



Research article

Research productivity in the United Arab Emirates: A 20-year bibliometric analysis



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ABSTRACT

Background: Despite increased attention on science and research in the United Arab Emirates (UAE), little is known about the national state of research productivity and how it evolved over time.

Methods: Using the world's largest bibliometric database (Scopus), we reviewed research productivity in the UAE (1998–2017) in various disciplines and normalized it to population size and gross domestic product. We summarized the quality of research using conventional metrics of research quality and compared the performance of the UAE to its geographic region and to other countries of similar population size and economic standing.

Results: Over the past 20 years, there was a 16-fold increase in the number of research publications from the UAE, and a 6- and 3-fold increase when normalized to population size and gross domestic product, respectively. Growth was observed across all disciplines, with an increasingly diverse research portfolio, and was coupled with a slight increase in the quality of publications. The crude productivity in the UAE was higher than that observed for the gulf cooperation council or Arab region, but lower when normalized to gross domestic product, or when compared to two countries outside the Arab region with remarkable research growth.

Conclusions: Over the past 20 years, the UAE witnessed a significant increase in research productivity, coupled with a slight increase in quality and diversity of research. Accounting for the UAE's economic standing, and compared to other countries with excellent research output, the UAE has significant potential for further growth with increased resources for research and development.

1. Introduction

Since its inception as a federation nearly half a century ago, the United Arab Emirates (UAE) has witnessed rapid progress across many dimensions of development. Located in Southwest Asia with a land area of nearly 84,000 square meters and an estimated population of nearly 10 million, the UAE's economy is the second largest in the Arab world with increasing emphasis on diversification and reducing the historical reliance on oil.

In the most recent report from the United Nations, the UAE's human development index, a summary measure for progress in life expectancy, access to knowledge and the decency of living standards, was the highest in the Arab world and positioned the country in the “very high human development” category, a classification attained by only a handful of Arab countries (United Nations Development Programme, 2018). Recent

developments signaled increased national attention on science and research in the UAE. These included the appointment of a federal Minister of State for Advanced Sciences, the formation of a national Science Council and the declaration of a national Advanced Sciences Agenda. Several strategies adopted by the federal and local governments have also highlighted the central role for scientific research in the coming years.

Despite the aforementioned developments, little is known about the current state of research productivity in the UAE or how it evolved over time. Published reports on the topic to date were limited in scope and time frame and typically focused on quantity of research output (Neves and Lammers, 2007; Bissar-Tadmouri and Tadmouri, 2009; Osman and Afifi, 2010). Measurement of research impact and productivity at the national and regional levels is an important exercise carried out by multiple countries and agencies around the globe. The advancement of technologies and the continued development of large bibliographic

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databases have supported research productivity measurements and offered guidance for research strategies.

The objective of the present study is to provide an updated and systematic examination of the development and current state of research productivity in the UAE. Such study is both timely and important and would provide a much-needed evidence base to inform current and future efforts to upscale the research agenda in the country. To achieve this objective, we use the world's largest bibliometric database (Scopus) to quantitatively review the research productivity in the UAE over the past two decades in various disciplines, summarize the quality of such research using conventional metrics of research quality, and compare the performance of the UAE to its geographic region as well as to other countries with notable growth in research productivity over the same period.

2. Methods

2.1. Quantity of research output

Data on number of research publications were derived from SciVal, a searchable electronic bibliometric repository. SciVal is based on Scopus, an electronic research citation database covering nearly 40,000 English language titles in life sciences, physical sciences, health sciences, and social sciences. We report the annual number of research publications over a 20-year period from 1998 to 2017 (the last complete year with available data at the time of this analysis). In addition to research output, we also report annual research productivity normalized to population and size of the economy as quantified by Gross Domestic Product (GDP). Population and GDP (current US \$) data were based on the demographic and socio-economic (full dataset) of the United Nations Educational, Scientific and Cultural Organization (UNESCO) or the World Bank (for Singapore) (UNESCO Institute for Statistics, 2018; The World Bank, 2018). Population size was available from UNSECO for the period 1999–2017, as well as the GDP data for the period 1999–2016. All these data sources are dynamic databases with regular updates; the data used here are the most recent data available at the time of this analysis. Population- and GDP-normalized data are presented as number of research articles per 1 million capita, and number of research articles per 100 million US dollars, respectively. Definitions, sources, and timeframe of the indicators used in this analysis are shown in Table 1.

2.2. Quality of research output

We used CiteScore and Field-Weighted Citation Impact (FWCI) as surrogates for quality of research publications. Both are reported by SCOPUS. CiteScore is a measure of journal impact and is based on the number of citations received by a journal in a given year for all articles published in that journal in the preceding three years divided by the number of articles published in Scopus in those three years. FWCI adjusts

Table 1
Definitions, sources, and timeframe of the indicators used.

INDICATOR	DEFINITION	SOURCE	TIMEFRAME
RESEARCH OUTPUT/ARTICLES	Total number of documents that include articles, reviews, and conference proceedings covered by Scopus.	SciVal/Scopus	1998–2017
POPULATION	Total Population	UNESCO and World Bank	1999–2017
GDP	Total GDP (current \$ US)	UNESCO	1999–2016
CITESCORE	see Methods	SciVal/Scopus	2013–2017
FIELD WEIGHTED CITATION IMPACT (FWCI)	see Methods	SciVal/Scopus	2013–2017

for field-specific differences in citation frequencies by dividing the number of citations received for a publication by the average number of citations received by publications in the same field, of the same type, and published in the same year. A FWCI of 1.0 indicates that the publication has been cited at a world average for similar publications.

2.3. Temporal trends

We used the compound annual growth rate (CAGR) to characterize change in publication quantity over time. CAGR represents the year-on-year constant growth rate over a specified period of time, and is calculated by the formula:

$$CAGR = [(final\ value / starting\ value)^{1/n} - 1] \times 100$$

where n is the total number of years.

2.4. Research disciplines

We examined research productivity across different fields. Scopus classifies publications in 27 subject areas. For the present analysis, we aggregated the 27 subject areas into the following 7 main research disciplines: 1) Medicine and Life Sciences, 2) Engineering, Energy, and Material Sciences, 3) Business and Economics, 4) Physical Sciences, 5) Humanities and Social Sciences, 6) Computer Science, and 7) Multidisciplinary research (Table 2).

2.5. Regional and global context

To provide context for UAE-based research productivity data, we compared the UAE data over time to the average data from the 6 Gulf Cooperation Council (GCC) countries (UAE, Kingdom of Saudi Arabia, Kuwait, Bahrain, Oman and Qatar) as well as the average data from the 22 countries of the League of Arab States. For comparative purposes, we also report and compare research productivity data to Saudi Arabia, the largest GCC country, as well as Ireland and Singapore, two countries outside the Arab region of lower population size and GDP to the UAE and with significant growth in scholarly output over the past two decades.

Table 2
The 7 main research disciplines based on the aggregated 27 Scopus subject areas.

MAIN DISCIPLINES/FIELDS	SCOPUS SUBJECT AREAS
MEDICINE AND LIFE SCIENCES	Agricultural and Biological Sciences Biochemistry, Genetics and Molecular Biology Dentistry Health Professions Immunology and Microbiology Medicine Neuroscience Nursing Pharmacology, Toxicology and Pharmaceutics Psychology Veterinary
ENGINEERING, ENERGY, AND ENVIRONMENTAL SCIENCES	Chemical Engineering Energy Engineering Environmental Science Material Science
BUSINESS AND ECONOMICS	Business, Management and Accounting Decision Sciences Economics, Econometrics and Finance
PHYSICAL SCIENCES	Chemistry Earth and Planetary Sciences Mathematics Physics and Astronomy
HUMANITIES AND SOCIAL SCIENCES	Arts and Humanities Social Science
COMPUTER SCIENCE	Computer Science
MULTIDISCIPLINARY	Multidisciplinary

3. Results

3.1. Quantity of research output

Over the past two decades, there was an approximately 16-fold increase in the number of annual research publications from the UAE, increasing from 380 publications in 1998 to 6,159 publications in 2017 (Fig. 1A). This represents an annual growth rate (CAGR) of 15.0% over the twenty-year period. The growth in UAE-based research productivity was comparable with growth in the Arab as well as GCC countries, but with a numerically higher annual growth rate for the UAE (CAGR 15.0%) compared to the GCC (CAGR 12.4%) or the Arab countries (CAGR 11.1%) over the twenty-year period (Fig. 1A). The most notable growth in research productivity in the UAE occurred in the past 5 years reaching a CAGR of 12.3%, compared to 8.4% for GCC countries and 7.3% for Arab League countries (Fig. 1A, see CAGR table). Consequently, the proportion of UAE share of publications within the GCC countries increased from 11.2% in 1998 to 17.6% in 2017 and similarly within the Arab countries from 3.8% in 1998 to 6.9% in 2017 (data not shown).

A notable increase in UAE's research productivity was also observed when data were normalized to population size. Over the past 2 decades (from 1999–2017), there was a 6-fold increase in the number of research publications normalized to population size, reaching approximately 655 publications per million inhabitants in 2017, with a CAGR of 9.1% (Fig. 1B). The growth rate accelerated over the past decade and most notably over the last 5 years (Fig. 1B, see CAGR table). The population normalized research output of the UAE was similar to that observed for GCC countries over the same time period, but approximately 2–3 folds higher than that of other Arab League countries (Fig. 1B).

When normalized to GDP, there was approximately a 3-fold increase in the UAE's research productivity between 1999 and 2016, with a CAGR of 7.1% (Fig. 1C). However, the annual number of publications per GDP for the UAE was lower than the average for GCC and Arab League countries, with 2016 numbers at less than half of the Arab League average and approximately 40% less than the GCC average (Fig. 1C).

3.2. Research disciplines

Growth in the UAE-based research output was observed across all 7 research disciplines with CAGR over the past two decades ranging from 10% in "Medicine and Life Sciences" to 26% in "Computer Science" and "Business and Economics" (Fig. 2A). While more than half of the UAE-based publications in 1998 were in the "Medicine and Life Sciences" disciplines, the research output in 2017 was more diverse having increased contributions from other disciplines, with highest growth in relative contributions from the "Business and Economics" and "Computer Science" disciplines (Fig. 2B). By 2017, publications in the "Engineering, Energy, and Environmental Sciences" were the most prevalent at about 30% of all publications, followed by near equal contribution from "Physical Sciences" and "Medicine and Life Sciences" at approximately 20% each (Fig. 2B).

3.3. Quality of research output

Over the past 5 years (2013–2017), the proportion of UAE-based articles published in the top 10th percentile (by CiteScore) ranked journals increased slightly from 23% to 26% with a CAGR of 2.6%. This metric was consistently higher in the past 5 years for the UAE compared to the average for GCC and Arab League countries (Fig. 3A). The UAE's FWCI over the period from 2013 to 2017 was slightly higher than the world average in all disciplines with the exception of "Humanities and Social Sciences" (Fig. 3B). The FWCI for UAE-based research was similar to that of the average of GCC countries in almost all disciplines, and higher than the average for Arab League countries in all fields except for "Physical Sciences" and "Humanities and Social Sciences" where it was comparable (Fig. 3B).

3.4. Selective comparison to other countries

We also compared the publication output of UAE to three other countries (Saudi Arabia, the largest GCC country; as well as Ireland and Singapore, both with lower population size than the UAE, but with increased focus on research and development in recent years). All three countries had higher annual numbers of published articles over the last 20 years (from 1998–2017), and in 2017 had 2.3–3.5 folds higher number of published articles compared to the UAE (Fig. 4A). However, the relative growth rate, as measured by CAGR, was highest for the UAE (15%) followed by Saudi Arabia (12.7%) over this period of time. When normalized to population size, the UAE research performance was similar to that of Saudi Arabia, but notably lower than Ireland and Singapore (4 or 6 folds, respectively), albeit with a higher growth rate over this period of time, and the highest CAGR over the last 5 years (Fig. 4B). Similarly, when normalized to GDP, the UAE research productivity was notably lower than all 3 countries, although with a higher relative growth rate in the UAE's research productivity (CAGR of 7.1% for the UAE from 1999 to 2016) (Fig. 4C). The UAE's FWCI (1.25) over the period from 2013 to 2017 was lower than Saudi Arabia (1.42), Ireland (1.61) and Singapore (1.75).

4. Discussion

We conducted a bibliometric review of quantity, quality, and diversity of research productivity in the UAE over the past two decades and compared it to its geographic context as well as to two countries with a notable increase in research performance over that time frame. Our review yielded several key observations. First, there has been a remarkable 16-fold increase in the number of research publications from the UAE over the past 20 years. The increase in research productivity was still notable, but less so, when normalized to population size (6-fold increase) or GDP (3-fold increase). Second, the growth in research productivity was observed across all disciplines, with an increasingly diverse national research portfolio over the study time frame. Third, the growth in research quantity was coupled with a slight increase in the quality of publications. Fourth, while the UAE outperforms the average GCC or Arab country in the number of publications, adjustment for GDP reflects an unrealized potential for higher research productivity. Finally, when compared to two countries outside the Arab region with remarkable research growth over the past two decades, UAE-based research productivity is significantly lower but with a promising relative growth rate, particularly in recent years.

There are several likely drivers to the remarkable growth in research productivity in the UAE over the past two decades. Since the establishment of the first national university in the country in 1976, the number of public as well as private higher education institutions has increased significantly. Increasingly, many of the larger UAE universities have also strengthened their emphasis on research productivity in an effort to bolster international recognition and ranking. Intramural funding for research by higher education institutions was also coupled by introduction of few national sources of extramural funding such as the Sheikh Hamdan Award for Medical Sciences, the Al Jalila Foundation, and most recently the National Fund (Sundouq Al Watan). In addition, governmental strategies focusing on renewable energy and sustaining the economy beyond oil and gas industries have encouraged research in the sectors of engineering, energy, and environmental sciences. The focus on a diversified economy with emphasis on tourism, service industries, business and free trade may have also supported research and development in the business and economics disciplines.

Examination of research productivity in the UAE in light of its GDP and in the context of its geographic region suggests an unrealized potential for increased support to the science agenda. For example, while the UAE's GDP accounts for 27% of the total GDP of GCC countries, its share of research publications from the GCC amounts to 18%. Likewise, research publications from the UAE account for 7% of all publications

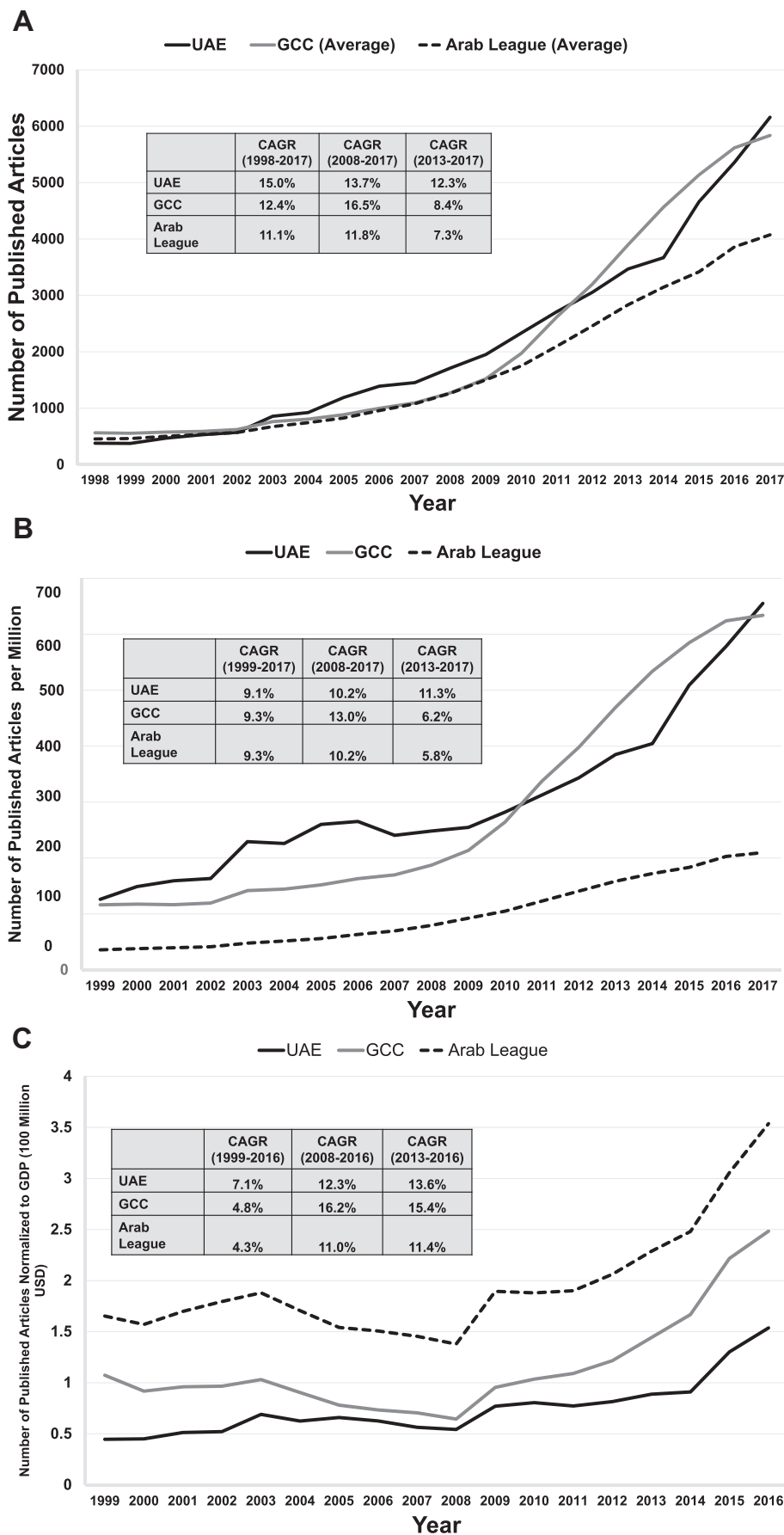
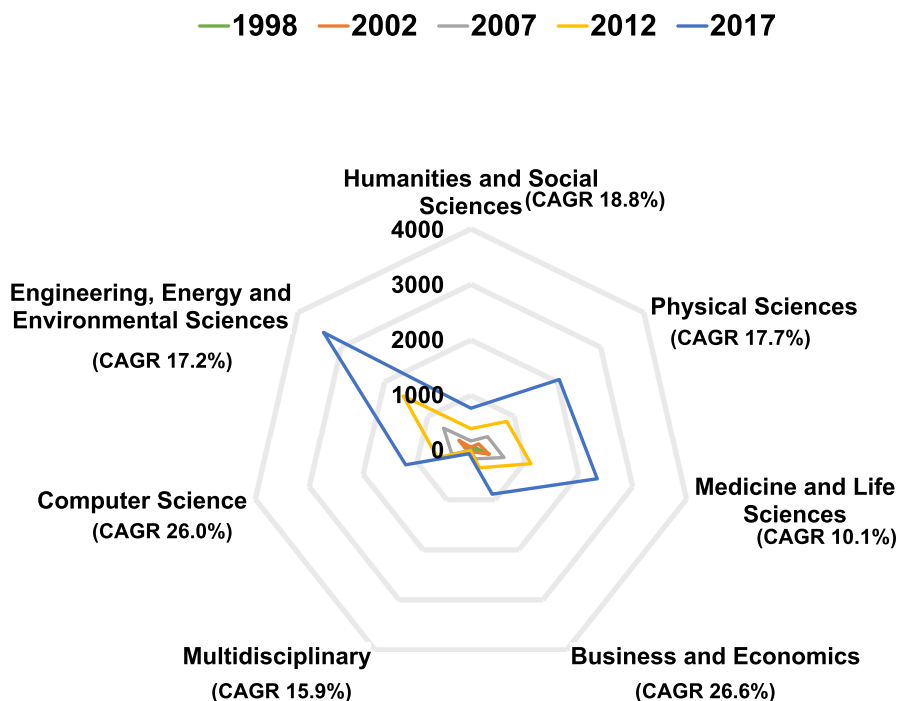


Fig. 1. Scholarly output in the United Arab Emirates (UAE) compared to the average of countries in the Gulf Cooperation Council (GCC) and the Arab League over a ~20-year period. A. The number of published articles over time. B. The number of published articles over time normalized to population size (per 1 million inhabitants). C. The number of published articles over time normalized to gross domestic product (GDP) in current US dollars. The table inserts in the figures show the growth rate over time as measured by the compound annual growth rate (CAGR).

A



B

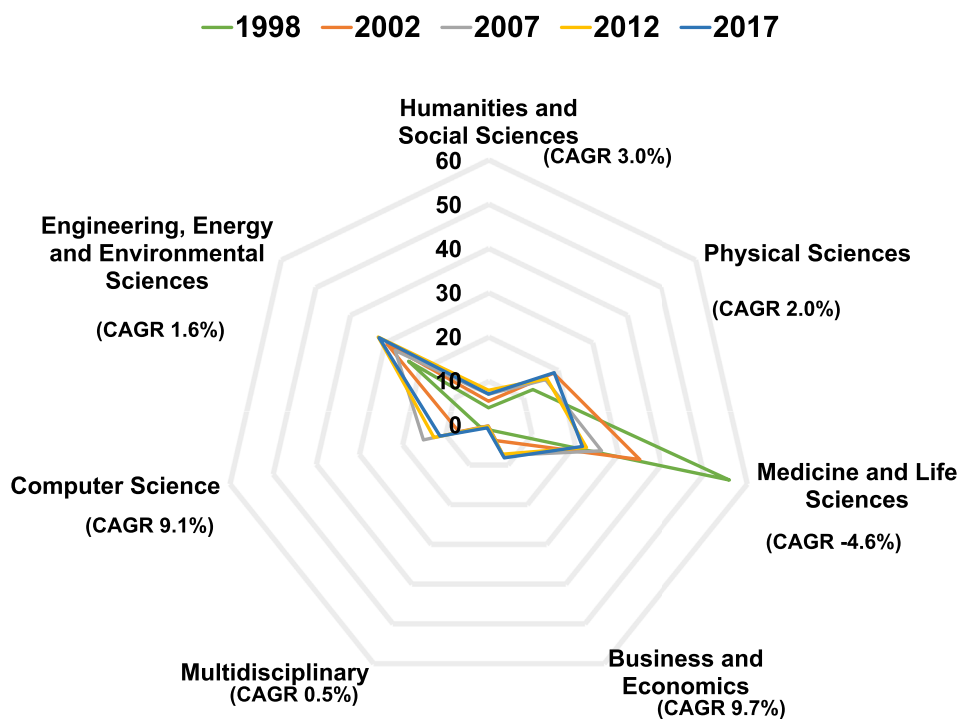


Fig. 2. Scholarly output from the United Arab Emirates (UAE) stratified by key disciplines over time shown in 5-year increments from 1998-2017. A. The number of published articles from the UAE over time in various disciplines, and the corresponding compound annual growth rate (CAGR) for each discipline. B. The proportion of UAE published articles from the various disciplines over time, and the corresponding compound annual growth rate (CAGR) for each discipline.

from the Arab world while its GDP accounts for 14% of the Arab region GDP. Similarly, the UAE's share of global GDP is more than 2.5 times its share of publication output (0.47% share of world GDP and 0.19% share of world publications in 2016). The successful implementation of the UAE's ambitious national science agenda would require further development of the research infrastructure supported by increased public

investment in scientific inquiry. Implementation should also be supported by creating additional incentives for the private sector to invest in research and development in alignment with the national strategy. These recommendations are supported by a large body of theoretical and empirical evidence linking increased research and development spending to short-as well as long-term economic growth. A recent study utilizing

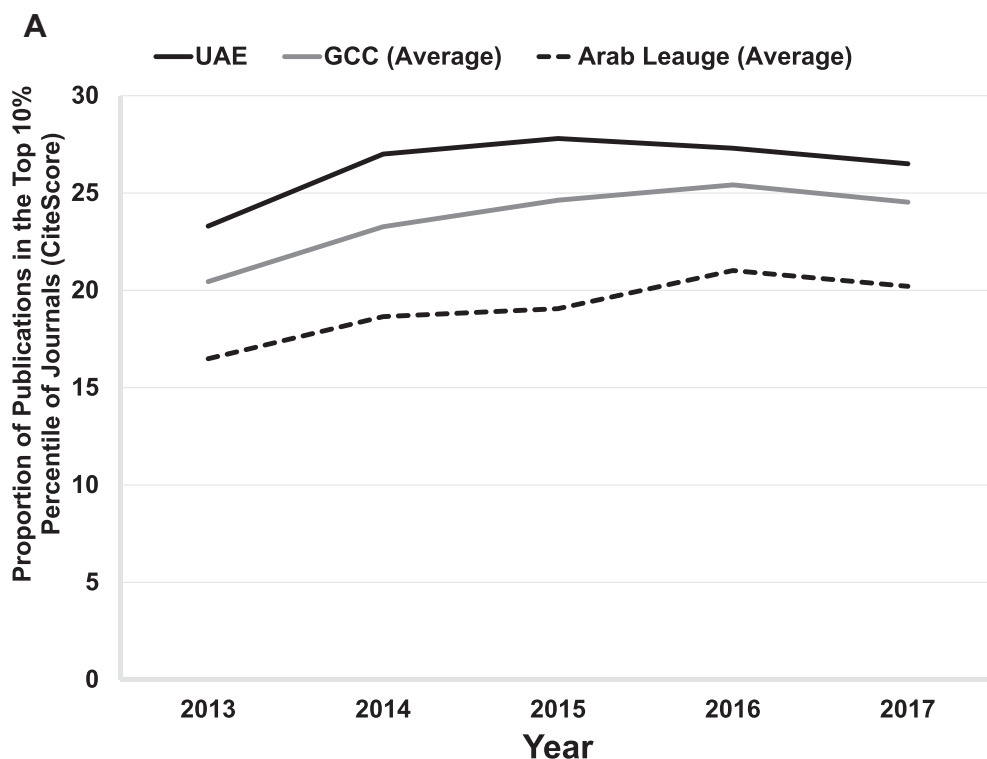
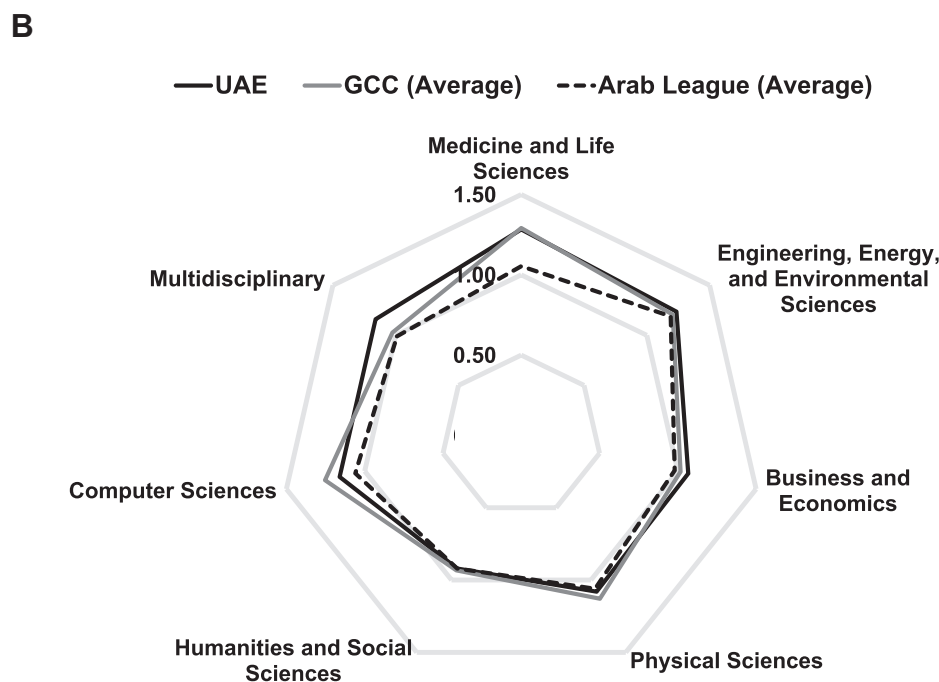


Fig. 3. Quality of United Arab Emirates (UAE)-based publications from 2013-2017 as measured by percent publications in top 10th percentile journals, based on CiteScore, and by Field-Weighted Citation Impact (FWCI). A. Publications in top 10th percentile journals (2013–2017) compared to that of Gulf Cooperation Council (GCC) and the Arab League averages. B. Overall FWCI of UAE publications (from 2013-2017) in various disciplines compared to that of GCC and Arab League countries. A FWCI of 1.0 (middle grey polygon) indicates that the publication has been cited at a world average for similar publications.



data from 52 developed and developing countries documented a nearly one to one contribution of research and development spending to GDP growth on the long term regardless of the development stage of the country (Gumus and Celikay, 2015).

We realize that normalization of research output to population or GDP levels may not be the most valid measure to capture research productivity at the national level.

A more accurate representation of research output would require adjustment to specific inputs such as expenditure on research and development both as crude levels as well as proportion of national GDP, and the number of researchers and relevant human capital as opposed to

total population. The reliance on total population and GDP in the present analysis may be particularly limiting when examining research productivity in a young and developing nation such as the UAE where growth in population and GDP has focused on the support of basic national infrastructure during the early years of the federation. In addition, such granular data on research inputs are limited for the UAE and the Arab region in general. When available, the data suggest a relatively low ratio of researchers to total population and of research and development spending to total GDP. For example, the UNESCO estimated 2,003 researchers per million population in the UAE in 2015, compared to 6,659 and 4,575 researchers per million in Singapore and Ireland, respectively

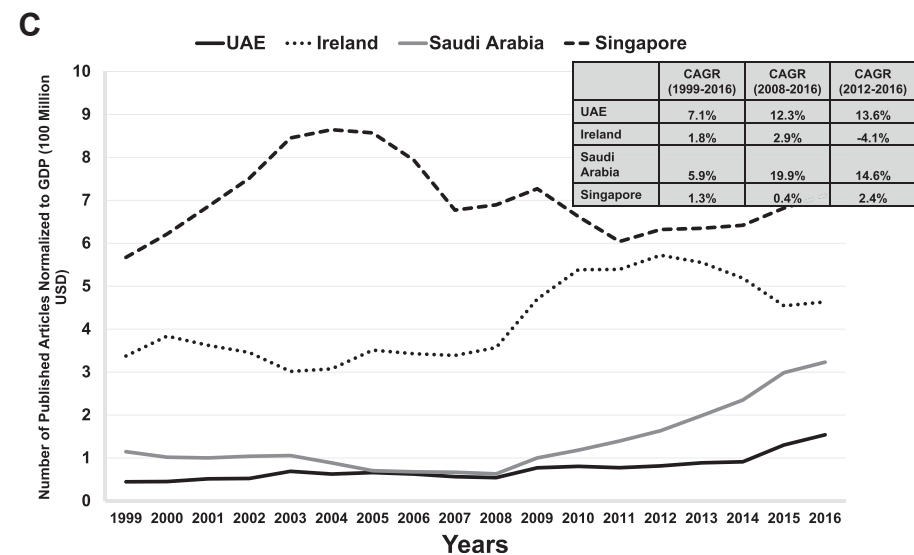
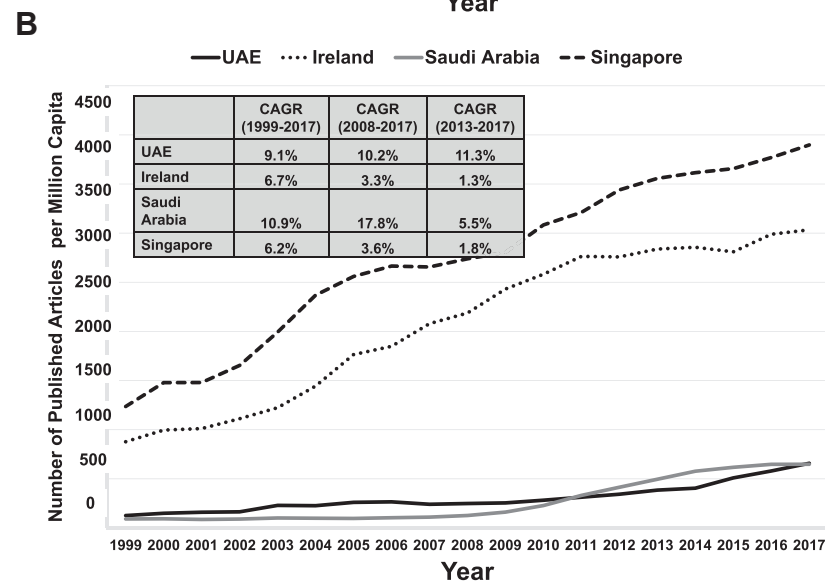
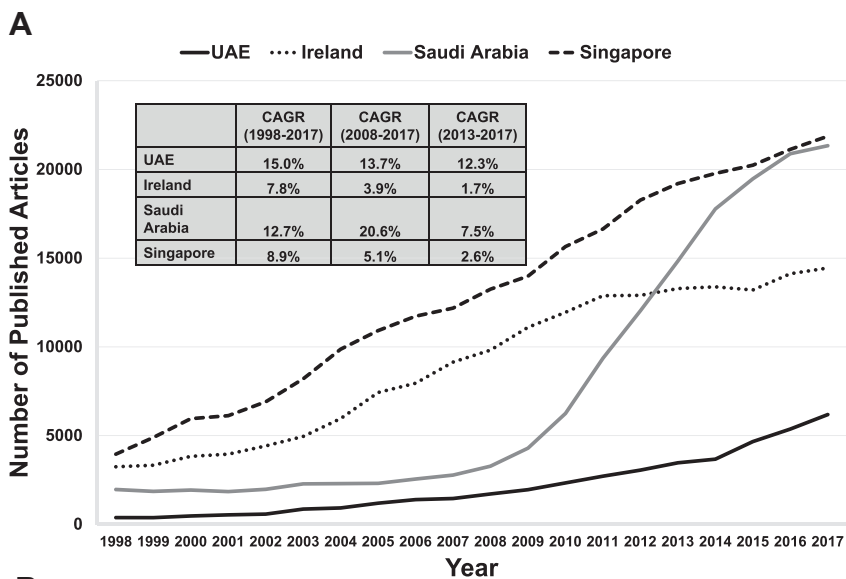


Fig. 4. Scholarly output in the United Arab Emirates (UAE) compared to Saudi Arabia, Ireland, and Singapore over a ~20-year period. A. The number of published articles over time. B. The number of published articles over time normalized to population size (per 1 million inhabitants). C. The number of published articles over time normalized to gross domestic product (GDP) in current US dollars. The table inserts in the figures show the growth rate over time as measured by the compound annual growth rate (CAGR).

in 2016. Similarly, research and development spending in the UAE was reported at 0.86% of GDP, compared to 2.2% and 1.5% for Singapore and Ireland, respectively. With the UAE's increased focus on scientific advancement and building a knowledge-based economy, accurate and systematic collection of data on research inputs will be necessary to inform national efforts to advance the science agenda and increase research productivity.

The present analysis portrays a strong and encouraging growth pattern for research output in the UAE. Recent developments are promising to sustain and enhance the observed growth over the past two decades. These include the appointment of a Minister of State for Advanced Sciences who chairs a National Science Council to advise the federal government on matters related to scientific research. The recent endorsement of a National Agenda for Advanced Sciences is likely to stimulate and focus research activities in the UAE across key sectors. The very recent announcement by the UAE cabinet of a talent visa to attract scientists to the country signals a policy commitment at the federal level to make the UAE more attractive to scientific talent.

The present study needs to be considered within the inherent limitations of bibliometric analyses. While we used Scopus, other bibliometric databases (e.g. Google Scholar) may have provided different quantitative outputs. In addition, the choice of Ireland and Singapore for comparative purposes was relatively arbitrary and other comparisons may provide additional insights. Moreover, development of a research enterprise in any country is a multifaceted endeavor and the monitoring of research productivity is only one aspect of that endeavor and needs to be considered in context.

5. Conclusions

Over the past 20 years, the UAE witnessed a remarkable increase in the number of research publications, coupled with a slight increase in quality and diversity of research. Accounting for the UAE's economic standing, and compared to other countries with excellent research output, the UAE has significant potential for further growth with increased resources for research and development.

Declarations

Author contribution statement

Ahmad Al Marzouqi: Conceived and designed the experiments;

Performed the experiments; Analyzed and interpreted the data; Wrote the paper.

Mohamad Alameddine, Alawi Alsheikh-Ali: Conceived and designed the experiments; Analyzed and interpreted the data; Wrote the paper.

Amer Sharif: Conceived and designed the experiments; Wrote the paper.

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Competing interest statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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