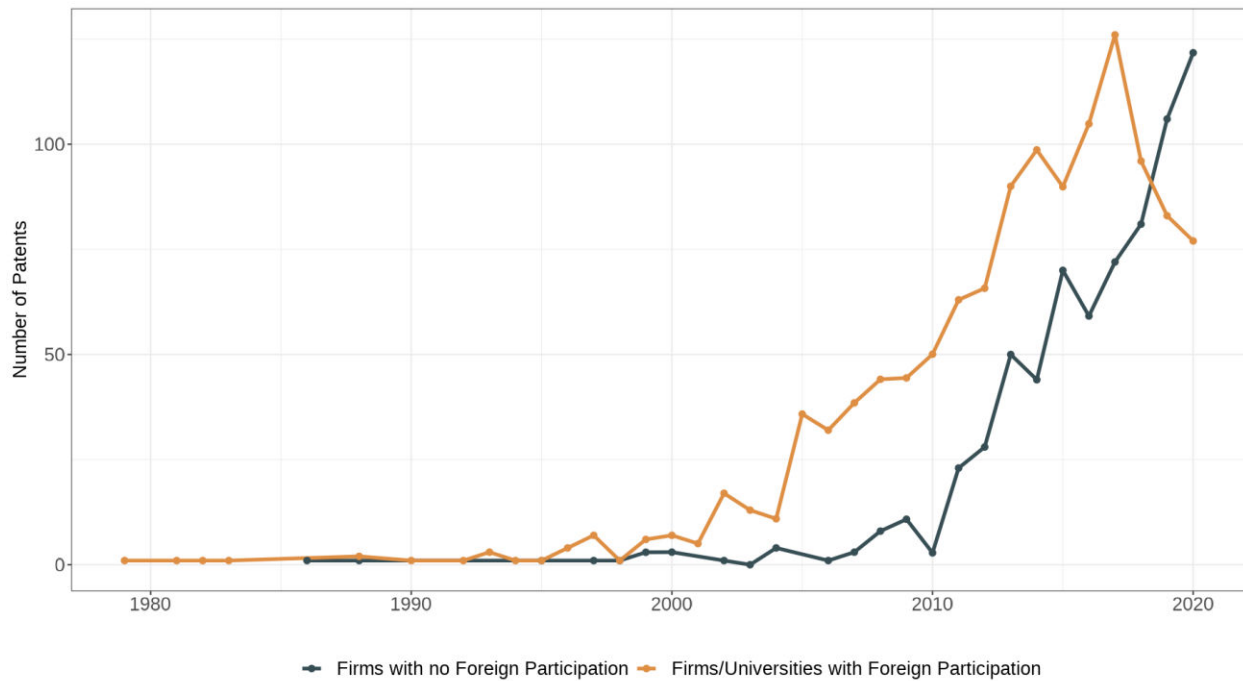
Focusing on attracting foreign firms for research and development (R&D) is crucial for the United Arab Emirates' R&D sector and its broader economy. In recent years, the global landscape for cross-border R&D investments has seen significant growth, not

only in OECD countries but in countries aspiring to attract and retain foreign investments in manufacturing and sophisticated services provision. This trend underscores competition among cities and regions to attract these investments and foreign workers with high quality research-skills, driven by the expectation that they will create high-quality manufacturing capabilities, enhance local innovation capabilities, and establish the country as a recognized technological hub which is the UAE's government aspiration for 2030.

**The inflow of R&D activities by foreign firms and universities can initiate a process of collective learning within the local economy, fostering collaboration with local inventors and the recombination of new and existing knowledge.** While foreign firms invest abroad to access knowledge assets outside their home regions, they often balance the need to acquire new knowledge against the risk of unintentional knowledge spillovers to potential competitors. This dynamic creates a unique opportunity for local economies to benefit from the advanced knowledge and technologies of these foreign entities, enriching the local R&D landscape. The interaction between foreign MNEs and local entities can lead to a fruitful exchange of knowledge and expertise, contributing significantly to the advancement of the UAE's R&D sector and enhancing its global competitiveness (Crescenzi et al., 2022).

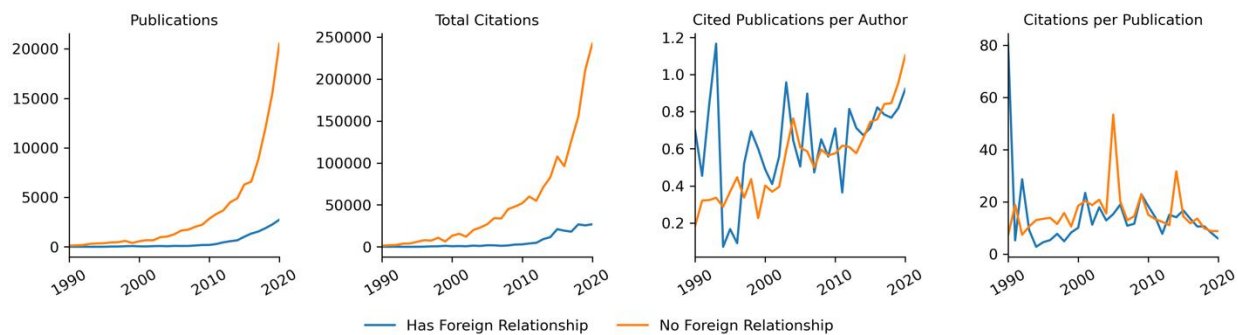
**Firms with foreign participation led the way in firm patenting in the early days of the innovation sector in the UAE but it has decreased since 2017.** As the UAE's grew and established itself a hub for the exports of services, its patenting rate started to grow. While part of the growth can be attributed to individuals residing in the UAE, foreign firms produced a sizeable part of the UAE's research output which until 2018 led above the production of domestic firms with no foreign participation. Since 2010, patenting from local actors has accelerated especially through local universities such as Khalifa University and UAE University (Figure 30). In the case of publications, the production has been concentrated on local universities, which are responsible for most of the growth in the last few years; however, there has been significant growth stemming from international universities since the second half of 2000s, as more foreign universities established campuses in the UAE.

*Figure 30. Number of Patent Families where the Assignee is a Firm, by Ownership (1980-2020)*



Source: PATSTAT; NER; authors' calculations.

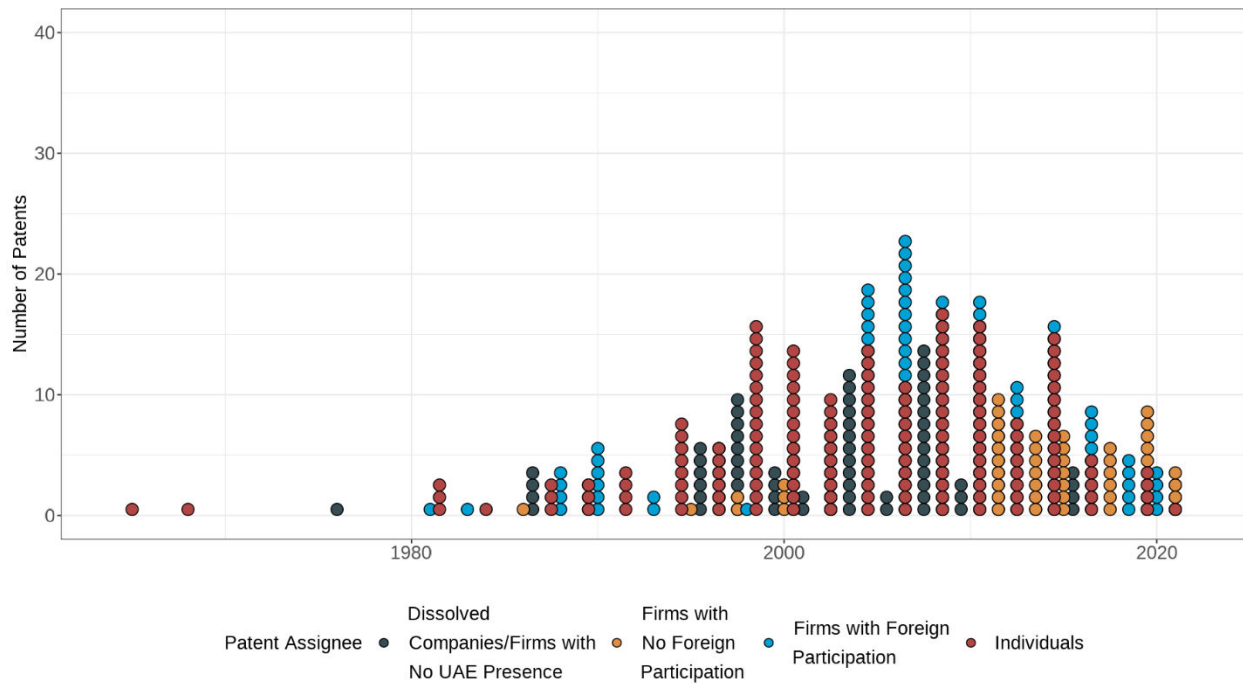
*Figure 31. Scientific Productivity of UAE Institutions Over Time*



Source: OpenAlex; authors' calculations.

**Despite being one of the most significant groups as patent assignees, foreign firms are not the main group of first movers when introducing technology classes.** From the early part of the 2000s to the mid-2010s, technology classes were mostly first patented by individuals, firms that are now dissolved or firms that have no UAE presence currently. Since the mid-2010s, there has been a significant presence of local firms and universities, which could be suggestive of added capabilities acquired either through the relatedness of other technologies or the attraction of researchers (from foreign firms or other countries) that are introducing those capabilities into the UAE economy.

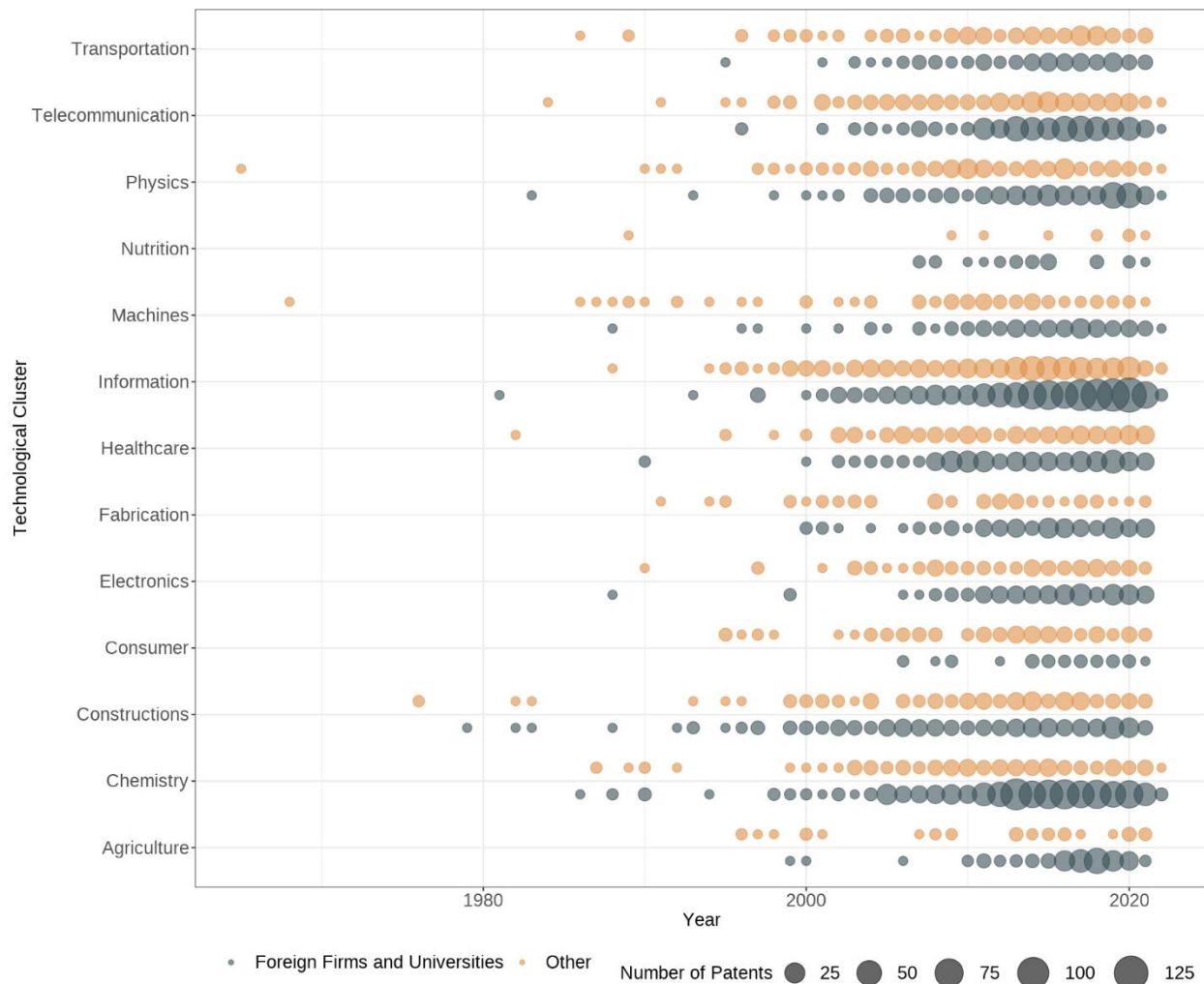
Figure 32. Agents that Introduced a Technology Sub-Class for the First Time (1970-2021)



Source: PATSTAT; NER; authors' calculations.

**Despite not being the main introducer of technologies into UAE's technological capabilities, firms with foreign participation tend to be key actors in patenting in different technological clusters, such as Information, Chemistry, and Telecommunication.** Foreign firms and universities are among the main innovators, providing key knowledge inputs to the creation of new technologies in the UAE, especially in technology classes typically associated with industries where there is a significant presence of SOEs, such as polymers, oil well drilling, and telecommunication. Additionally, the UAE has been able to localize research stemming from foreign firms in information technologies. This sector has benefitted from an increase in the availability of foreign skilled labor in its sector working in STEM occupations, which has affected not only patenting in these technologies but scientific works in the Computer Science sub-fields.

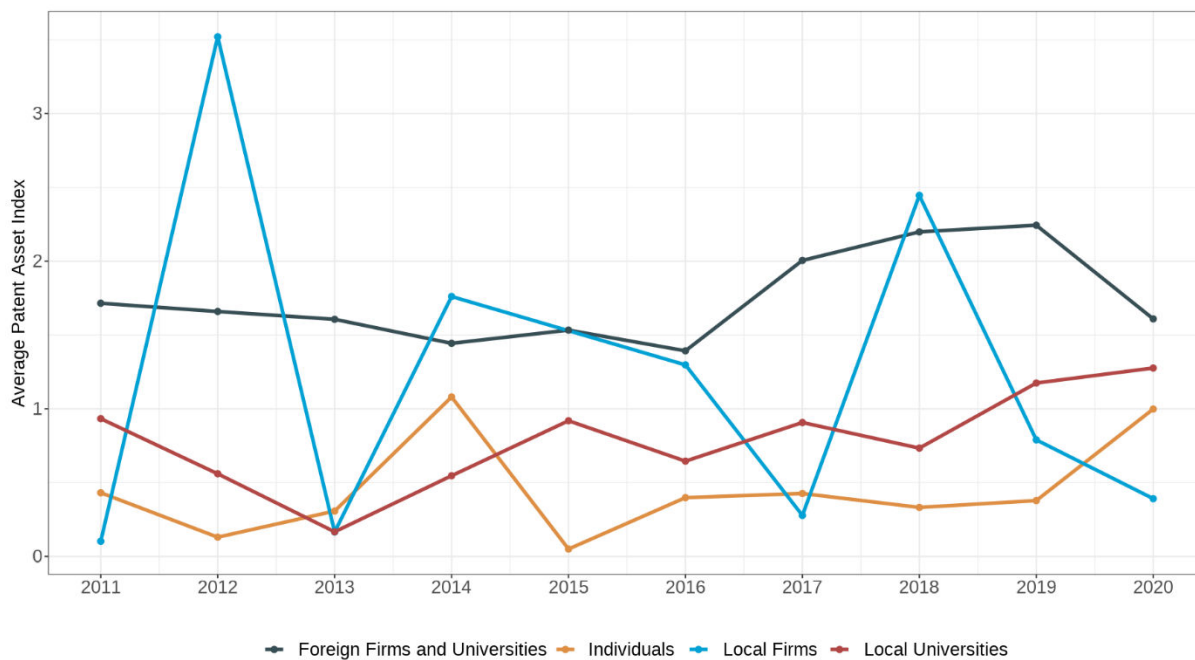
Figure 33. Patent Families by Technology Cluster and Foreign Ownership Presence



Source: PATSTAT; NER; authors' calculations.

**Patents filed by foreign firms and universities tend to be more valuable on average than other groups, as they are more frequently cited and are covered in more markets.** On the other hand, the quality of the patents created by local firms tends to be volatile and highly dependent on the overall capabilities of the assignee filing for the patent and due to the overall low patent numbers. Similarly, patents in which the assignees are individuals or local universities have consistently the lowest quality among all groups, which is suggestive of the lower commercial viability of the technologies created. However, there has been modest growth in the value of the patents created by local universities as they have become relatively more globally collaborative: UAE-based inventors were 100% of the inventors in 2013 and 87.5% in 2019.

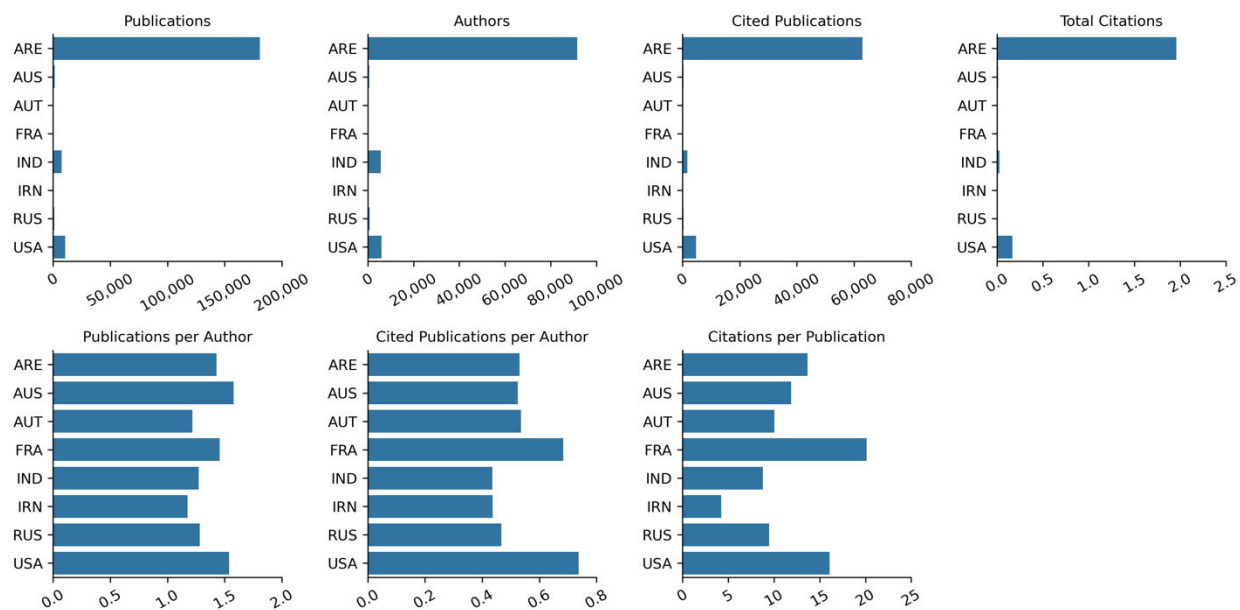
Figure 34. Average Patent Asset Index, by Year of Filing



Source: PATSTAT; PatentSight; authors' calculations.

**In the case of Scientific Publications, there is significant heterogeneity in the quality of the publication depending on the country of origin of the institution.** While the number of publications is highly concentrated in local universities, there is a significant share of the publications that comes from universities whose parent universities are in India and the United States. In terms of the overall quality of the publications, those that originated in French and American universities tend to be of higher quality, potentially driven by a higher degree of connectedness and centrality in international networks. However, it is important to note that French publications are done by INSEAD (See Table 6, Appendix 1) in low numbers. This highlights the need for further inter-universities collaboration that would increase the knowledge spillovers from international campuses to local universities.

Figure 35: UAE Institutions by Country of Parent Institution



Source: OpenAlex; authors' calculations.

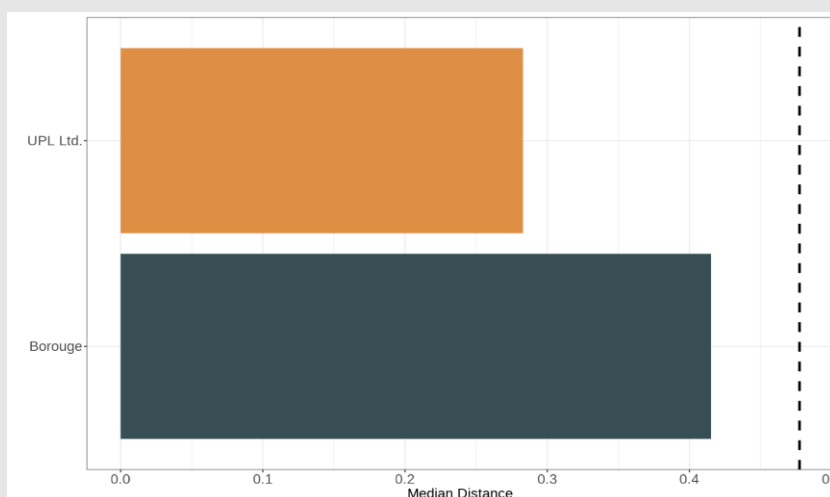
### Box 1: The Cases of Borouge and UPL Ltd.

**Borouge** is a joint venture founded in 1998 between Abu National Oil Company (ADNOC) and Borealis, a chemical company from Austria. In 2015, the joint venture inaugurated an innovation center in Abu Dhabi whose main purpose was to focus on the innovation of polymer development and application. **UPL Ltd.** is an Indian Multi-National Corporation headquartered in Mumbai that manufactures agrochemicals and industrial chemicals. The firm opened an office in Dubai in 2014, where it conducts some of its Research and Development operations. Both firms have used inventors based in the UAE to file for patents since the late 2000s and account for 7% of the portfolio of patents with UAE-based inventors since 2010.

Borealis, one of the parent companies of Borouge, owns and operates an additional four research centers in Finland, Austria, China, and Sweden, which enables the joint-venture to integrate and access into its organizational networks of collaboration. UPL currently owns 25 R&D facilities around the world which include places like Mexico, India, and the United States. These network of research centers allow local inventors to tap into international knowledge pools to recombine it with local knowledge a create new technologies. Since 2014, on average, Borouge uses 10 UAE inventors per patent (around 45% of the total inventors involved), while UPL utilizes 19 UAE inventors per patent (around 45% of the total inventors involved).

Since 2010, Borouge has patented in 20 different technology sub-classes in the UAE, of which it was the first applicant of only two (in chemicals and consumer products) while UPL patented in 20 different classes for which it was only first mover in two (both in agriculture). Despite the diversity in patenting technology subclasses and the access to international networks, both firms patented early in technologies that were closer to the set of capabilities (defined as RPOP > 0.75 in 5 years before first patent) that the UAE had just before the entry of the firm. This highlights the importance of a more targeted approach to the attraction of firms that will locate their R&D activities in the UAE.

*Figure 36. Median Distance from Capabilities to Other Technological Sub-Classes*



### 3.3 The Role of Scientific Collaboration

**Scientific collaboration is an important tool to accelerate innovation and acquire scientific capabilities from others.** The prevalence of teams in science has increased rapidly over the last few decades (Wagner et al., 2015; Wuchty et al., 2007). Such collaborations provide significant rewards, offering extensive benefits to both science and society, and are an essential element in addressing contemporary global challenges as was demonstrated through research on COVID-19 (Nature, 2021). Collaborative efforts in science have been recognized for their ability to bridge organizational, disciplinary, and cultural divides, thus expanding the potential for discovery (Dusdal & Powell, 2021). Scientific collaboration has been shown to provide more atypical combinations of knowledge and gather more funding (Uzzi et al., 2013). International collaborations in particular, have been growing as a share of all papers produced, and produce more well-cited papers (Adams, 2013). Collaborations with established authors produce more cited papers, and provide lasting positive impacts to early career researchers (Akcigit et al., 2018; Azoulay et al., 2010). It is thus important that the UAE leverage scientific collaborations as a tool to acquire and develop its scientific capabilities.

**In the context of the UAE, collaboration has been key to developing its innovation portfolio.** The country collaborates extensively across various fields, with a focus on research topics that are growing globally, including AI and other STEM fields. The UAE seems to have forged key partnerships in areas where it seeks to develop a competitive edge, leveraging the expertise and resources of established global players. Moreover, international collaborations serve as a path for the UAE to access diverse knowledge resources, which is particularly beneficial for firms and institutions in the UAE as it diversifies away from an oil-based to an innovation-based economy. By partnering with universities and research institutes globally, the UAE can tap into a wider pool of innovation and expertise, enhancing its own capabilities in scientific publishing and patenting. In summary, the UAE's approach to scientific collaboration reflects a global trend toward interconnected research efforts. By strategically aligning with international partners and focusing on fields that support its developmental objectives, the UAE can position itself to benefit from global scientific collaborations.

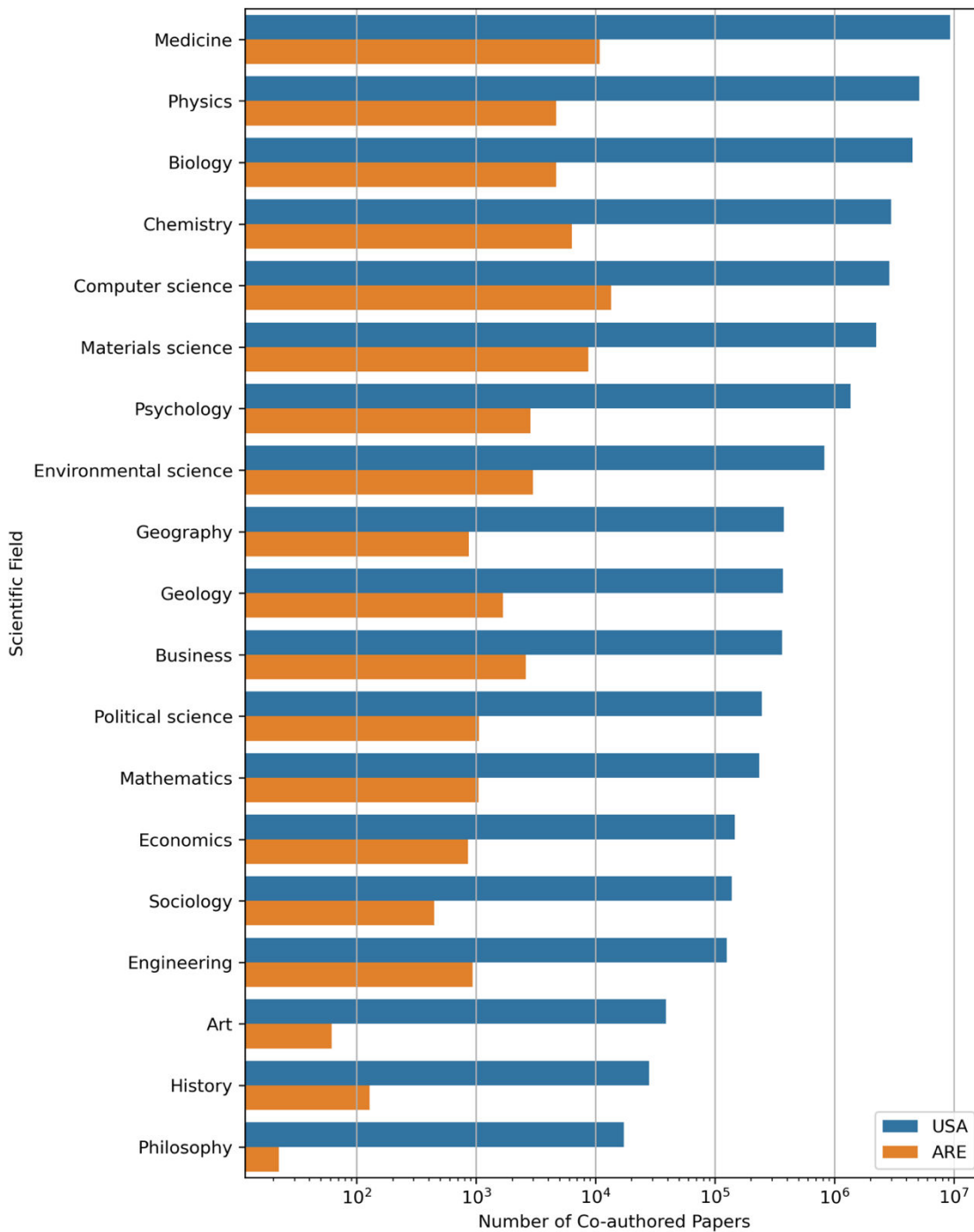
**We used OpenAlex data to analyze the landscape of scientific collaboration for the UAE.** To measure international scientific collaborations, we identified unique pairs of authors' country affiliations on each paper, using this as a proxy for collaborative activity. We adopted this approach as citations take time to accrue, and we wanted to consider the latest trends in scientific collaborations. Several other studies have used the number of co-authorships to understand scientific collaboration patterns (van der Wouden & Youn, 2023; Wagner et al., 2019). By focusing on the presence of international co-

56 | Scientific and Technical Innovation in the United Arab Emirates

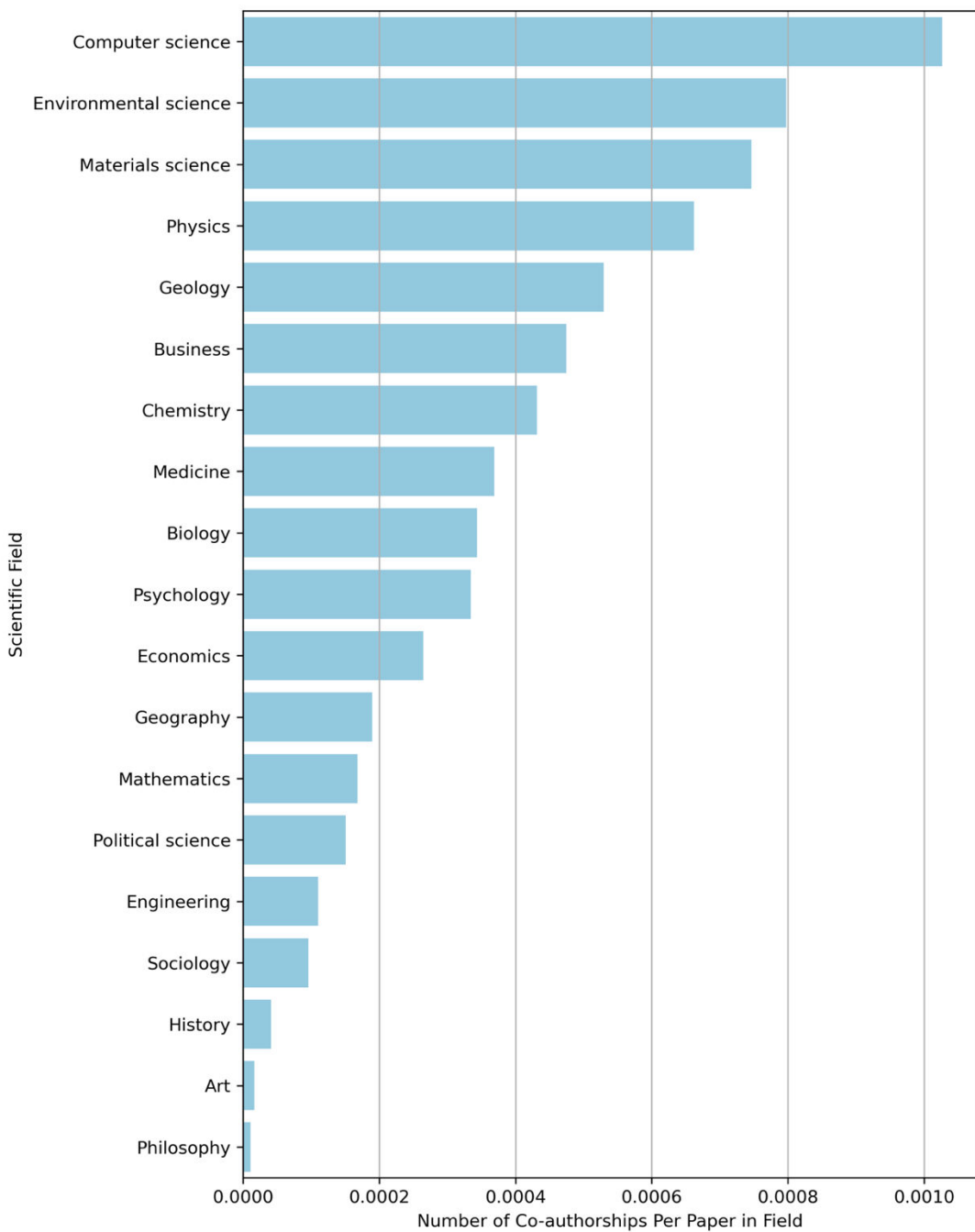
authorship as a direct indicator of collaboration, rather than the subsequent citation impact, our analysis captures the most recent collaborative activity between countries.

**The UAE has its research collaborations mostly concentrated in computer science, environmental science, and materials science.** Figure 37 illustrates a striking contrast in the scale of international scientific collaborations of the UAE in comparison to the United States (USA) and underscore the UAE's focused engagement in certain scientific fields. In comparison with the USA, the UAE demonstrates a smaller volume of collaborative scientific publications across a wide range of disciplines, with strengths noted in fields such as Computer Science, Environmental Science and Materials Science. This suggests a concentrated area of expertise and possibly a strategic direction in the country's research endeavors. Furthermore, when adjusting for the overall prevalence of works in these fields (Figure 38), the UAE shows a higher ratio of co-authorships per paper within these same fields, indicating a robust level of collaboration relative to the size of its academic community. These patterns of collaboration, especially in emerging and complex fields, are indicative of the UAE's innovation potential. This strong foundation of collaborations could help build an innovation ecosystem that leverages international partnerships and scientific mobility to amplify its innovation capabilities.

Figure 37. Collaborations in Scientific Publications for UAE vs. USA



*Figure 38: Collaborations in Scientific Fields for UAE, Adjusted by General Prevalence of Works*



**The UAE's research collaborations are mostly with the US, with some notable partnerships with the UK, China, India, Australia, and Saudi Arabia.** The strong concentration of research collaborations with the US is reflective of the fact that most of the research in the world occurs in the US. Further, collaborations with Saudi Arabia might

be because of shared research interests, and low distance. To account for the factors that are simply borne out of the size of countries' overall research outputs or out of distance, we use a gravity model as shown in the regression table (Table 5). Global scientific collaborations follow a gravity model pattern, where collaboration likelihood diminishes with distance but also varies based on specific country characteristics. The UAE could actively seek to build collaborations in regions where they are currently fewer than expected, perhaps by providing incentives for joint research ventures and scientific projects, thus broadening the UAE's innovation network, and enhancing its global scientific impact.

**From a policy perspective, the UAE's focused collaboration pattern presents an opportunity to further leverage these relationships to boost innovation.** Encouraging deeper engagement with these key partners could involve creating joint research grants or funds, establishing international innovation hubs, or promoting researcher exchange programs. Scientific collaborations have been shown to be a key driver of increasing researcher productivity in the last few decades (Nature, 2021).

**Global scientific collaborations follow a gravity model pattern, where collaboration likelihood diminishes with distance and is based on fixed country characteristics.** This is in line with previous literature on the topic (van der Wouden & Youn, 2023). The negative residuals for the UAE in Table 5 highlight where collaborations are less frequent than expected, indicating potential untapped opportunities for scientific partnership expansion. The UAE seems to be collaborating a lot less than expected with China, which might be because China itself has grown its scientific institutions dramatically only in the last two decades. This represents a significant opportunity to expand scientific partnerships. Other countries with which the UAE has fewer collaborations than expected include Japan, Russia, Spain, Germany, and Italy. The heatmap in Figure 40 displays both positive residuals (in orange) and negative residuals (in blue). Positive residuals indicate countries with unexpectedly high collaboration rates, suggesting that cultural, historical, or institutional factors may be promoting these partnerships beyond what is typical for the UAE's size and geographical position.

Figure 39: Co-authorships between UAE and Other Countries

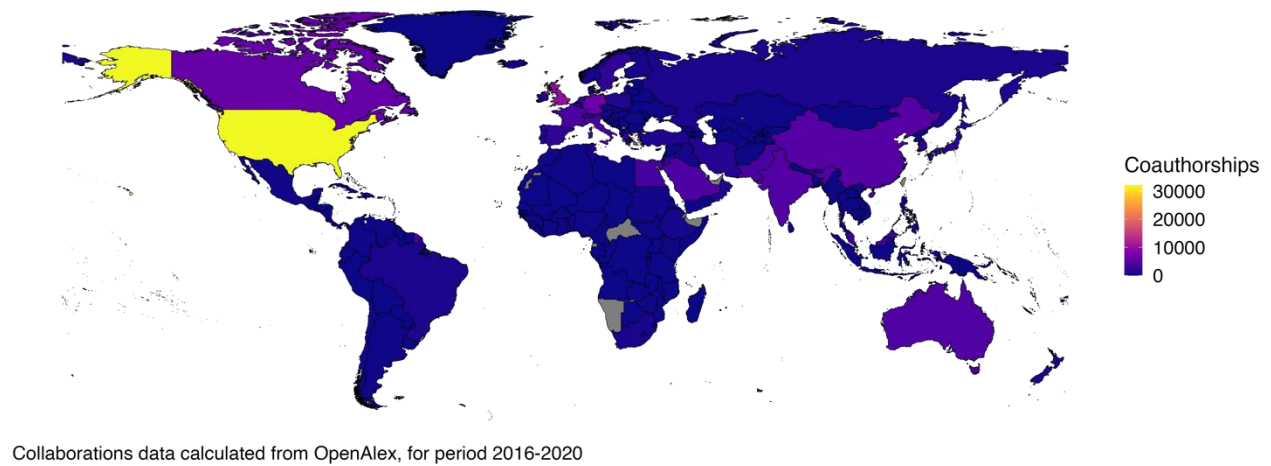


Table 5: Gravity Model of International Scientific Collaboration Network

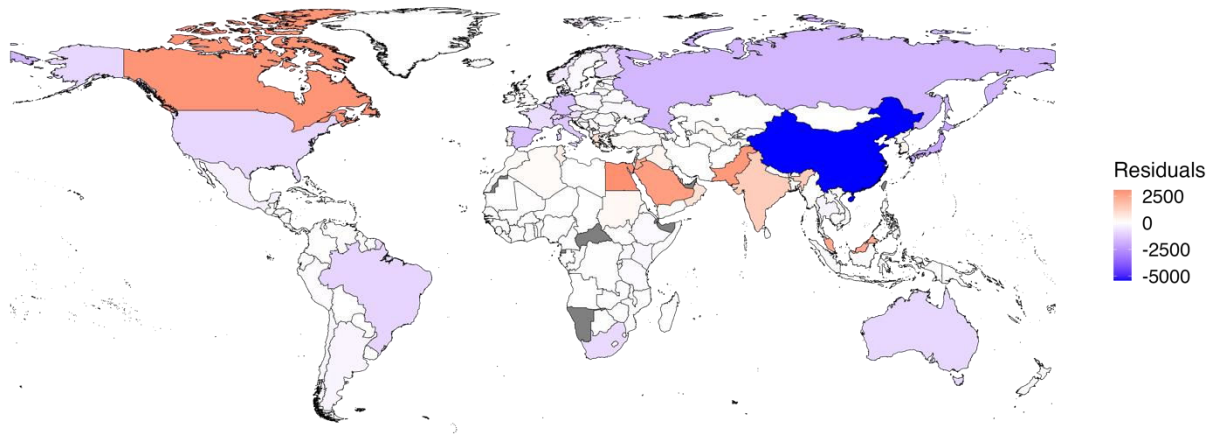
|                                                   | overall  | by concept |  |
|---------------------------------------------------|----------|------------|--|
| Log Distance                                      | -0.48*** | -0.50***   |  |
|                                                   | (0.04)   | (0.04)     |  |
| Num. Obs.                                         | 37056    | 748638     |  |
| R2                                                | 0.97     | 0.95       |  |
| Origin FE                                         | X        | X          |  |
| Destination FE                                    | X        | X          |  |
| Scientific Field FE                               |          | X          |  |
| + p < 0.1, * p < 0.05, ** p < 0.01, *** p < 0.001 |          |            |  |
| Data source: OpenAlex                             |          |            |  |
| Collaborations data for period 2016-2020          |          |            |  |
| Regressions are PPML with fixed effects           |          |            |  |

| Partner Country | Residuals |
|-----------------|-----------|
| CHN             | -4500     |
| JPN             | -2500     |
| RUS             | -2000     |
| ESP             | -1500     |
| DEU             | -1200     |
| ITA             | -1000     |
| BRA             | -800      |
| BEL             | -700      |
| USA             | -600      |
| AUS             | -500      |
| ZAF             | -400      |
| CHE             | -300      |
| FRA             | -200      |
| AUT             | -100      |
| FIN             | -50       |

Period of Analysis: 2016-2020

*Figure 40: Residuals for UAE from Gravity Model of International Scientific Collaboration Network*

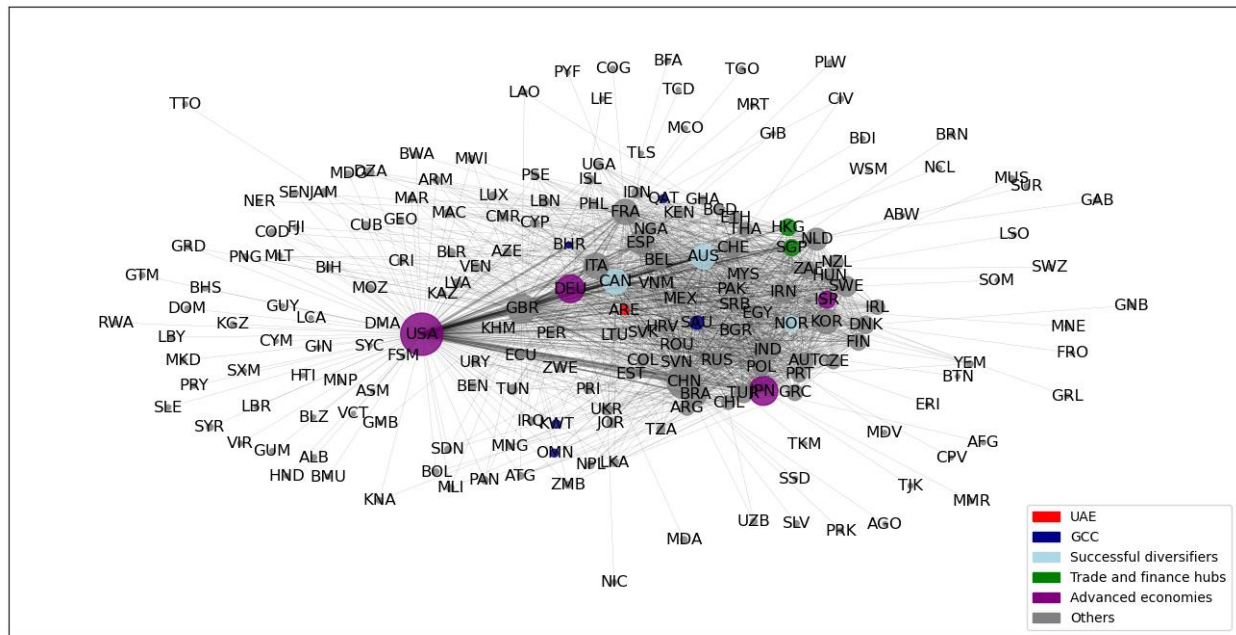


Collaborations data calculated from OpenAlex, for period 2016-2020

**The international scientific collaboration network reveals that the UAE is mostly connected to the global research community through the hubs of the US and the UK.** Figure 41 shows the international scientific collaboration (co-authorship) network. The nodes are countries, and the edges show significant co-authorship links<sup>17</sup>. While the UAE's links are not immediately visible because of the noisy nature of the network visualization, the primary links to the UAE are to the US and to the UK. This suggests that there is an opportunity for the UAE to collaborate with a more diverse set of countries, to position itself as a more central player in international scientific activity. As identified earlier, China is an important research partner that the UAE is collaborating with lesser than expected and represents a significant opportunity for increased research collaboration.

<sup>17</sup> The maximum spanning tree of the network is displayed, in addition to any edges that signify at least 1000 collaborations between the pair of countries.

Figure 41: International Scientific Collaboration Network

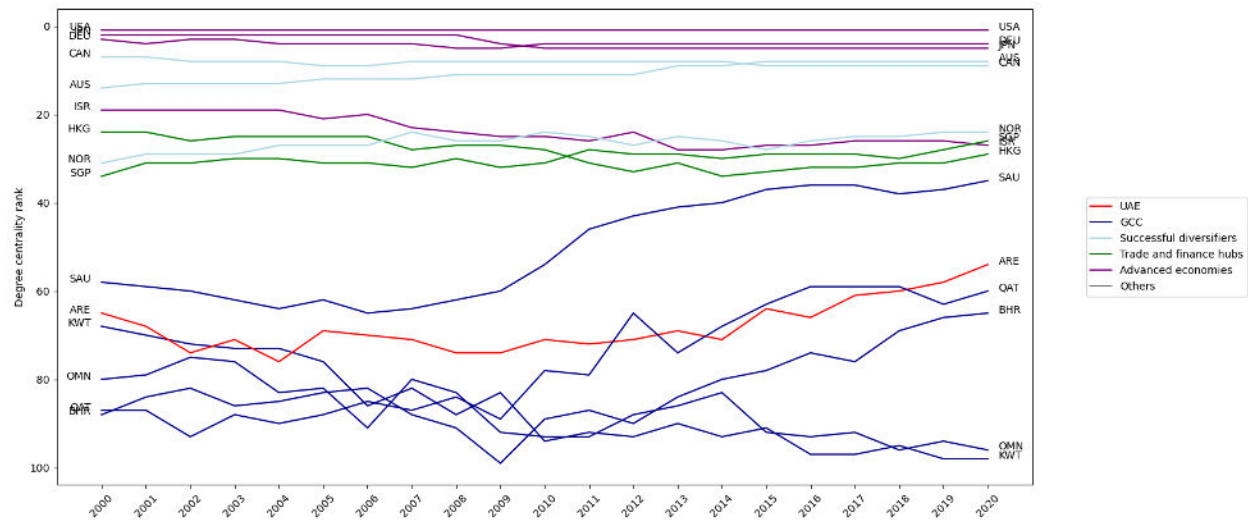


**The UAE has improved its position within the scientific collaboration network albeit only slightly, as defined by a variety of centrality measures.** The figures illustrate the UAE's degree, betweenness, and eigenvector centrality within the international research collaboration network. Degree centrality, reflecting the number of research collaborations, shows the UAE's engagement in the global research community. Betweenness centrality, indicates the UAE's position as an intermediary between other countries in the network, and eigenvector centrality, a measure of connectedness to well-connected collaborators. The UAE has a rank of about 50 in all three metrics.

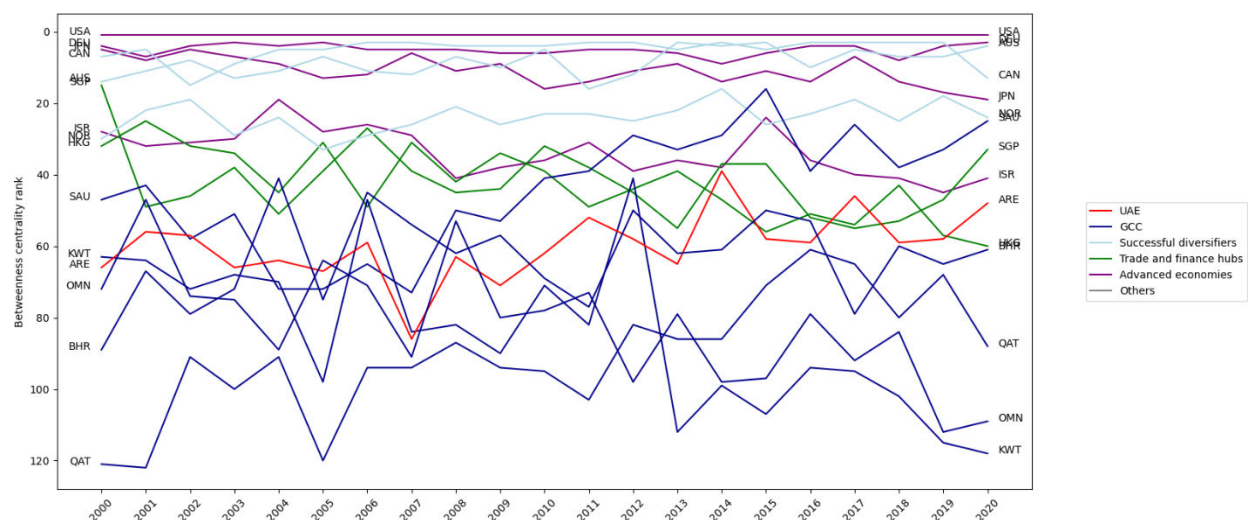
**The UAE's degree centrality rank (i.e., rank of total number of research collaborations) has steadily risen over time, meaning that it has improved its scientific collaborations with other countries.** The UAE ranks higher than Qatar, Bahrain, Oman, and Kuwait when it comes to number of research collaborations but is far lower in ranking compared to Saudi Arabia, which ranks closer to 40. A similar trend is observed in other metrics of centrality. Betweenness centrality, which measures the extent to which the UAE is an intermediary between other countries in the network, has remained mostly steady over time. The UAE's eigenvector centrality, which measures the extent to which the UAE is connected to well-connected collaborators, has also remained mostly steady over time. This contrasts with Saudi Arabia, which has seen a steady increase in all its centrality metrics over time. This implies that the UAE is not often used

as an intermediary by other countries to access additional research partnerships. The UAE may also benefit from deeper integration with central countries in the network. This could lead to a spill-over effect, enhancing the UAE's own centrality and innovation capabilities. These increases in centrality metrics could come naturally with the UAE's continued investment in scientific research and innovation.

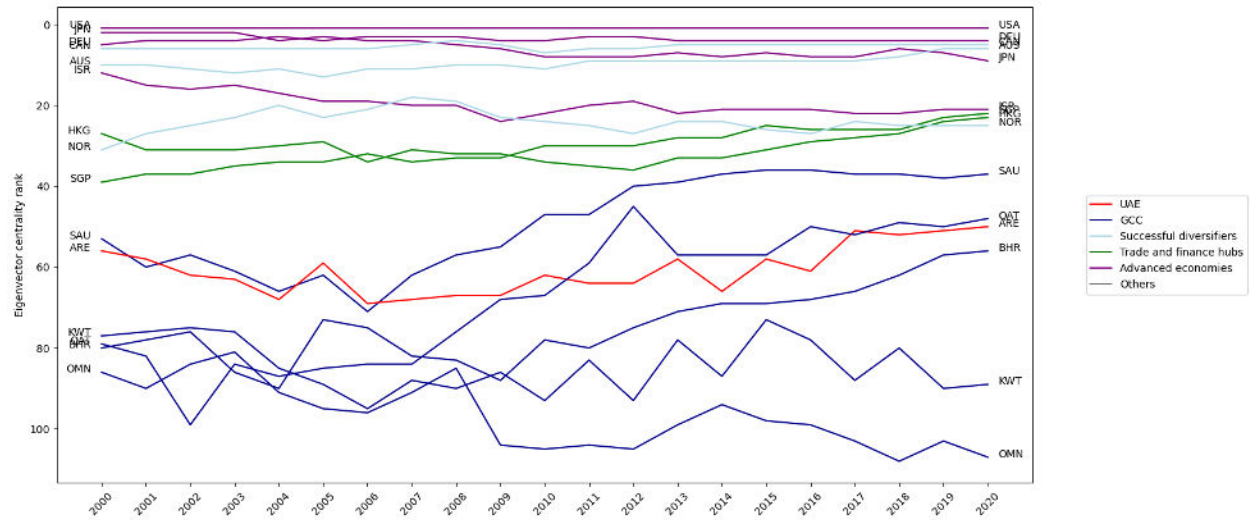
*Figure 42: Degree Centrality Ranks in the International Scientific Collaboration Network.*



*Figure 43: Betweenness Centrality Ranks in the International Scientific Collaboration Network.*



**Figure 44: Eigenvector Centrality Ranks in the International Scientific Collaboration Network**



## 4. Ideas for Science & Innovation Policy

**The UAE has made significant progress in advancing its innovation capabilities in the last few years but there is a role for public policy to aid in this process.** Achieving the goals of the National Innovation Strategy would likely involve a combination of policies with varying scope. As outlined in this report, developing a successful innovation sector that translates the hefty investments that the UAE is making in innovation activities into economic progress requires a combination of inputs that might require targeted policy action on each of them.

**Increasing current levels of research output might require significantly increasing the number of researchers available in the UAE.** There are indications that the current density of researchers in the UAE is a result of the current demand for R&D skills for the UAE's current industrial structure, which can also be a result of the spatial distribution of R&D capabilities in the world. As the UAE diversifies into new economic activities, the country can take steps to accompany this diversification process with policies that encourage the attraction of researchers and the resulting co-location of R&D activities in the country.

**Undergraduate and pre-doctoral research assistantships could affect scientific productivity and the probability of choosing a research career.** Evidence suggests that early exposure to research has larger long-term effects on the selection of a research career than innovation-specific abilities that an individual can have (Bell et al., 2017). Similarly, the exposure of recent medical graduates to a National Institutes of Health research program made them more likely to publish, mentor more trainees, and receive more citations in their work (Azoulay et al., 2021). Currently, UAE's main universities, namely UAE University and Khalifa University, offer graduate research assistantships to graduate students that could be expanded to include recent graduates with a bachelor's degree, as they currently represent the biggest share of STEM students in the UAE and could prove a source of future researchers as the R&D capabilities of the country mature and develop. As the UAE adds technological capabilities and its industry demands more research skills, the availability of researchers locally trained could prove beneficial as there will be less barriers needed to assimilate into the local R&D workforce.

**The attraction and migration of researchers to local universities and firms could lead to the development of more technologies, conditional on having the appropriate environment for their R&D activities.** In general, migrant inventors tend to "import" knowledge from their home countries, which allows the recipient countries to increase patenting. This points to migrant inventors as channels of technology-specific diffusion across different countries in the world (Bahar et al., 2020). While these mobile inventors

play a key role in the diffusion of technologies, a capable R&D labor force and gradual additions of capabilities would prove beneficial in sustaining these gains beyond the tenure of the migrant inventors. This policy in combination with the training of future researchers would potentially bolster and expand its R&D sector in the future as new researchers use this “imported” knowledge to recombine it with local knowledge.

**Sovereign Wealth Funds (SWFs) and SOEs could be a source for targeted acquisitions and joint ventures for the addition of R&D activities of companies that are close to the UAE’s related capabilities.** As evidenced by the case of Borouge’s innovation center, joint ventures can be a source of added capabilities in the intensive and extensive margin as long as there is relatedness in the technological capabilities. In this case and the case of GlobalFoundries (acquired by Mubadala in 2009), there was a gap between the establishment of the firm and the initial patenting of technologies<sup>18</sup>, as the UAE likely lacked the implied capabilities needed to push the technological frontiers of these companies. This could prove to be an effective medium-term policy to develop capabilities in related technologies.

**These joint ventures not only facilitate international collaborations but also enhance capabilities by leveraging the close organizational links with its research centers and international offices.** Multinational firms have been an important driver of innovation in the UAE, as they have not only introduced technologies into the country but attracted and relocated researchers to perform R&D activities. By leveraging the country's SOEs and SWFs financial prowess to attract international firms and its researchers, the UAE could build upon its revealed set of capabilities while also adding technologies that are in their adjacent possible. Similarly, these joint ventures will provide the means to tap into the new knowledge being created by other subsidiaries and research centers through collaboration of the researchers and the codified knowledge of the firm.

**The use of Free Zones is a successful story of a policy tool utilized to attract FDI and could prove useful for attracting R&D investments.** Free Zones in the UAE have become facilitators of the provision of public inputs and have allowed for policy experimentation in fields such as artificial intelligence (Daboin et al., 2023). This has allowed for the establishment of foreign firms within the boundaries of the free zones that have contributed to the growth in the fields of Computer Science and the patenting of Information Technologies. Providing public goods that enable the development of closely related new technologies, such as in the case of UPL in the Dubai Multi-Commodities Centre (DMCC), could unlock UAE’s latent technological capabilities.

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<sup>18</sup> Borouge was established in 1998 and patented for the first-time using UAE inventors in 2008. Global Foundries was established in 2009 and patented for the first-time using UAE inventors in 2018.

**Enabling and enhancing the use of infrastructure investment for capabilities spillover might require fostering collaborations between the users of such infrastructure and other local actors.** The investments made in infrastructure by local firms and universities, including SOEs, might require enhanced coordination from the Federal Government and the Emirates to achieve the desired spillovers outcomes from these investments. In its current form, the UAE is dedicating one of the highest expenditures per researcher levels in the world to achieve one of the highest levels of expenditures per output in the world, both in publications and patents. While there is growth to be expected in the future, maximizing the overall output of these investments will require reducing the barriers of collaboration between SOEs, local firms and universities, and foreign firms and universities.

**Finally, diagnosing the R&D sector in the UAE requires a better understanding of their expenditures composition, its industries, and the current capital stock available for its support.** The capital stock is an essential part of the production of new ideas and its scarcity can slow down the rate of growth of new ideas (Growiec et al., 2023). However, the placement of major R&D investments in places where there is a mismatch between local capabilities and the needs of the project can persistently hinder innovation and the spillovers into the local innovation ecosystem and its production structure (Crescenzi, 2021). Public policies for innovation in the UAE require significant coordination between institutions in the Federal Government, the Emirates, and the State-Owned Enterprises. As such, this coordinated effort needs readily available and disaggregated data that minimizes the barriers to this coordination and allows for effectively targeted place-based policies.

## 5. Conclusion

**The UAE has made significant progress in its R&D efforts measured through patents and scientific publications but there is still a gap to be closed with its peers.** This underperformance stems mainly from its relatively low density of researchers relative to the nation's GDP per capita, despite high levels of foreign skilled worker attraction and substantial expenditures per researcher. Despite the consistent growth in both its expenditure levels and research output, there could be indications of a mismatch between these investments and the actual outcomes in research productivity.

**Unlocking these opportunities requires a more nuanced approach to R&D investment, targeting specific fields and technologies where the UAE exhibits latent potential.** There is merit for a targeted approach towards the technologies and fields where the UAE shows some revealed capabilities, while also keeping in mind the current global innovation trends where the country can make an impact. This approach can be implemented by encouraging multinational collaborations and making the most of foreign R&D investments, as shown by the growing involvement of local universities and international organizations in the UAE's patenting activities.

**In summary, the UAE has made remarkable progress in the last ten years, yet it requires judicious and strategic public policy intervention.** This involves a multifaceted approach incorporating a diverse set of policy tools dedicated to target different areas and sectors. Expanding the researcher base, leveraging educational programs for scientific productivity, attracting global research talents, and optimizing investments and infrastructure are key to realizing the UAE's vision as a global innovation hub. The role of Sovereign Wealth Funds, State-Owned Enterprises, and the strategic use of Free Zones are instrumental in this context, marking the path for a coordinated and effective innovation policy that resonates with the UAE's economic aspirations.

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## Appendix 1: Additional Descriptives

Figure 45. Publications per Million People and GDP per Capita, Adjusted by Natural Resources Rent

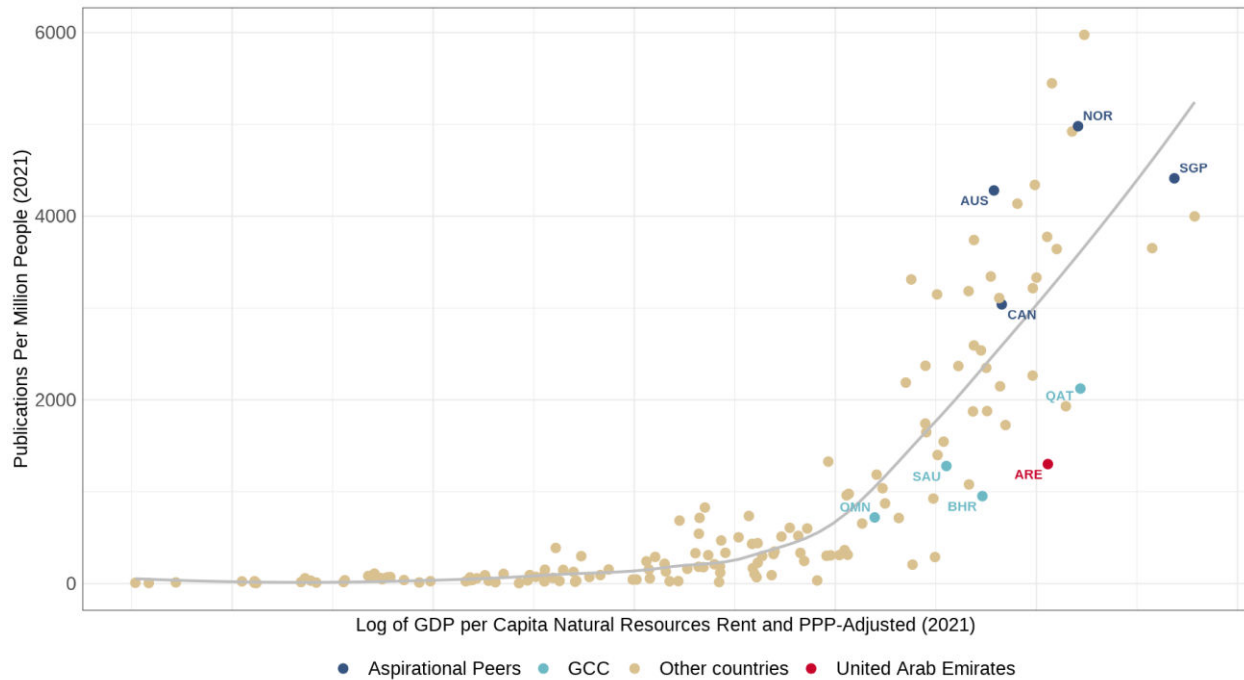
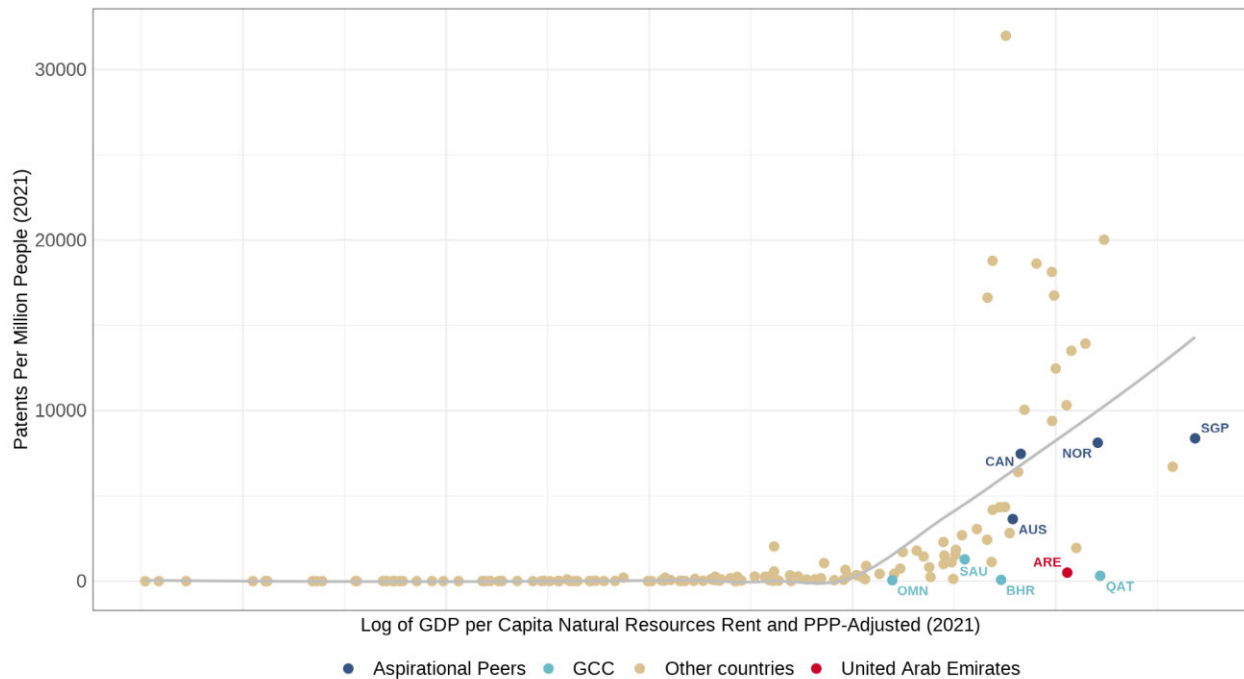


Figure 46. Patents per Million People and GDP per Capita, Adjusted by Natural Resources Rent



*Figure 47. Fastest Growing Technologies in the World*

### Top Growing Technologies

World (2017 - 2022)

| IPC TECHNOLOGY SUBCLASS                                               | PATENT ASSET INDEX* | CAGR (5-YEARS) | CAGR (10-YEARS) |
|-----------------------------------------------------------------------|---------------------|----------------|-----------------|
| Internet of Things                                                    | 11,589              | <b>81.4%</b>   | 76.2%           |
| Electronic Solid-State Devices                                        | 6,920               | <b>58.5%</b>   | 56.2%           |
| Computer Systems Based On Specific Computational Models               | 314,461             | <b>52.4%</b>   | 32.6%           |
| Electronic Memory Devices                                             | 10,422              | <b>49.5%</b>   | 37.5%           |
| Mechanical Or Pressure Cleaning Of Carpets, Or Other Textile Articles | 1,629               | <b>45.9%</b>   | 30.6%           |
| Unmanned Aerial Vehicles                                              | 3,554               | <b>44.3%</b>   | 72.3%           |
| Geothermal Collectors                                                 | 1,690               | <b>41.3%</b>   | 37.4%           |
| Image or Video Recognition or Understanding                           | 172,791             | <b>38.5%</b>   | 25.1%           |
| Organic Electric Solid-State Devices                                  | 36,481              | <b>37.7%</b>   | 43.6%           |
| Computational Chemistry                                               | 9,263               | <b>36.1%</b>   | 38.0%           |

\*Patent Asset Index is a measured computed by PatentSight which normalizes citations by technology class, age, and office and multiplies it by the Market Coverage at the patent level. Then, they were aggregated at the Technology Subclass level.

Source: PatentSight

*Figure 48. Biggest Technologies in the World*

### Top Technologies

World (2017 - 2022)

| IPC TECHNOLOGY SUBCLASS                                                 | PATENT ASSET INDEX* | CAGR (5-YEARS) | CAGR (10-YEARS) |
|-------------------------------------------------------------------------|---------------------|----------------|-----------------|
| Electric Digital Data Processing                                        | <b>1,787,167</b>    | 5.3%           | 5.4%            |
| Semiconductor Devices                                                   | <b>1,012,556</b>    | 2.6%           | 1.8%            |
| Transmission Of Digital Information                                     | <b>973,181</b>      | 5.1%           | 5.3%            |
| Preparations For Medical, Dental, Or Toilet Purposes                    | <b>867,427</b>      | 5.7%           | 3.6%            |
| Wireless Communication Networks                                         | <b>704,636</b>      | 6.8%           | 7.4%            |
| Specific Therapeutic Preparations                                       | <b>678,939</b>      | 6.8%           | 4.7%            |
| Analysing Chemical Or Physical Properties Of Materials                  | <b>614,180</b>      | 6.9%           | 5.3%            |
| Pictorial Communication                                                 | <b>592,235</b>      | 1.8%           | 1.6%            |
| Diagnosis; Surgery                                                      | <b>588,561</b>      | 6.9%           | 5.6%            |
| Data Processing Systems Adapted For Administrative, Or Similar Purposes | <b>491,332</b>      | 10.3%          | 8.5%            |

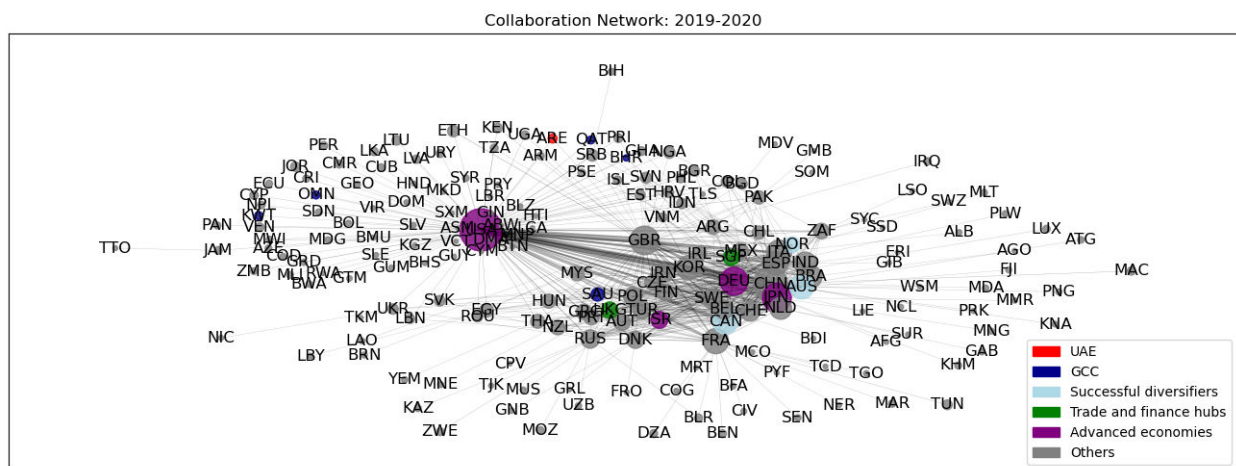
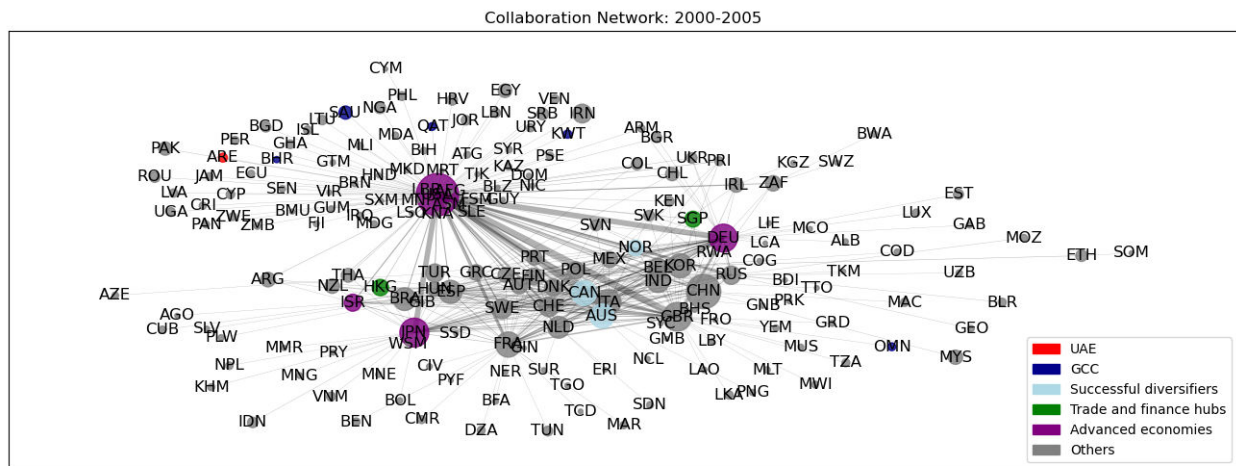
\*Patent Asset Index is a measured computed by PatentSight which normalizes citations by technology class, age, and office and multiplies it by the Market Coverage at the patent level. Then, they were aggregated at the Technology Subclass level.

Source: PatentSight

*Table 6: Institutions with Foreign Relationships Publishing in the UAE*

| <b>Institution</b>                                               | <b>Country</b> | <b>Publications</b> | <b>Total Citations</b> | <b>Cited Publications per Author</b> | <b>Citations per Publication</b> |
|------------------------------------------------------------------|----------------|---------------------|------------------------|--------------------------------------|----------------------------------|
| New York University Abu Dhabi                                    | USA            | 7310                | 132851                 | 1.07                                 | 21.94                            |
| Amity University                                                 | IND            | 6104                | 13675                  | 0.22                                 | 2.93                             |
| Tawam Hospital                                                   | USA            | 3323                | 32898                  | 0.53                                 | 12.7                             |
| Birla Institute of Technology and Science, Pilani - Dubai Campus | IND            | 1486                | 11810                  | 0.7                                  | 15.74                            |
| University of Wollongong in Dubai                                | AUS            | 1253                | 9918                   | 0.52                                 | 11.9                             |
| Synergy University Dubai                                         | RUS            | 1121                | 7173                   | 0.47                                 | 9.46                             |
| Islamic Azad University, UAE Branch                              | IRN            | 182                 | 545                    | 0.44                                 | 4.26                             |
| MODUL University Dubai                                           | AUT            | 137                 | 1461                   | 0.54                                 | 10.05                            |
| INSEAD                                                           | FRA            | 67                  | 1250                   | 0.68                                 | 20.11                            |
| Intel (United Arab Emirates)                                     | USA            | 3                   | 37                     | 0.67                                 | 12.33                            |

Figure 49: Evolution of the International Scientific Collaboration Network



## Appendix 2: Density as a Predictor of Future Technological and Scientific Capabilities

Table 7: Predicting growth in scientific publications using density.

|                               | World   |            |              |                 | UAE     |            |              |
|-------------------------------|---------|------------|--------------|-----------------|---------|------------|--------------|
|                               | (RCA)   | (Growth %) | (Appearance) | (Disappearance) | (RCA)   | (Growth %) | (Appearance) |
| (Intercept)                   | 0.00    |            |              |                 | -0.17   | -2.58***   | -5.90***     |
|                               | (0.01)  |            |              |                 | (0.16)  | (0.70)     | (1.73)       |
| Density (IHS)                 | 1.96*** | 0.25***    | 4.41***      | -2.04***        | 1.87*** | 1.21+      | 3.84*        |
|                               | (0.02)  | (0.07)     | (0.45)       | (0.48)          | (0.38)  | (0.62)     | (1.85)       |
| Base Year Value (IHS)         |         | -0.27***   |              | -2.05***        |         | -0.56***   |              |
|                               |         | (0.02)     |              | (0.15)          |         | (0.12)     |              |
| Base Year Product Total (Log) |         |            |              |                 |         | 0.45***    | 0.29+        |
|                               |         |            |              |                 |         | (0.07)     | (0.16)       |
| Radial Product Growth         |         |            |              |                 |         | 9.82***    | 16.60***     |
|                               |         |            |              |                 |         | (1.63)     | (4.83)       |
| Num. Obs.                     | 30636   | 14666      | 15558        | 6283            | 276     | 106        | 170          |
| R2                            | 0.27    | 0.47       | 0.22         | 0.56            | 0.08    | 0.46       | 0.15         |
| Country FE                    |         | X          | X            | X               |         |            |              |
| Scientific Field FE           |         | X          | X            | X               |         |            |              |

+ p < 0.1, \* p < 0.05, \*\* p < 0.01, \*\*\* p < 0.001

Data source: OpenAlex

Density from period 1995-2010, Growth measured for period 2010-2018

Appearance and disappearance regressions are Logit. Rest are OLS.

*Table 8: Predicting growth in patenting activity using density.*

|                               | World   |            |              |                 | UAE    |            |              |
|-------------------------------|---------|------------|--------------|-----------------|--------|------------|--------------|
|                               | (RCA)   | (Growth %) | (Appearance) | (Disappearance) | (RCA)  | (Growth %) | (Appearance) |
| (Intercept)                   | 0.02*** |            |              |                 | -0.16  | -8.16**    | -7.35**      |
|                               | (0.00)  |            |              |                 | (0.34) | (2.89)     | (2.68)       |
| Density (IHS)                 | 2.09*** | 4.01***    | 8.29***      | -14.96***       | 2.74*  | 16.29      | 6.57         |
|                               | (0.01)  | (0.52)     | (1.42)       | (2.22)          | (1.37) | (11.33)    | (9.50)       |
| Base Year Value (IHS)         |         | -0.39***   |              | -0.97***        |        | -1.12***   | 1.97         |
|                               |         | (0.03)     |              | (0.07)          |        | (0.20)     | (13.37)      |
| Base Year Product Total (Log) |         |            |              |                 |        | 0.70***    | 0.67***      |
|                               |         |            |              |                 |        | (0.09)     | (0.13)       |
| Radial Product Growth         |         |            |              |                 |        | 3.43*      | 6.12**       |
|                               |         |            |              |                 |        | (1.67)     | (2.15)       |
| Num. Obs.                     | 132924  | 25556      | 83155        | 13180           | 636    | 163        | 472          |
| R2                            | 0.15    | 0.36       | 0.27         | 0.51            | 0.01   | 0.33       | 0.14         |
| Country FE                    |         | X          | X            | X               |        |            |              |
| IPC4 Technology Class FE      |         | X          | X            | X               |        |            |              |

+ p < 0.1, \* p < 0.05, \*\* p < 0.01, \*\*\* p < 0.001  
Data source: PATSTAT 2023  
Density from period 1995-2010, Growth measured for period 2010-2018  
Appearance and disappearance regressions are Logit. Rest are OLS.