an open access journal

Citation: Hayatdavoudi, J., Kaltenbrunner, W., & Costas, R. (2023). Science and research landscapes across D-8 organization member countries from a historical perspective: The policy context and collective agendas. *Quantitative Science Studies*, *4*(2), 466–488. https://doi.org/10.1162/qss_a_00249

DOI:
https://doi.org/10.1162/qss_a_00249

Peer Review:
https://www.webofscience.com/api/gateway/wos/peer-review/10.1162/qss_a_00249

Received: 21 February 2022
Accepted: 10 February 2023

Corresponding Author:
Javad Hayatdavoudi
j.hayatdavoudi@cwts.leidenuniv.nl

Handling Editor:
Vincent Larivière

The MIT Press

RESEARCH ARTICLE

Science and research landscapes across D-8 organization member countries from a historical perspective: The policy context and collective agendas

Javad Hayatdavoudi[1], Wolfgang Kaltenbrunner[1], and Rodrigo Costas[1,2]

[1]Centre for Science and Technology Studies, Leiden University, Leiden, The Netherlands
[2]DSI-NRF Centre of Excellence in Scientometrics and Science, Technology and Innovation Policy (SciSTIP), Stellenbosch University, Stellenbosch, South Africa

Keywords: D-8 countries, economic development, intergovernmental forum, publications, R&D

ABSTRACT

Intergovernmental Economic Organizations usually leverage the scientific capacity of their member countries to ensure economic prosperity through consensual science policies. The D-8 Organization for Economic Cooperation is an intergovernmental economic forum constituting eight developing Muslim-majority countries with a host of recent initiatives toward encouraging interstate scientific and technological collaborations. This study presents an overview of the forum's overarching science policies and the research performance in the member countries in the past two decades. The individual D-8 countries' performance over a set of STI indicators is analyzed to examine the driving forces of the STI system in the member countries. The findings revealed marked disparities among the countries in economic prosperity, R&D expenditure, and the stock of researchers in their STI systems. Although the aggregate research volume of the D-8 countries almost quadrupled over the 2010s compared with the previous decade, there are salient differences in the research capacity and scientific impact among these countries. GDP, R&D expenditure, human development index, GNI per capita, and the number of researchers (FTE per million inhabitants) contribute to explain the growth of publications in some of the D-8 countries. Knowledge sharing, transfer of technology, research collaboration, and investment in R&D infrastructure among the member countries underline the recent overarching scientific policy initiatives of the D-8 organization.

1. INTRODUCTION

Toward the end of the 20th century and early at the turn of the new century, the world witnessed concerted economic initiatives in the form of intergovernmental forums including, but not limited to, G7, G20, OECD, D-8, BRICS, and ECO, with a primary focus on either global or regional economic challenges depending on their scope and inclusivity. Typical in these coalitions is an initial narrow scope but an extension of agendas and sometimes membership in later stages of organizational development. Given the contribution of science to economic growth and competitiveness, some of these forums, such as G20 and D-8, began to call upon scientific knowledge and research-based evidence in policy-making and seeking solutions to global challenges, such as climate change, sustainability, and food security (Royal Society, 2011, pp. 31–36). The D-8 Organization for Economic Cooperation is an intergovernmental forum established to foster economic cooperation among eight Muslim-majority developing countries: Bangladesh, Egypt, Indonesia, Iran, Malaysia, Nigeria, Pakistan, and Turkey. These eight countries currently accommodate about two-thirds of the population in the 57 member states of the Organization of Islamic Cooperation (OIC).

Against the backdrop of the broader global initiatives launched by intergovernmental forums to engage science and innovation in tackling global issues and securing sustainable socioeconomic development, the present study aims to address policy-making in science, technology, and innovation (STI) by the D-8 organization and to portray a developmental picture of science policy and research performance in the member countries in the past two decades (2000–2019). To this end, the study presents a brief review of some of the STI policies of the D-8 organization. Besides, a set of input STI indicators will be gauged against research publications to examine the country-level driving forces of the science and innovation systems in the D-8 countries. Where viable, the D-8 countries' collective performance across the input-output indicators will be compared with other regional/income groups. The research performance of the D-8 countries will be characterized based on the bibliographic data indexed in Elsevier's Scopus database.

2. BACKGROUND

The D-8 forum was officially established in 1997 following the Istanbul Declaration at the Summit of Heads of States in Turkey. According to the UN Department of Economic and Social Affairs Population Dynamics, the D-8 member countries currently have a population of around 1.16 billion, accounting for 15% of the total world population[1]. Of the D-8 countries, Turkey and Indonesia are simultaneously members of the G20 while Iran, Pakistan, and Turkey are on the board of the Economic Cooperation Organization (ECO) as well. The D-8 countries span a wide geographical area, ranging from Sub-Saharan Africa (Nigeria), North Africa (Egypt), Western Asia (Iran and Turkey), South Asia (Bangladesh and Pakistan), to South-East Asia (Indonesia and Malaysia). These are among the largest economies in their respective regions, as with Nigeria and Egypt in Africa, Turkey and Iran in Western Asia, and Indonesia and Malaysia in South-East Asia (see Figure 1).

According to the D-8 Secretary General, the current collective GDP of the D-8 member countries amounts to US$4 trillion. The members have an export quota of US$1.5 trillion, an intra-trade of US$110 billion and about 5% of the world's GDP[2]. The D-8 secretary general, Ku Shari (2021), reported that member countries of the D-8 organization account for about 50% of the OIC's total trade, noting that D-8 countries will be "the next Economic Powerhouse" based on macroeconomic indicators.

The D-8 leaders have consensually decided to foreground STI polices as a means and driver of economic development by leveraging their research capacity toward more economic benefits. To encourage collective R&D initiatives among the member countries, the Leaders' Summit, held in October 2017, approved of the establishment of the D-8 Research Centre and the D-8 International University (D-8 Organization, 2021a). Besides, the D-8 organization has embarked on launching the D-8 Network of Pioneers for Research and Innovation (D-8 NPRI Platform; D-8 Organization, 2021c) as an ambitious initiative to foster all-out interstate R&D collaborations among a host of research entities, most notably universities, within the member countries. The organization has also established a D-8 Technology Transfer and Exchange Network (D-8 TTEN) to facilitate the transfer of innovative technology and capacity-building in the member countries through the push of the private sector. One should, however, note that

[1] https://population.un.org/wpp/Download/Standard/Population.

[2] https://developing8.org/secretary-general/.

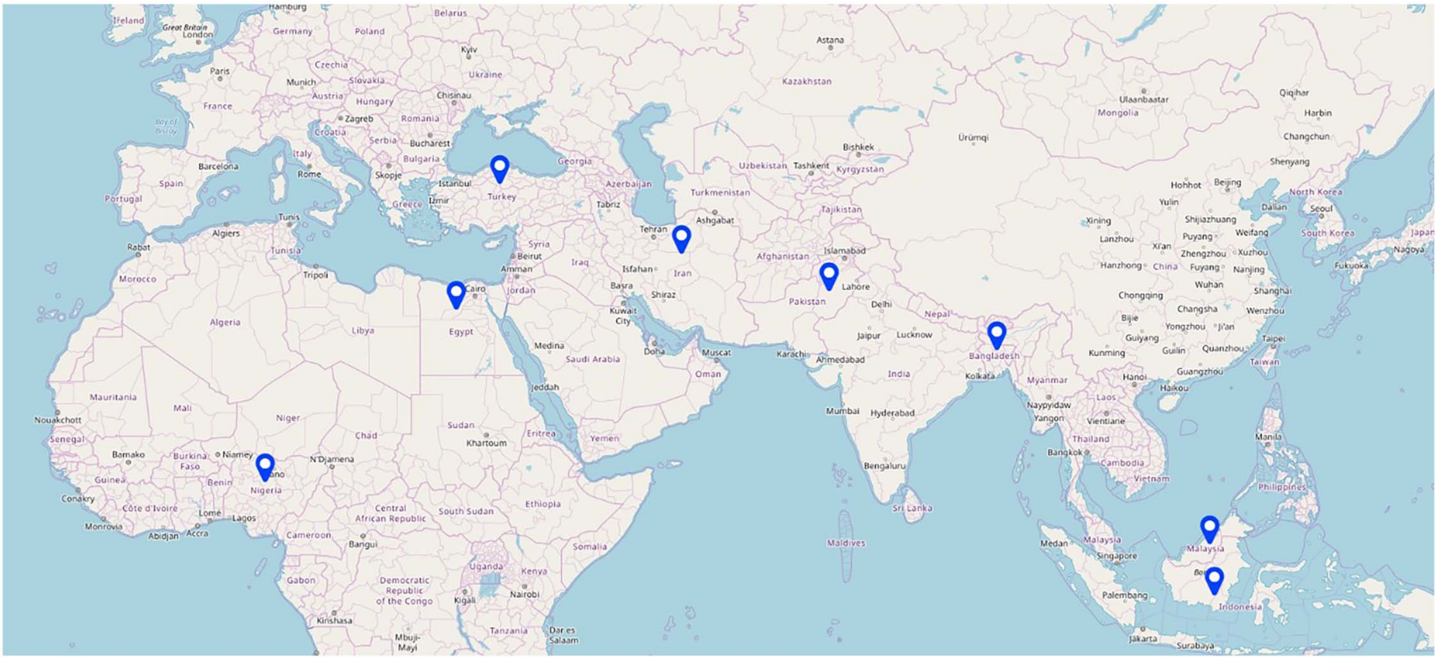

Figure 1. Geolocation of the D-8 countries (created with mapline).

D-8 member countries constitute a heterogeneous alliance with different geopolitical and sociocultural backgrounds, which might have shaped their distinct macroeconomic and scientific development over time.

The D-8 organization's science policy fits well within the broader context of the OIC objectives. In his preface to the Atlas of Islamic World Science and Innovation (2014, p. 7), the then OIC Secretary General noted, "enhancing and developing science, technology and innovation; and encouraging research and cooperation among Member States in these fields, figure highly among the objectives of the OIC Charter." One of the objectives of the D-8 Decennial Roadmap for 2020–2030 is for the members to promote cooperation in science and technology through engaging universities and research centers. They have also committed themselves to working towards UN SDG objectives. The D-8 Decennial Roadmap (D-8 Organization, 2021b, p. 15) makes frequent references to scientific collaboration, R&D cooperation and knowledge sharing across all levels of aggregate including governments and institutions.

2.1. D-8 vs. World Growth of Publications

Based on Elsevier's Scopus data, the D-8 countries collectively produced 2.57% and 5.80% of the total world publications during the 2000s and 2010s, respectively. Notwithstanding the meager global share of the D-8 publications, the aggregate growth rate of their output was notably large, with an increase of 265% in the 2010s compared to the preceding decade (see Figure 2). The following query was used to collect data and compute the figures.

```
PUBYEAR > 1999 AND PUBYEAR < 2020 AND (LIMIT-TO ( AFFILCOUNTRY , "Turkey" ) OR
LIMIT-TO ( AFFILCOUNTRY , "Egypt" ) OR LIMIT-TO ( AFFILCOUNTRY , "Nigeria" ) OR
LIMIT-TO ( AFFILCOUNTRY , "Malaysia" ) OR LIMIT-TO ( AFFILCOUNTRY , "Pakistan" )
OR LIMIT-TO ( AFFILCOUNTRY , "Iran" ) OR LIMIT-TO ( AFFILCOUNTRY , "Indonesia" )
OR LIMIT-TO ( AFFILCOUNTRY , "Bangladesh" ) )
```

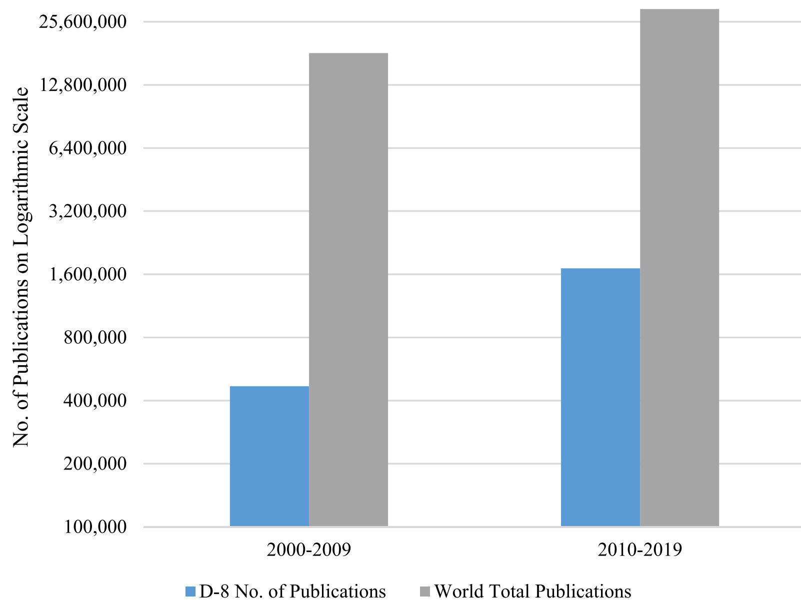

Figure 2. Number of publications in the past two decades indexed in Scopus (retrieved from Scopus online interface in August 2021).

3. LITERATURE REVIEW

Knowledge is an important driver of sustained economic development and growth in the long run (Chen & Dahlman, 2004). Scientific research and innovation are key elements contributing to an innovative and knowledge economy (SESRIC, 2016, p. 3) and to economic growth (Falk, 2007). Chen and Dahlman (2004) found that a 1% increase in the number of journal articles of a country was correlated with "a 0.22 percentage point increase in annual economic growth …" (p. 40). The Royal Society report (2011, p. 5) acknowledged the uncontested role of science in economic development such that "the recognition of the role that science can play in driving economic development, and in addressing local and global issues of sustainability, has led to increased research activity and the application of scientific method and results within less developed countries." Intergovernmental organizations have tried to advance overarching STI policies and frameworks to create an enabling environment, facilitate STI cooperation and address global challenges (Chaturvedi, Rahman, & Ravi Srinivas, 2019).

In the context of the D-8 organization, Malaysia, Turkey, and Iran are among the top R&D disbursers. Turkey and Iran were reported to have the largest numbers of researchers relative to their populations and to "publish nearly half of the OIC's scientific papers," with Iran being granted the largest number of patents (Atlas of Islamic World Science and Innovation, 2014, p. 8). From 2000 to 2011, Iran was granted 4,513 patents accounting for 31.8% of all patents in the OIC region while Malaysia obtained 2,353 patents in the same period accounting for 16.6% of the total in OIC league (Atlas of Islamic World Science and Innovation, 2014, p. 37). Patents are an important proxy of the innovative capacity and initiatives within a country. Analyzing the data from 92 countries during the period 1960–2000, Chen and Dahlman (2004, p. 44) found a statistically significant positive correlation between the patents granted to the residents of a country and long-term economic growth such that a 20% annual increase in the granted USPTO patents would contribute to economic growth by 3.8% points per year. Safahieh and Sharifi Fard (2020) studied the scientific publications and technological outputs (measured through patents) of the D-8 countries during the period 1997–2017. They found that although Iran ranked second after Turkey in terms of the number of publications and citations, it fell to a far lower rank regarding the ratio of technological to scientific outputs. They also found a significant positive correlation of the number of publications with both citation counts and the number of technological outputs for some of the countries.

Some of the D-8 countries have declared plans for increasing their expenditure on R&D. Iran announced an ambitious plan to increase its expenditure on R&D as a percentage of GDP to 4% by 2030 (Sawahel, 2009). Early in the 2010s, Egypt's elected president pledged to increase the country's R&D expenditure to 2.5% of its GDP, hoping that science would bring "a renaissance in Egypt" (El-Akkad, 2012). Indonesia, on the other hand, planned in 2011 to increase its gross expenditure on R&D (GERD) more than 12-fold from 0.08% to 1% of GDP by 2014 under the Innovation Initiative 1-747 (Shetty, Akil et al., 2014, p. 27). Malaysia, under its Ninth Malaysia Plan (2006–2010), aimed for an allocation of 1.5% of its GDP to R&D by 2010. The target, however, was missed, resulting in a subsequent readjustment to 1% of GDP by 2015 under the Tenth Malaysia Plan 2011–2015 (Day & Muhammad, 2011). As reported in the Atlas of Islamic World Science and Innovation (2014), R&D investment in the OIC member countries is mostly done by government and the public higher education sector. Still, relying on their stronger private sectors, Turkey and Malaysia were reported to have curated a larger portion of their R&D funds through businesses. Some D-8 countries, such as Nigeria and Pakistan, however, almost lacked R&D investment by the private sector (Atlas of Islamic World Science and Innovation, 2014, p. 22). Iran has paid assiduous attention to its STI system over the last two decades, aiming to make a transition to a knowledge economy (UNCTAD, 2016). Although Iran is rich in natural resources, most notably in oil and gas, it has reduced the share of oil revenues in its GDP, down from 32.4% in 2005 to 22.2% in 2019. This has been the case with other D-8 member countries: Oil revenue as a percentage of GDP decreased in Egypt from 12.3% in 2005 to 4% in 2019; in Nigeria from 18.6% in 2005 to 7.4% in 2019; in Indonesia from 5.3% in 2005 to 0.9% in 2019; and in Malaysia from 7.2% in 2005 to 2.4% in 2019[3]. In the case of Iran, this decrease coincided with policy-making and investment in knowledge enterprises and science and technology parks. Malaysia has similarly pursued a policy under its Vision 2020 plan to become a knowledge economy by 2020 with a transition toward high-technology industries (Day & Muhammad, 2011). According to the latest World Economic Forum statistics, the average score of capacity for innovation in D-8 countries was 4.16 in 2017, which was above the world's average. Well above the average were Malaysia (5.4) and Indonesia (4.8) as the top performers while Bangladesh (3.8) and Egypt (3.4) recorded the lowest scores among the D-8 members (World Economic Forum, Executive Opinion Survey, 2017).

In their report on the research landscape in the Middle East, North Africa, and Turkey (MENAT), Adams, El Ouahi et al. (2021) shortlisted a set of deficiencies in the science systems of the Muslim-majority countries as OIC members. They reported that collective research output in the MENAT region increased 20-fold in the past four decades. The report revealed that while Iran and Turkey were the largest research economies in the region, their international collaboration was about 25% on average. In this regard, they fell far behind Egypt, which had 60% international collaboration. Hariri and Riahi (2014) studied the scientific collaboration of the D-8 countries between 2000 and 2012. They reported that Turkey, Iran, and Malaysia produced the lion's share of research output among the D-8 countries.

The current deficiency in science, technology and innovation in the Muslim world was earlier acknowledged in the OIC Vision 1441 (OIC Conference on Science and Technology,

[3] https://data.worldbank.org/indicator/NY.GDP.PETR.RT.ZS.

2003, p. 3). The document delineated a set of issues that resulted in this deficiency, including low expenditure on R&D as a proportion of GDP, a small proportion of scientists and researchers involved in R&D, and a minor share of research publications in the world. The OIC Vision 1441 called for a commitment of the member states to fervently support a science and technology cause to meet the new economic challenges and promote their socioeconomic development (OIC Conference on Science and Technology, 2003, pp. 4–7).

Moed and Halevi (2014) developed a bibliometric model of scientific development in a case study on 25 Asian countries, including five of the D-8 countries in the continent. Their results showed that Iran, Malaysia, and Pakistan made a compound annual growth rate of publications, indexed in Scopus, above 15% in the period 1997–2012. They also found that doctoral students played a significant role in increasing the publication outputs in the Asian countries under study. Moed (2016) conducted a study to capture the effect of political dynamics of the Middle East on research output of the Persian Gulf region states. He noticed, based on his bibliometric model of scientific development, that Iran was one or two steps ahead of other countries in the region in terms of scientific development. He observed that Iran was the only country to have developed its own R&D infrastructure over the past three decades, "… despite the economic boycotts to which it has been subjected during most of the time" (Moed, 2016, p. 5).

4. METHODOLOGY

The present study adopts a descriptive-analytical method to characterize the research performance in the D-8 countries over the past two decades (2000–2019). To this end, a select number of STI input indicators are examined in conjunction with research output as a proxy for scientific and technical knowledge. The input-output indicators are used to outline the science system in the countries over the past two decades. In addition, statistical analyses are done to identify the potential contribution of each input indicator to the output indicator. Accordingly, individual data sets of STI indicators were created for the D-8 countries based on the data extracted from the UNESCO Institute for Statistics (UIS)[4] and the OIC Statistics (OICStat)[5] databases. Other data sets were compiled of the publications, collaboration, and citations of the D-8 countries based on the data extracted from Elsevier's Scopus online interface and the CWTS in-house SQL snapshot of the Scopus database (Snapshot 2021, April). The citations were counted for the publications in the given periods as the total times cited until the date of data retrieval (2021). The citation window is variable; thus, for the publications in a given year, the citations are counted until the data retrieval date. As the UIS and OICStat databases lacked data on some indicators, national STI reports and scoreboards were also scanned to fill in the missing data in the data sets. The data from the UIS and OICStat databases were collected as of August 2021 and further complemented in September 2021. The data from Scopus were retrieved and recorded between August and November 2021.

4.1. STI Indicators

The STI indicators are briefly defined in Table 1. Economic-based indicators are measured in current U.S. dollars so that they carry the inflation effect (Shelton & Foland, 2010, p. 3). Some indicators are expressed in current purchasing power parity (PPP) in U.S. dollars as an adjustment of the purchasing power of different currencies, which makes it possible to compare countries against a standard baseline.

[4] UNESCO Institute for Statistics Data Centre, Montréal, Canada (https://data.uis.unesco.org/).
[5] https://www.sesric.org/oicstat.php.

Table 1. STI indicators by type

Indicator type	Indicator name	Definition
Input	GDP (current U.S.$)	Gross domestic product (GDP) is a measure of the total value added as a result of the production of goods and services in the economy during a reference period (OECD data, 2021)[6].
	GDP per capita (in current US$)	GDP divided by the total population of the country.
	GERD in ’000 current PPP$	Gross domestic expenditure on R&D (GERD) “covers all expenditures for R&D performed in the economy during a specific reference period” (OECD, 2015, p. 109).
	GERD per capita (in current PPP$)	All expenditures on R&D per inhabitant of the country during a given period (OECD, 2015).
	GERD as a percentage of GDP	GERD as a percentage of the GDP of a country in a given period, which is alternatively called R&D intensity.
	GNI per capita, atlas method (current U.S.$)	Gross national income (GNI) constitutes GDP and the net revenue from abroad. GNI per capita is GNI divided by the midyear population of the country. The indicator value is expressed in US$ to facilitate comparisons across different countries (World Bank, 2021)[7].
	Human development index (HDI)	A complex measure calculated as the geometric mean of three indicators: life expectancy index, education index, and GNI index (UNDP HDRO)[8].
	No. of PhD students/enrollments	Total number of PhD students enrolled/studying in PhD programs in both public and private institutions.
	Enrollment, tertiary education	Total number of students enrolled in tertiary education institutions (both public and private) in a given period.
	Researchers per million inhabitants (FTE)	Total number of researchers as a proportion of one million population of a country in a given period. The full-time equivalent (FTE) adjustment gives an account of the actual time spent on R&D activities by researchers in a given context in a certain period.
Output	Publications	The data on all document types of publications were extracted from the Scopus database (online interface and/or CWTS SQL Server) as a proxy for the body of knowledge produced in a country/territory. Alongside the total number of publications, the data on citations, collaboration, and field distribution were retrieved from the databases as well.

4.2. Data Deficiency

One of the major issues in characterizing STI and drawing comparisons *inter alia* is the relative deficiency in data on important input-output indicators for the D-8 countries. For example, the UIS database provides few or no data points on the number or proportion of researchers, R&D intensity, and GERD per capita for some D-8 countries. Where available, the data are often fragmentary, with breaks across years in the series. This severely limits the possibility of presenting a thorough profile of these countries across all individual indicators. All analyses, however, are carried out here with this caveat in mind. Furthermore, various sources and databases provide STI statistics for the countries that are at times inconsistent. In addition, data collection and reporting

[6] https://data.oecd.org/gdp/gross-domestic-product-gdp.htm.
[7] https://data.worldbank.org/indicator/NY.GNP.PCAP.CD.
[8] https://hdr.undp.org/en/content/human-development-index-hdi.

methodologies in some cases pose serious questions as to the reliability and accuracy of the data (Day & Muhammad, 2011, p. 22–23). To avoid such inconsistency and ensure, at least, the comparability of the data, the UIS and OICStat databases were used as the main sources of data on STI input indicators for all countries. Exceptions are only in the number of PhD students/enrollments for Iran[9] and Malaysia[10], where the data were obtained from official government documents.

4.3. Generalized Estimating Equations (GEE) Analysis

According to Shelton and Foland (2017), the explanatory power of the statistical or mathematical models could be used to capture the correlations between input and output R&D variables. Generalized estimating equations (GEEs) were run in SPSS 26 to examine the contribution of input indicators to the publications count for each country in 2000–2019. GEE is an advanced statistical analysis that estimates the parameters of generalized linear models (GLM) in time-series analyses. The data on each country were separately compiled in Excel files and imported into SPSS for analysis. The data structure was converted to the longitudinal structure for GEE analysis. Owing to the deficiency of the input data for some countries, as shown in Table 2, the statistical analysis was only carried out for Turkey, Iran, Egypt, and Malaysia independently. The missing data points were imputed using the random data generation technique. Accordingly, 15 imputations were run for every country data set, and the simulated values closest to the observed data points were selected to fill in the missing data. In the first run of statistical analysis, univariate GEE was carried out with individual variables, and only the variables with a *p*-value smaller than 0.2 ($p < 0.2$) were passed into the multivariate GEE analysis for every country (Chowdhury & Turin, 2020). The multiple GEE analysis was used to examine the likely contribution of input variables to the publication count for each country over time in the exchangeable correlation matrix structure. The level of significance was considered smaller than 0.05 for the multiple GEE tests in this study.

5. RESULTS

5.1. D-8 Countries' Performance Across STI Indicators

As an important barometer of the economy[11], GDP has been subject to fluctuations with occasional leaps and slumps in the D-8 countries over the past two decades. One should bear in mind, however, that this is nominal GDP measured in current U.S. dollar prices, which reflects the inflation effect in the GDP values across the years[12].

Figure 3 illustrates the average GDP per capita (a) and average HDI (b) of the D-8 countries by decade. These two indicators are juxtaposed to provide a more robust picture of the socioeconomic conditions. As shown in Figure 3, Turkey and Malaysia lead other countries in terms of the average GDP per capita in the two consecutive decades. In the 2010s, they clearly stand out from the rest of the cohort as their average GDP per capita is almost double their closest comparator, Iran. According to the World Bank classification of income groups, Turkey and Malaysia currently lodge among the upper middleiincome economies, while other D-8 countries sit among the lower middle-income nations[13]. The countries, however, are remarkably

[9] https://irphe.ac.ir.

[10] https://mastic.mosti.gov.my/.

[11] https://www.imf.org/external/pubs/ft/fandd/basics/gdp.htm.

[12] https://datahelpdesk.worldbank.org/knowledgebase/articles/114942-what-is-the-difference-between-current-and-constan.

[13] https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups.

Table 2. Data availability on STI indicators by country during the period 2000–2019

	Input indicators										Output indicator
Country	GDP (current US$)	GDP per capita (current US$)	GERD in ’000 current PPP$	GERD per capita (in current PPP$)	GERD as a percentage of GDP (R&D intensity)	Human development index (HDI)	No. of PhD students/ enrollments	Enrollment, tertiary education	Researchers per million inhabitants (FTE)	GNI per capita, Atlas method (current US$)	Publications (Scopus)
Iran	☑	☑	⊡	⊡	⊡	☑	⊡	☑	⊡	☑	☑
Turkey	☑	☑	⊡	⊡	⊡	☑	☒	⊡	⊡	☑	☑
Egypt	☑	☑	⊡	⊡	⊡	☑	☒	⊡	⊡	☑	☑
Nigeria	☑	☑	☒	☒	☒	⊡	☒	⊡	☒	☑	☑
Pakistan	☑	☑	⊡	⊡	⊡	☑	☒	⊡	⊡	☑	☑
Bangladesh	☑	☑	☒	☒	☒	☑	☒	⊡	☒	☑	☑
Indonesia	☑	☑	⊡	⊡	⊡	☑	☒	☑	⊡	☑	☑
Malaysia	☑	☑	⊡	⊡	⊡	☑	☑	☑	⊡	☑	☑

☑ fully available data across the time series; ⊡ available data with breaks across the time series; ☒ data not available.

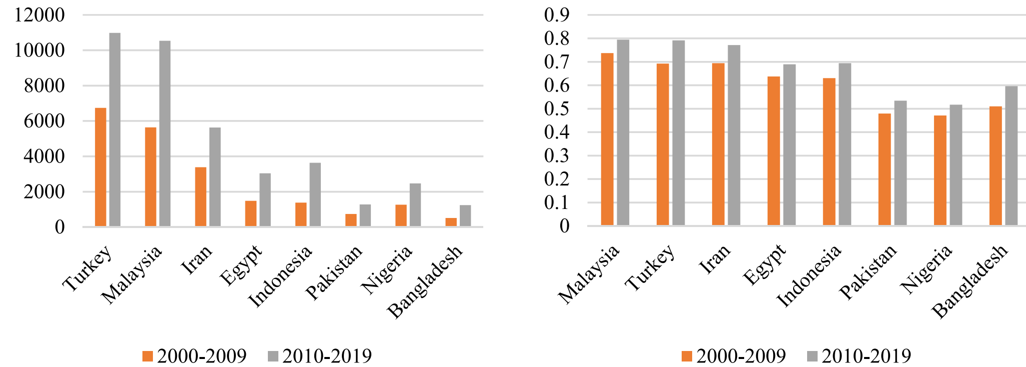

Figure 3. (a) Average GDP per capita (current US$) vs. (b) average HDI values in the D-8 countries over the past two decades (source: UIS database).

more homogenous in HDI, with Malaysia, Turkey, and Iran leading other countries while being closely followed by Indonesia and Egypt.

With regard to R&D intensity, Malaysia leads other D-8 countries by consistently allocating an average of over 1% of its GDP to R&D in the 2010s. As shown in Figure 4, Turkey, which was a close comparator of Malaysia in the 2000s, lags far behind in the 2010s, with an average R&D intensity value of 0.86%. Iran, which was a close comparator of Turkey in the 2000s, spent only half the average of Turkey in the 2010s. Egypt, however, showed a sizeable intensification of R&D expenditure as a percentage of its GDP, with an average value of around 0.62% in the 2010s. The average R&D intensity almost trebled in Indonesia over the 2010s.

Taken together, however, the average R&D intensity in the D-8 countries was meager compared with other regional or income groups over the last two decades. As shown in Figure 5, Northern America was the largest R&D spender, allocating an average of 2.6% of its GDP to R&D in the last two decades. The world's average GERD as a percentage of GDP approximated that of Europe. The growth rate of average R&D intensity was most conspicuous in

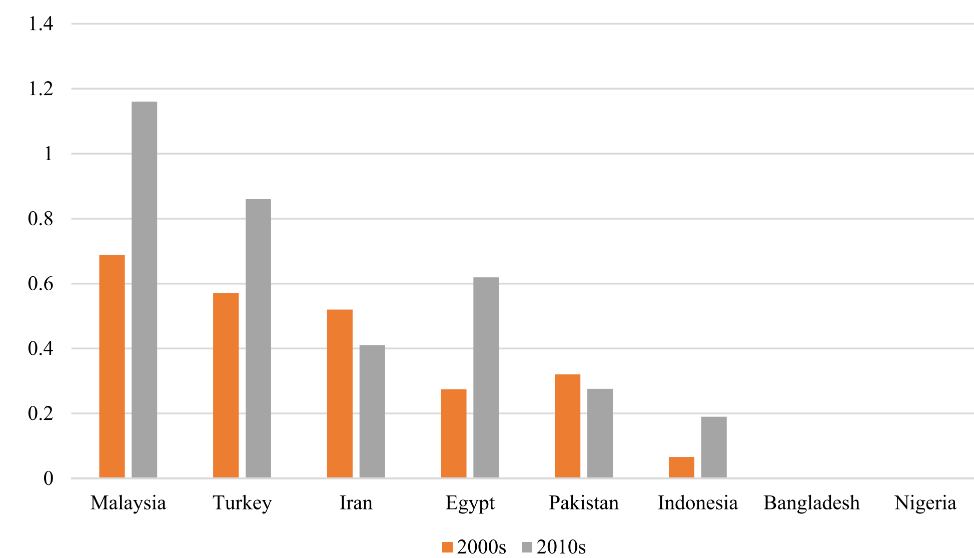

Figure 4. Average R&D intensity in the D-8 countries by decade (source: UIS database). Data for Bangladesh and Nigeria were unavailable. For other countries, the values were missing for some years.

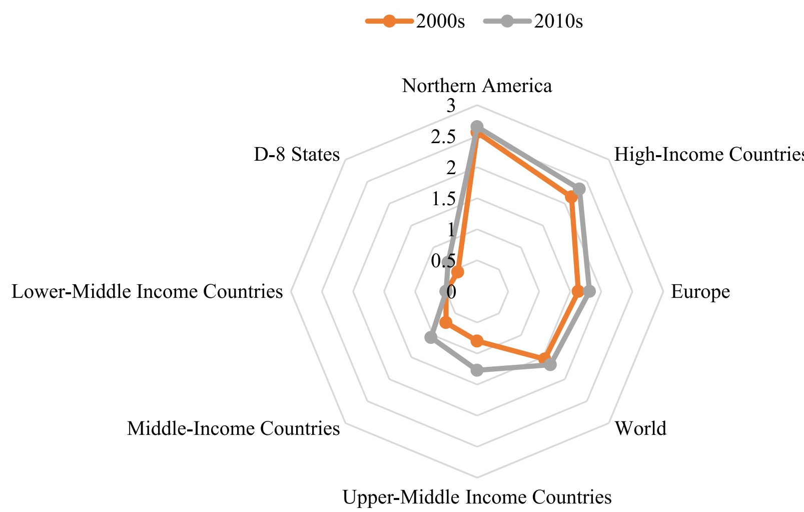

Figure 5. Collective average R&D intensity in country groupings by region and income (source: UIS database) (calculated as average of ratios for the country-years for which the data were available).

the upper middle-income countries with around 59% increase in the 2010s compared with the previous decade. The collective growth rate of average R&D intensity in the D-8 cohort was 50% in the 2010s compared with the 2000s, which is higher than that of the middle-income countries, with around 48%.

An important input to the STI system is human resources (HR) engaged in R&D as researchers who work toward the "conception or creation of new knowledge" (OECD, 2015, p. 162).

As shown in Figure 6(a), Iran leads D-8 countries in the 2000s with an average of over 728 FTE researchers per million inhabitants. However, Malaysia takes over in the 2010s with an

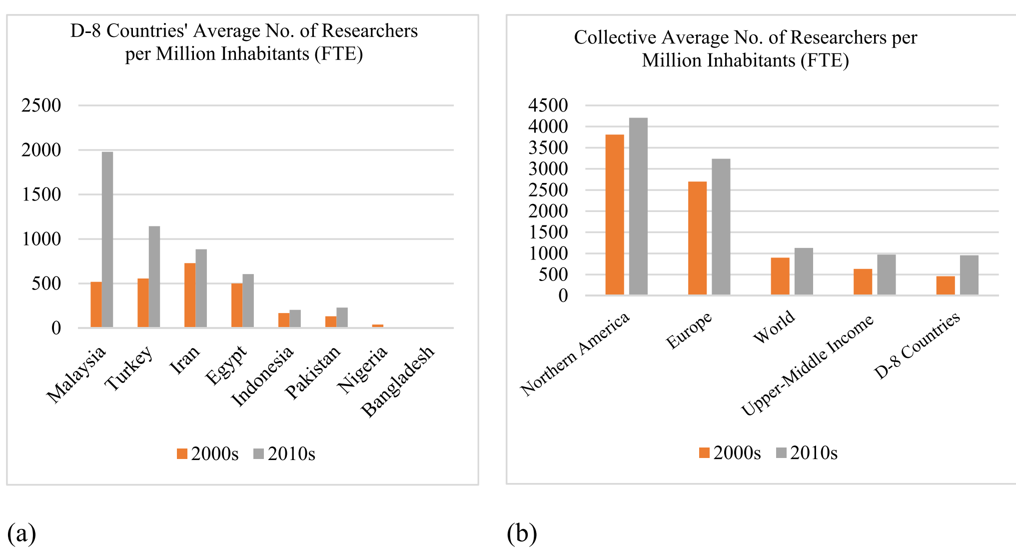

Figure 6. (a) Average number of researchers per million inhabitants (FTE) in the D-8 countries (computed based on the available country-year data points across the time series) vs. (b) collective averages by regional and income groupings; these averages were computed based on the available country-year data points across the time series. Thus, the values represent partial average data for each cohort (source: UIS database).

Table 3. Annual growth rate of tertiary enrollment in D-8 countries (year-over-year percentage) (source: OICStat database)

	Iran	Indonesia	Malaysia	Egypt	Bangladesh	Turkey	Pakistan	Nigeria
2000	7.39	2.18	16.02		2.46			
2001	11.74	−3.47	1.44		20.89			
2002	−0.21	5.23	13.50	6.84	−2.64	4.39		
2003	9.44	8.36	14.80	−7.34	2.57	14.34		
2004	14.03	3.19	0.72	7.78	−6.38	2.82	29.82	4.49
2005	8.77	3.13	−4.69	4.04	10.99	6.78	50.31	7.90
2006	12.82	−0.13	5.81	2.16	15.57	11.23	4.82	
2007	17.91	4.08	9.21	3.42	8.72	4.73	16.38	
2008	19.92	16.10	14.54	0.64	13.02	3.22	2.00	
2009	−1.24	9.95	8.51	2.67	22.22	15.46	25.90	
2010	13.17	2.91	6.07	3.05		20.69		
2011	8.61	7.26	−2.36	−15.10		8.15		8.52
2012	6.98	16.21	3.89	2.45	1.43	14.05	15.53	
2013	−0.83	3.04	3.72	7.67		14.29	5.42	
2014	7.27	0.62	1.01	2.69		9.99	0.86	
2015	2.50	8.98	15.43	12.77		10.79	−3.12	
2016	−9.46	8.11	2.65	−2.78		10.33	−0.82	
2017	−6.31	4.32	−6.56	4.49	2.37	7.62	4.60	
2018	−11.24	1.17	2.88	11.59	14.02	5.02	−3.26	
2019	−6.71		−5.19		17.29	2.84	37.60	

outstanding boom of around 1,978 FTE researchers per million inhabitants in average, up from around 519 in the 2000s. This is more than double Iran's average for the 2010s. Turkey also experienced a growth rate of over 100% in the average number of FTE researchers per million inhabitants in the 2010s, up from 555.7 in the 2000s. Egypt, Pakistan, and Indonesia follow the other three top performers with comparably lower proportions of researchers in their STI system. On the global stage, northern America consistently outperforms the world in the average number of FTE researchers per million inhabitants. Both northern America and Europe stand well above the world's average. The D-8 countries' collective average is on a par with the upper middle-income countries and closes in on the world's average in the 2010s. Along with increased researcher tallies, the results revealed that D-8 countries progressively expanded their higher education systems, with the number of enrollments in tertiary education sometimes increasing dramatically over the past two decades.

Despite the overall growth in the number of student enrollments in tertiary education over the last two decades, year-over-year data revealed occasional slumps in some D-8 countries, especially in the first half of the 2000s and the latter half of the 2010s (see Table 3). Since

2016, Iran witnessed the most considerable downtrend followed by Malaysia. Pakistan, however, recorded the most dramatic increases in the growth rate of tertiary enrollments since 2000. Moreover, the number of PhD students in Iran increased from around 19,000 in 2005 to over 147,000 in 2019. For Malaysia, PhD enrollments increased from about 10,000 in 2005 to around 40,000 in 2018.

Starting from a low base in the 2000s, almost all D-8 member countries, especially Iran, Turkey, and Malaysia, made clear signals of the development of their research enterprise with a large volume of scholarly publications in the 2010s. Turkey led the D-8 countries by far in the number of publications, with almost double the volume of its closest comparator, Iran, in the 2000s. In the 2010s, however, Indonesia recorded a phenomenal growth rate of around 1,140% to become the fifth most prolific country in the D-8 cohort in this decade (see Figure 7).

In the 2010s, Iran surpassed Turkey in the total number of publications. With regard to the aggregate number of publications in the past two decades, Turkey still leads the cohort, followed by Iran, Malaysia, and Egypt. Pakistan and Indonesia have almost the same share of publications. Taken together, the collective average growth rate of all document types of publications was 265% for D-8 countries in the 2010s.

According to Wuchty, Jones, and Uzzi (2007), research in the fields of science and social sciences has become substantially collaborative over time. Consistent with the global authorship trends, the publications of the D-8 countries have progressively become more collaborative. While Egypt and Nigeria published a smaller share of their output as multiauthor papers (i.e., publications contributed by two or more authors), other countries were more homogeneous, with 86–91% of multiauthor as opposed to single-author publications in the 2000s. In the 2010s, the D-8 publications became even more collaborative, with Malaysia and Pakistan publishing around 96% of their scholarly output as multiauthor papers. Turkey, however, maintained the same ratio across the two decades. All D-8 countries performed above the world's average of multiauthor ratios in the 2000s and 2010s (see Figure 8).

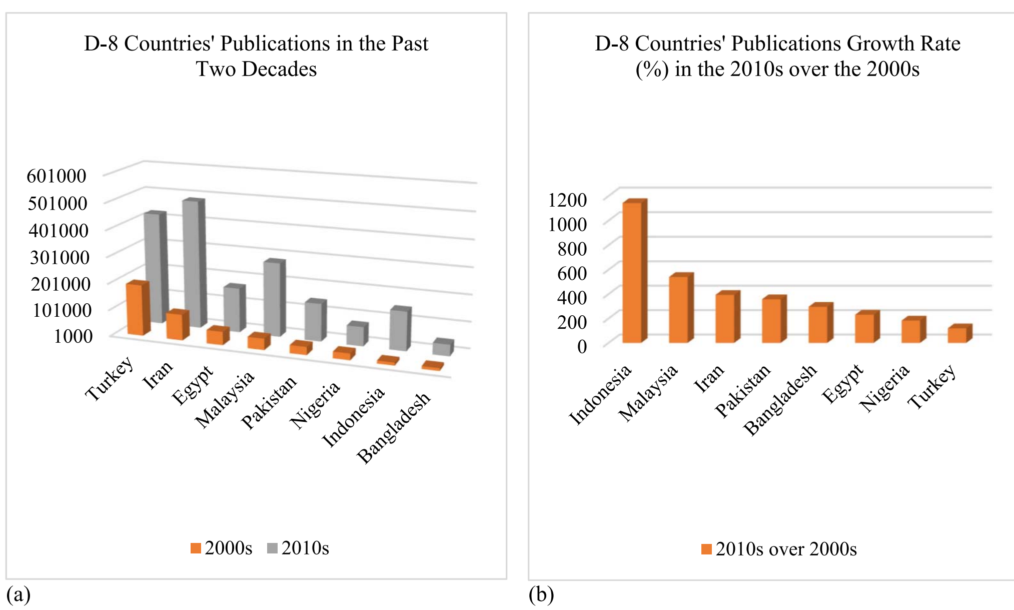

Figure 7. D-8 countries' (a) publications and (b) growth rates in the past two decades. The publication counts include all document types indexed in Scopus. The growth rates are calculated for each country based on the total publication counts (data from CWTS SQL Server).

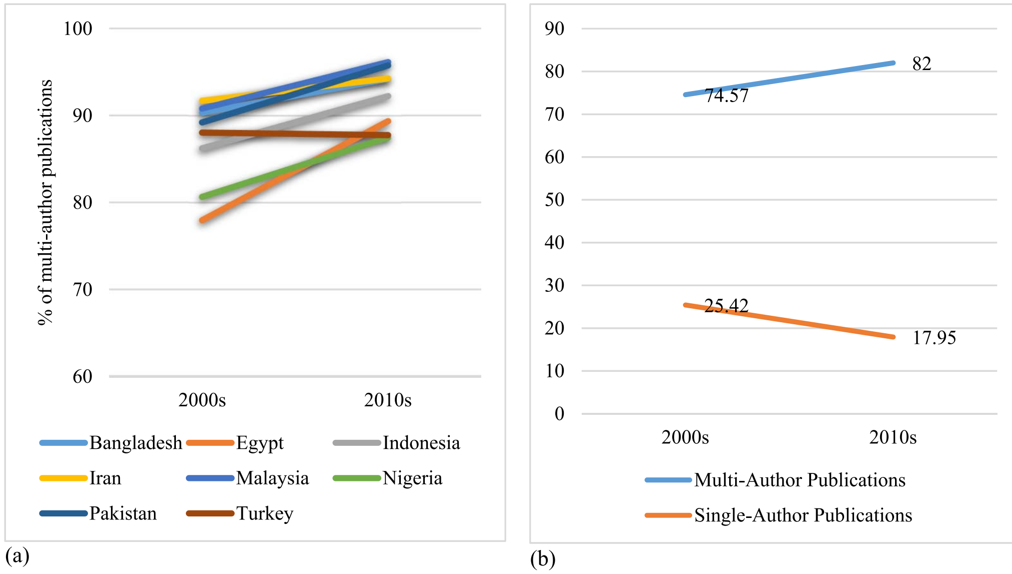

Figure 8. (a) Percentage of multiauthor publications in D-8 countries and (b) of single- vs. multiauthor publications in the world in the past 2 decades (data from CWTS SQL Server).

Citations are a well-known proxy for scientific impact. Indonesia leads the D-8 countries with the highest average citations per publication for its documents published in the 2000s. For the documents published in the 2000s, Indonesia, Bangladesh, and Turkey showed the highest citation impact. Indonesia, however, recorded an important relative change in its average citations per publication for the 2010s documents, retreating to eighth place in the cohort. All D-8 countries, except Indonesia, fell below the world's average of citations per

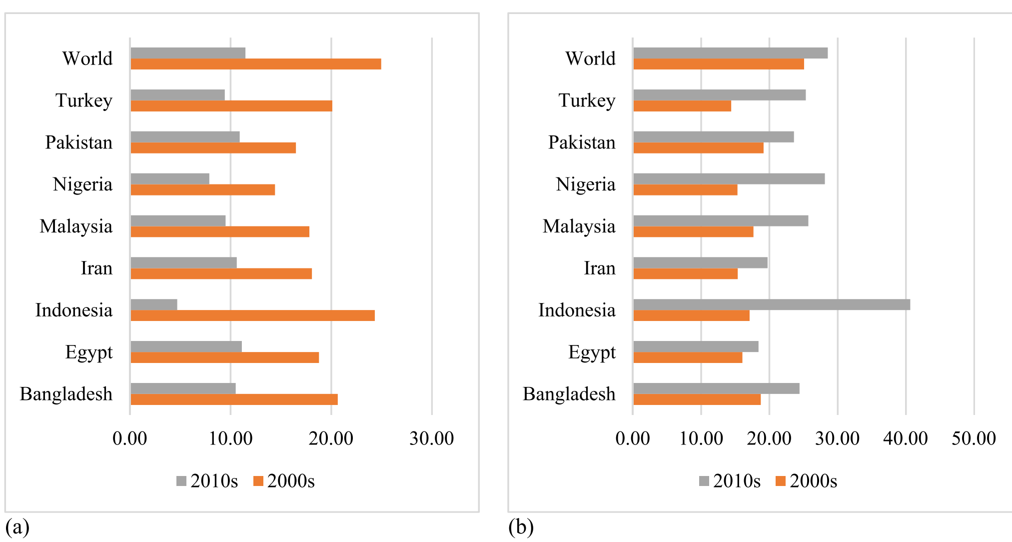

Figure 9. (a) Citations per publication and (b) percentage of uncited publications of the D-8 countries vs. the world average (data from CWTS SQL Server).

Table 4. Research collaboration between country pairs during the period 2000–2019 (data from Scopus online interface)

	Turkey	Iran	Pakistan	Bangladesh	Egypt	Nigeria	Malaysia	Indonesia
Turkey		5,723	3,844	332	3,014	595	2,510	484
Iran			2,732	292	2,034	489	9,328	306
Pakistan				965	2,503	610	7,023	574
Bangladesh					442	249	3,572	413
Egypt						503	2,473	365
Nigeria							3,947	311
Malaysia								8,916
Indonesia								

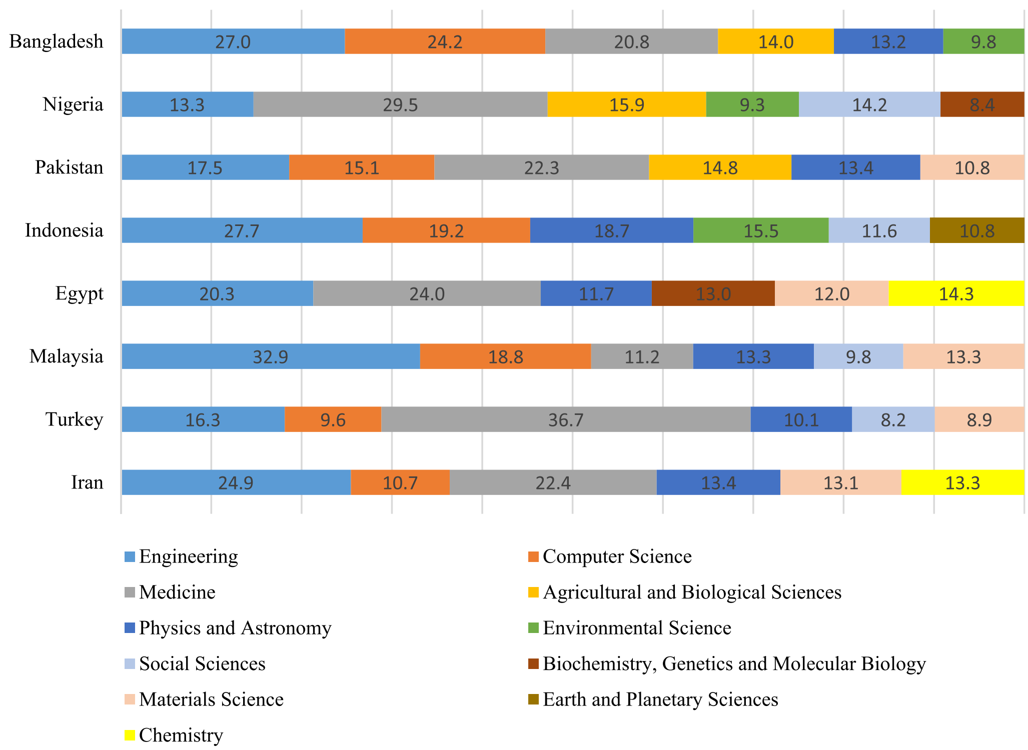

Figure 10. Percentage distribution of the D-8 documents by the top six subject areas per country in the 2010s (data from Scopus online interface).

publication[14] for their publications in the 2000s. Still, some of them have managed to approximate the world's average citations for their publications in the 2010s. Indonesia and Nigeria have the highest ratio of uncited publications to their total output in the 2010s. Indonesia, nevertheless, stands out with the largest share of uncited publications as a percentage of its total output in the 2010s with a share of over 40% (see Figure 9).

[14] Calculated as the sum of all citations to all documents indexed in Scopus divided by the total number of publications during 2000s and 2010s.

Despite their remarkable growth in the number of publications over the last two decades, the D-8 members demonstrated an inertia in bilateral research collaboration so that their pairwise collaborative publications did not exceed a few thousands at the outside. Still, Malaysia is the country with whom other D-8 members collaborate more in research. Indonesia, Bangladesh, and Nigeria have the lowest shares of research collaboration with other D-8 members (see Table 4).

A breakdown by Scopus subject area of the D-8 countries' documents in the 2010s revealed that all the countries have produced a substantial share of their output in engineering and medicine. Malaysia showed the highest share of output in engineering research (~33%) as a percentage of its total publications, while Turkey had the largest share of publications in medicine (~37%) as a percentage of its total publications. Other relevant research areas of activity for most countries include physics and astronomy and computer science (see Figure 10).

5.2. Generalized Estimating Equations (GEE) Analysis

5.2.1. Iran

Multivariate GEE analysis was used to examine the likely contribution of input indicators to the publications volume for Iran over time. The results show that each U.S.$10 million unit (see Table 5). increase in GDP is associated with an increase of four items in the number of publications. Moreover, one unit increase in GERD per capita (in current PPP$) is associated with 713.2 items increase in publications. The results also show a positive association of the number of PhD students with the publications volume of Iran over time. Both GNI per capita and the number of researchers (FTE per million inhabitants) have significant positive associations with the publication volume. Accordingly, one-unit increase in the former is associated with

Table 5. Multiple GEE analysis for Iran

			95% Wald confidence interval		Hypothesis test		
Parameter	B	Std. error	Lower	Upper	Wald chi-square	df	p
(Intercept)	−753,535	226,494.3	−1,197,456	−309,615	11.1	1	0.001*
Time	364.2	114.6	139.5	588.8	10.1	1	0.001*
GDP per capita (current US$)	−27.7	3.8	−35.1	−20.3	54.2	1	<0.001*
GDP (current U.S.$)	4E−07	5.28E−08	2.97E−07	5.04E−07	57.593	1	<0.001*
GERD in '000 current PPP$	−0.009	0.0006	−0.01	−0.008	238.077	1	<0.001*
GERD per capita (in current PPP$)	713.2	37.8	639.1	787.4	355.6	1	<0.001*
Human development index	25,550.5	19,560.6	−12,787.6	63,888.6	1.7	1	0.191
GERD as a percentage of GDP	−11,109.8	1,195.4	−13,452.8	−8,766.8	86.4	1	<0.001*
No. of PhD students	0.2	0	0.1	0.2	44.1	1	<0.001*
Enrollment, tertiary education	-8.1×10^{-5}	0.0006	−0.001	0.001	0.019	1	0.891
Researchers per million inhabitants (FTE)	8	2	4	12	15.5	1	<0.001*
GNI per capita, Atlas method (current U.S.$)	1.6	0.5	0.6	2.6	9.1	1	0.003*

* Significant at <0.05 level.

Table 6. Multiple GEE analysis for Malaysia

Parameter	B	Std. error	95% Wald confidence interval		Hypothesis test		
			Lower	Upper	Wald chi-square	df	*p*
(Intercept)	26,001.3	158,171.1	−284,008.3	336,010.8	0.027	1	0.869
Time	−36.9	80.1	−193.8	120.1	0.2	1	0.645
GDP per capita (current U.S.$)	−7.6	0.4	−8.4	−6.8	365.2	1	<0.001*
GDP (current U.S.$)	3.0×10^{-7}	1.2×10^{-8}	2.7×10^{-7}	3.2×10^{-7}	551.8	1	<0.001*
GERD in ’000 current PPP$	-5.4×10^{-5}	0.0007	−0.001	0.001	0.007	1	0.935
GERD per capita (in current PPP$)	40.8	24.7	−7.5	89.1	2.7	1	0.098
Human development index	84,038.4	10,506.5	63,446.0	104,630.8	64.0	1	<0.001*
GERD as a percentage of GDP	−2,726.7	1,260.8	−5,197.9	−255.5	4.7	1	0.031*
Enrolment in PhD (public and private)	−0.005	0.02	−0.045	0.034	0.07	1	0.791
Enrollment, tertiary education	−0.02	0.001	−0.02	−0.015	256.7	1	<0.001*
Researchers per million inhabitants (FTE)	6.2	0.2	5.7	6.6	676.3	1	<0.001*
GNI per capita, Atlas method (current U.S.$)	−0.65	0.19	−1.03	−0.28	11.8	1	0.001*

* Significant at <0.05 level.

1.6 items increase in publications while one more researcher (FTE per million inhabitants) is associated with an increase in publications of eight items.

5.2.2. *Malaysia*

The results of GEE analysis for Malaysia show a significant positive association of GDP growth with publications volume so that each U.S.$10 million unit increase in GDP is associated with an increase in publications by three items. In addition, one decimal unit increase in HDI is associated with an increase of 840.4 publication items. The number of researchers (FTE per million inhabitants) shows a significant positive association with the number of publications. Accordingly, an increase of one researcher (FTE per million inhabitants) is associated with a 6.2 item increase in publications (see Table 6).

5.2.3. *Turkey*

The results of GEE analysis for Turkey show that GERD (in ’000 current PPP$) has a significant positive association with the publications volume over time. Moreover, one decimal value increase in HDI is associated with an increase in publications by 831.5 items. The model also reveals a significant positive association of GNI per capita with the publications volume, such that one U.S.$ unit increase in GNI per capita is associated with an increase in publications by 1.2 items (see Table 7).

5.2.4. *Egypt*

The results of GEE analysis for Egypt show a significant positive association of GDP growth with increases in the publication count so that each U.S.$10 million unit increase in GDP is associated with an increase in the publications count by nine items (see Table 8).

Table 7. Multiple GEE analysis for Turkey

Parameter	B	Std. error	95% Wald confidence interval Lower	Upper	Hypothesis test Wald chi-square	df	*p*
(Intercept)	−4,202,885.1	929,187.5	−6,024,059.2	−2,381,711.1	20.5	1	<0.001*
Time	2,073.9	464.9	1,162.5	2,985.3	19.9	1	<0.001*
GDP per capita (current U.S.$)	5.6	3.7	−1.6	12.9	2.3	1	0.127
GDP (current U.S.$)	-8.5×10^{-8}	5.3×10^{-8}	-1.8×10^{-7}	1.8×10^{-8}	2.6	1	0.106
GERD in ’000 current PPP$	.004	.001	.002	.005	13.9	1	<0.001*
GERD per capita (in current PPP$)	−381.0	102.9	−582.8	−179.2	13.7	1	<0.001*
Human development index	83,151.3	38,148.8	8,381.0	157,921.5	4.7	1	0.029*
GERD as a percentage of GDP	16,516.2	10,145.1	−3,367.8	36,400.2	2.7	1	0.104
Enrollment, tertiary education	.002	.003	−.003	.007	.7	1	0.389
Researchers per million inhabitants (FTE)	−6.2	8.5	−22.9	10.5	.5	1	0.468
GNI per capita, Atlas method (current U.S.$)	1.2	.60	.04	2.4	4.1	1	0.043*

* Significant at <0.05 level.

Table 8. Multiple GEE analysis for Egypt

Parameter	B	Std. error	95% Wald confidence interval Lower	Upper	Hypothesis test Wald chi-square	df	*p*
(Intercept)	−1,145,885	845,010.4	−2,802,075	510,305.2	1.84	1	0.175
Time	595.2	441.57	−270.3	1,460.6	1.82	1	0.178
GDP per capita (current U.S.$)	−7.2	2.89	−12.9	−1.5	6.2	1	0.013*
GDP (current U.S.$)	9.4×10^{-8}	3.5×10^{-8}	2.54×10^{-8}	1.63×10^{-7}	7.22	1	0.007*
GERD in ’000 current PPP$	0.00206	0.001092	−8.1E−05	0.004201	3.56	1	0.059
GERD per capita (in current PPP$)	59.6	129.26	−193.8	312.9	0.21	1	0.645
Human development index	−62,337.6	65,071.72	−189,876	65,200.6	0.92	1	0.338
GERD as a percentage of GDP	−19,508	7,761.23	−34,719.7	−4,296.2	6.32	1	0.012*
Enrollment, tertiary education	0.0002	0.001	−0.0024	0	0.02	1	0.886
GNI per capita, Atlas method (current U.S.$)	−1.1	1.35	−3.8	1.5	0.71	1	0.400

* Significant at <0.05 level.

6. DISCUSSION

6.1. Socioeconomic Status and Research Performance of D-8 Countries

The present study shows marked differences in the socioeconomic status and research performance among D-8 countries over the last two decades. Both GDP, as a measure of a country's wealth, and GDP per capita are noticeably different among the D-8 countries. Turkey and Malaysia had the highest average GDP per capita over the last two decades and clearly stood out, as upper middle-income economies, from the rest of the cohort. All countries, however, enjoyed a higher average GDP per capita in the 2010s compared to the preceding decade, with Indonesia and Bangladesh recording the highest growth rates of 163% and 144%, respectively. Malaysia, Turkey, and Iran had the highest average HDI scores in the last two decades. Egypt was on a par with Indonesia, while Pakistan, Bangladesh, and Nigeria had lower average HDI scores. Moreover, Malaysia and Turkey spent the highest share of their GDPs on R&D, and hence were the top performers in R&D intensity among the cohort. In sum, Malaysia and Turkey consistently outperformed other D-8 countries in GDP per capita, HDI, and R&D intensity over the last two decades. Nevertheless, the average R&D intensity in all D-8 countries, even in the top performers, is still far below the world average.

Trained human resources engaged in R&D are an important asset in the knowledge economy. Iran in the 2000s and Malaysia in the 2010s enjoyed the highest ratios of FTE researchers per million inhabitants among D-8 countries, while Malaysia and Turkey both stood above the world average of FTE researchers per million inhabitants in the 2010s. The results reveal that the higher education (HE) system has dramatically expanded in the D-8 countries over the past two decades. However, the sharp year-over-year increases in the number of enrollments in tertiary education sometimes stumbled, with periods of downtrend in some D-8 countries, especially in the latter half of the 2010s. This may raise a concern as to the sustainability of the HE system in these countries and may disturb the continuous supply of skilled human resources to the science system and the economy. PhD students/enrollments, however, showed a consistent uptrend in both Iran and Malaysia, with an increase rate of over seven times in the former and four times in the latter by the end of the 2010s against the baseline year of 2005.

Academic research and publishing are ways to transfer scientific knowledge into the realm of the economy (Bienkowska, 2010). Starting from a low base in the first half of the 2000s, the D-8 countries gradually increased their publication outputs, though at different paces, with Turkey standing out from the rest. Indonesia, Malaysia, and Iran recorded the most marked growth rates in their number of publications in the 2010s. There are sharp differences among countries in publication volume as, for instance, the decade-long aggregate publication count of Bangladesh in the 2010s is smaller than Iran's publication output in 2014. Consistent with the global trend, research has become progressively collaborative in the D-8 countries over the last two decades. According to Hollingsworth, Müller, and Hollingsworth (2008), the number of authors per paper has doubled over the last decades. They also found a direct association between economic development and the growth of research output. In the past two decades, the D-8 countries published more multiauthor papers than the world average. Regarding research impact, only Indonesian publications were on a par with the world average of citations per publication for papers published in the 2000s. Still, Indonesian publications showed a relatively large loss of impact in the 2010s. For publications of the 2010s, however, many other D-8 countries showed a citation impact close to the world average.

The findings reveal a meager share of pairwise research collaborations among the D-8 countries over the past two decades. The numbers of collaborative publications among

D-8 countries are sometimes as small as a few hundred for the whole period, which might result from a lack of determined plans informed by a higher-order policy framework to encourage research collaboration. A lack of sufficient ties among the member countries is also manifest in their trade relations. Almasi (2012) contended that "trade transactions between the [D-8] members in the past decade [2000s] shows that the growth of member countries' trade transactions with the countries outside of the [D-8] group has been higher than the growth with the [D-8] member countries" (p. 6167). The findings further showed that D-8 countries mostly plotted their research trajectories around medicine and engineering in the 2010s. Taken together, they collectively published around 24% and 23% of their research in the fields of medicine and engineering, respectively. Computer science and physics and astronomy were two other research areas of large activity, accounting for around 13% and 12%, respectively, of the collective scholarly output of the D-8 countries in the 2010s.

6.2. Contribution of STI Input Indicators to the Publication Output in D-8 Countries

In this study, GEE analysis was used to examine the contribution of STI indicators to the publication volume in the D-8 countries. The results showed that GDP, GERD per capita, the number of PhD students, the number of researchers (FTE per million inhabitants), and GNI per capita had significant positive associations with the publications volume in Iran over time. For Egypt, GDP showed a significant positive association with the volume of research output over time. For Turkey, GERD, HDI, and GNI per capita showed significant positive associations with the publication output. For Malaysia, GDP, HDI, and the number of researchers (FTE per million inhabitants) had significant positive associations with the publication volume over time. The results of GEE analyses are partially consistent with the findings of Shelton and Foland (2010) who reported that GERD share was the most significant predictor of national research publication output. The input effects in the statistical models demonstrated how national wealth, R&D expenditure, the stock of researchers, and human development could contribute to knowledge creation in service of the knowledge economy in some D-8 countries. Earlier research has suggested that not only binding publication policies (Shetty et al., 2014) but also the broader social, political, and economic circumstances can affect the volume of research output of the countries. Moed (2016, p. 4) wrote "Iran's research output declined during the first half of the 1980s under the influence of the Iraq–Iran War ..." but started to grow markedly since the 1990s. Butler (2019, p. 13) reported that the economic sanctions imposed on Iran since 2018 severely affected the research system, leading to a cut in budgets for "... equipment, supplies and travel ..." and barring international collaboration. The science system of Egypt also suffered "... decades of underinvestment, poor planning of the way research funds are spent, excessive bureaucracy, uninspiring curricula and political meddling ..." (Bond, Maram et al., 2012). Nevertheless, soon after the Arab Spring led to the Egyptian revolution, the new government pledged to boost an important input to the STI system of the country, R&D expenditure (El-Akkad, 2012). Economic crises may also take their toll on the STI system; for example, Malaysia's GERD as a percentage of GDP dropped markedly in 2008 compared with that in 2006 due to the global financial crisis and an oil price hike (Day & Muhammad, 2011). All these macrolevel forces that bear on the STI system may have their eventual impact on research output, which may serve as topics for future research.

Research has shown bilateral relations between knowledge production and economic growth in the countries. On the one hand, investment in R&D is found to be a strong predictor of the research publication volume (Shelton & Foland, 2010). On the other hand, the growth of scientific publications can predict some percentage of annual economic growth (Chen & Dahlman, 2004). The present findings reveal a number of domains where the strengths of the D-8 countries lie. They are among the largest economies in their respective geopolitical regions. The standard of living, measured through HDI in this study, has been on the rise in these countries, though at different paces. They have managed to expand their HE systems to secure a continuous flow of trained human resources in their economy and science system. They have often expressed their policy intention to increase their R&D investment through higher expenditures. Accordingly, they have realized marked growth rates in knowledge creation and publications over the last two decades. The countries, however, should be able to accommodate the sizeable growth in the stock of skilled HR in their economy and R&D systems. In addition, there are certain areas for synergy among the countries within the policy context of the D-8 organization. Not only technical knowhow but also R&D infrastructure could be shared among the countries through joint R&D initiatives. The science systems suffer certain deficiencies in the D-8 countries, however. They often allocate a small portion of their GDP to R&D, which is far below the world average. Moreover, considering the volume of their research output, these countries have already shown enormous inertia in mutual research collaborations.

However, one should note that development of R&D initiatives is not the only driver of socioeconomic development. Rather, many other factors contribute as well, including, but not limited to, human resources, foreign investment, engineering knowledge, infrastructures, technology transfer, and innovation collaborations with multinational companies. Therefore, it remains to be seen how the growth of academic research output and overarching research collaboration policies may contribute to macroeconomic indicators, sustainable development and productivity in the D-8 countries. As maintained by OECD (2012), cross-border STI cooperation requires unswerving commitment by the governments. In the same vein, effective overarching STI governance is of prime importance in the D-8 context. Addressing the need to rise to the current global challenges through innovative synergetic efforts, the D-8 Global Vision (2012–2030) (D-8 Organization, 2012) puts at its core collaboration in priority areas as well as the south–south cooperation cause among the member countries to support their long-term sustainable economic development.

7. LIMITATIONS OF THE STUDY

All analyses and deductions were made based on the data extracted from UIS, OICStat, and Scopus databases. Where noted, other sources were used and cited, such as the World Bank, OECD, and national STI scoreboard reports. Nevertheless, UIS and OICStat were the main sources of data on STI input indicators to ensure the consistency and comparability of the data across countries. The data on some input indicators, however, were missing in the series for some years, which was a major limitation. Data deficiency effectively restricts the possibility of presenting a full collective STI profile of the countries under study. With more comprehensive data, it would be possible to present more collective perspectives in future research agendas. Although Scopus is one of the largest bibliographic databases, it is likely that D-8 countries also publish a sizeable volume of their research in local periodicals in native languages or in journals not covered by Scopus. All deductions, however, are made with this caveat in mind in this study. Any decision by Scopus to curb or further expand its coverage of the journals in the future or changes in the publication dynamics at the global level will potentially change the publication counts at all aggregate levels.

AUTHOR CONTRIBUTIONS

Javad Hayatdavoudi: Conceptualization, Data curation, Formal analysis, Methodology, Software, Writing—original draft, Writing—review & editing. Wolfgang Kaltenbrunner: Conceptualization, Supervision. Rodrigo Costas: Conceptualization, Supervision, Validation, Writing—review & editing.

COMPETING INTERESTS

The authors have no competing interests.

FUNDING INFORMATION

This research received no funding.

DATA AVAILABILITY

The STI data sets contain all the raw data used in this study. As to the Scopus data, some queries were run directly on the online interface of the Scopus database, but the raw data were never downloaded. Thus, we only share the aggregate values as the output of queries. For other calculations based on the Scopus version available at CWTS, the raw data cannot be shared due to licensing restrictions of the data provider (Scopus). However, we provide the SQL queries and the aggregated data at https://doi.org/10.6084/m9.figshare.19168601.v2.

REFERENCES

Adams, J., El Ouahi, J., Pendlebury, D., & Szomszor, M. (2021). *The changing research landscape of the Middle East, North Africa and Turkey*. USA: Institute for Scientific Information (ISI).

Almasi, H. (2012). Investigating status of developing eight (D8) countries macroeconomic indices in line with developing economic cooperation with Iran. *African Journal of Business Management*, *6*(20), 6166–6176. https://doi.org/10.5897/AJBM11.2440

Atlas of Islamic World Science and Innovation. (2014). *Atlas of the Islamic world: Final report*. Retrieved from https://royalsociety.org/-/media/policy/projects/atlas-islamic-world/atlas-final-report.pdf.

Bienkowska, D. (2010). The Triple Helix balancing act—Industrial research institutes as knowledge intermediaries. *Triple Helix VIII International Conference on University, Industry and Government Linkages*, Madrid.

Bond, M., Maram, H., Soliman, A., & Khattab, R. (2012). *Science and innovation in Egypt*. Retrieved from https://royalsociety.org/~/media/policy/projects/atlas-islamic-world/atlas-egypt-report.pdf.

Butler, D. (2019). How US sanctions are crippling science in Iran. *Nature*, *574*(7776), 13–14. https://doi.org/10.1038/d41586-019-02795-y, PubMed: 31576034

Chaturvedi, S., Rahman, M., & Ravi Srinivas, K. (2019). *Leveraging science, technology and innovation for implementing the 2030 agenda*. Retrieved from https://www.g20-insights.org/policy_briefs/leveraging-science-technology-and-innovation-for-implementing-the-2030-agenda/.

Chen, D. H. C., & Dahlman, C. J. (2004). Knowledge and development: A cross-section approach. *World Bank Policy Research Working Paper 3366*. https://doi.org/10.1596/1813-9450-3366

Chowdhury, M. Z. I., & Turin, T. C. (2020). Variable selection strategies and its importance in clinical prediction modelling. *Family Medicine and Community Health*, *8*(1), e000262. https://doi.org/10.1136/fmch-2019-000262, PubMed: 32148735

D-8 Organization. (2012). *D-8 global vision (2012–2030)*. Retrieved from https://developing8.org/image/Otherdocument/7258441.pdf.

D-8 Organization. (2021a). *Concept note on D-8 network of pioneers for research and innovation (D-8NPRI)*. Retrieved from https://developing8.org/wp-content/uploads/2021a/01/Concept-paper-D-8NPRI.pdf.

D-8 Organization. (2021b). *D-8 decennial roadmap for 2020–2030*. Retrieved from https://developing8.org/wp-content/uploads/2021b/04/D-8-Decennial-Roadmap-2020-2030.pdf.

D-8 Organization. (2021c). *D-8 network of pioneers for research and innovation (D-8NPRI)*. Retrieved from https://developing8.org/wp-content/uploads/2021c/01/Concept-paper-D-8NPRI.pdf.

Day, N., & Muhammad, A. (2011). *Malaysia: The atlas of Islamic world science and innovation country case study no. 1*. Retrieved from https://www.sesric.org/imgs/news/atlas-country-case-malaysia.pdf.

El-Akkad, D. (2012). A university professor becomes Egypt's president. *Nature*. https://doi.org/10.1038/nature.2012.10890

Falk, M. (2007). R&D spending in the high-tech sector and economic growth. *Research in Economics*, *61*, 140–147. https://doi.org/10.1016/j.rie.2007.05.002

Hariri, N., & Riahi, A. (2014). Scientific collaboration between Iran and developing countries (D8) and some strategies for its promotion. *Science and Technology Policy Letters*, *4*(2), 73–86. [In Persian]

Hollingsworth, J. R., Müller, K. H., & Hollingsworth, E. J. (2008). The end of the science superpowers. *Nature*, *454*(7203), 412–413. https://doi.org/10.1038/454412a, PubMed: 18650902

Ku Shari, J. (2021). *Statement by the D-8 Secretary-General for 'ISC-D8 Joint Virtual Workshop on ISC E-Services for D-8*

Member States Journals'. Delivered to the Virtual Workshop held on August 31–September 1, 2021.

MASTIC. (2008). *Malaysian science & technology indicators report 2008*. Malaysia: MOSTI. https://mastic.mosti.gov.my/sti-survey-content-spds/malaysia-sti-indicators-report-2008

MASTIC. (2017). *Malaysian science, technology and innovation (STI) indicators report 2016*. Malaysia: MOSTI. https://mastic.mosti.gov.my/sti-survey-content-spds/malaysian-science-technology-innovation-sti-indicators-report-2016

MASTIC. (2021). *Malaysian science, technology and innovation indicators report 2020*. Malaysia: MOSTI. https://mastic.mosti.gov.my/sti-survey-content-spds/malaysian-science-technology-innovation-sti-indicators-report-2020

Moed, H. F. (2016). Iran's scientific dominance and the emergence of South-East Asian countries as scientific collaborators in the Persian Gulf Region. *Scientometrics*, *108*, 305–314. https://doi.org/10.1007/s11192-016-1946-x

Moed, H. F., & Halevi, G. (2014). Tracking scientific development and collaborations: The case of 25 Asian countries. *Research Trends*, *1*(38), Article 8.

OECD. (2012). *Meeting global challenges through better governance: International co-operation in science, technology and innovation*. Paris: OECD Publishing. https://doi.org/10.1787/9789264178700-en

OECD. (2015). *Frascati Manual 2015: Guidelines for collecting and reporting data on research and experimental development, the measurement of scientific, technological and innovation activities*. Paris: OECD Publishing. https://doi.org/10.1787/9789264239012-en

OIC Conference on Science and Technology. (2003). *VISION 1441. Kuala Lumpur declaration on science and technology for socio-economic well-being of the Ummah*. Kuala Lumpur: Academy of Sciences of Malaysia. Retrieved from https://www.oic-oci.org/docdown/?docID=56&refID=11.

Royal Society. (2011). *Knowledge, networks and nations: Global scientific collaboration in the 21st century*. RS Policy document 03/11. London, UK: The Royal Society.

Safahieh, H., & Sharifi Fard, Z. (2020). Comparative study of scientific and technological outputs of the Islamic Republic of Iran and other members of D8 countries. *Science and Technology Policy Letters*, *10*(4), 53–68. [In Persian]

Sawahel, W. (2009). *Iran: 20-year plan for knowledge-based economy*. Retrieved from https://www.universityworldnews.com/post.php?story=20090827175231370.

SESRIC. (2016). *Education and scientific development in OIC countries*. Ankara, Turkey: SESRIC. https://sesricdiag.blob.core.windows.net/sesric-site-blob/files/article/559.pdf

Shelton, R. D., & Foland, P. (2010). *The race for world leadership of science and technology: Status and forecasts*. Retrieved from https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.170.2960&rep=rep1&type=pdf.

Shelton, R. D., & Foland, P. (2017). Model-based forecasts of scientific indicators: China will soon lead the world in scientific publications. *Collnet 2017*, University of Kent, Canterbury, UK.

Shetty, P., Akil, H., Fizzanty, T., & Simamora, G. (2014). *Indonesia: The atlas of Islamic world science and innovation country case study*. Retrieved from https://royalsociety.org/~/media/policy/projects/atlas-islamic-world/2014-09-03-Atlas_Indonesia.pdf.

UNCTAD. (2016). *Science, technology and innovation policy review—Islamic Republic of Iran*. Switzerland: United Nations Publication.

World Economic Forum, Executive Opinion Survey. (2017). *Global competitiveness index 2017–2018*. Retrieved from https://reports.weforum.org/global-competitiveness-index-2017-2018/competitiveness-rankings/#series=EOSQ119.

Wuchty, S., Jones, B. F., & Uzzi, B. (2007). The increasing dominance of teams in production of knowledge. *Science*, *316*(5827), 1036–1039. https://doi.org/10.1126/science.1136099, PubMed: 17431139