Samuel Neaman Institute
For National Policy Research

A Comparative Outlook on the Development of Scientific and Technological Research in Israel and in Other Middle Eastern Countries by Quantitative Indicators

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12 Research Universities and The Higher Education System

Technion - Israel Institute of Technology

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Policy research and surveys are executed at the Samuel Neaman Institute and their conclusions and recommendations serve the decision makers at various levels. The policy research is conducted by the faculty and staff of the Technion and scientists from other institutions in Israel and abroad and specialist from the industry.

The research team is chosen according to their professional qualifications and life achievements. In many cases the research is conducted by cooperation with governmental offices and in some cases at the initiative of the Samuel Neaman institute and without direct participation of governmental offices.

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A COMPARATIVE OUTLOOK ON THE DEVELOPMENT OF SCIENTIFIC AND TECHNOLOGICAL RESEARCH IN ISRAEL AND IN OTHER MIDDLE EASTERN COUNTRIES BY QUANTITATIVE INDICATORS

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Abstract

Thomson Reuters has recently published a study of the many changes that have occurred in the last decade in research activities in the Muslim Middle East, as reflected in its database, ISI. The study reports impressive developments in terms of research policy, investments in research, and research outputs. These processes take place mainly in five countries: Turkey, Iran, Egypt, Saudi Arabia and Jordan. Our study presents a comparative analysis between these countries and Israel. The data presented is based on two main commonly used indicators: the number of publications, which provides an estimate of the research productivity, and the average citations per publication, which provides an estimate of their impact, which in turn reflects the quality of the research. In addition, data are presented relating to the indicators of the most cited publications and researchers, which serve as indicators of the quality and importance of the publications. We also analyzed the number of US patents registered from these countries.

The data presented indicate that the following processes have occurred during recent years:

- Significant and rapid progress of Iran and Turkey in many fields, relative to moderate progress (and sometimes, regression) of Israel in the same fields.
- Progressively smaller gaps between Israel, Iran and Turkey that are expressed initially in the number of publications, and later in the average citations per paper.
- Israel leads in most of the examined fields; however, Iran and Turkey have already surpassed Israel in some areas in the number of publications, and in a few areas even in the average citations of an article.
- Israel is far ahead in the number of patents registered in the USA.

The rapid progress in the Middle East is the result of a number of factors, such as high investments in scientific research, multiple initiatives for the establishment of research centers, collaborations with leading universities in developed countries, and so on. All these lead to narrowing the gap in scientific productivity and quality between Israel and these countries.

The stagnation, and in some fields even decline, in Israel's scientific productivity and quality is the result of sharp cuts in governmental budget allocations to the research universities over the first decade of the 21st Century ("the lost decade"). This led to a decline in the number of faculty members, because the inability of the universities to recruit

young faculty members; an increase in their average age, and a dangerous brain-drain. All these factors have adversely affected scientific productivity and its quality. Since the time constant to achieve research excellence is long, i.e., investments bear fruit only after many years, the full impact of the recent processes are yet to be felt.

*** The authors would like to express their gratitude to Prof. Zehev Tadmor and Prof. Moshe Moshe, for the interest they displayed in this study from the beginning.**

1. The Development of Research in the Middle East

Recently, several studies that review the progress of science, technology and innovation in countries with predominantly Muslim populations, especially in the Middle East, were published. The Royal Society has released a policy paper entitled, *A New Golden Era? - Prospects for Science and Innovation in the Islamic World* [1], which reviewed developments in the 57 countries belonging to the OIC (Organization of Islamic Conference). According to this work, there has been a shift in the scope of investments in R&D and in scientific activities in these countries, to the point of referring to it as a "Renaissance of science and innovation in Islam." The first signs of these trends were already noted in the journal *Nature* in 2006 [2].

In 2005, The OIC adopted, at the initiative of the Organization's general secretary E. Ihsanoglu, a program to promote science, known as "Vision 1441" [3] (the year 1441 according to the Islamic calendar is 2020), one of the goals of which is that, by 2015, 30% of those aged 18-30 will receive a university education; another goal is to invest 1.2% of the GDP in R&D, in comparison with the 0.38% invested at present. The British Royal Society is in the midst of a comprehensive study of science in Islamic countries, which should be completed by 2012. A study recently published by the Royal Society [4] points to the dramatic developments that have occurred in recent years in Turkey and Iran. Huge investments in higher education and in collaborations between academe and industry and in R&D have led to significant progress in the scientific accomplishments of these two countries, comparable in the rate of change to that of China. Another recently published study [5] examined the scientific productivity of the OIC countries in comparison with other countries, using quantitative indicators and data provided by the World Bank and the United Nations. It was found that countries whose economic status has improved show significant progress in scientific productivity, which is growing with time.

In the introduction to the work of Adams et al. from Thomson Reuters [6], which was published recently, Professor Ahmed Zewail (1999 Nobel Laureate in Chemistry of Egyptian origin, who is a faculty member at the California Institute of Technology - Caltech) points out the three components needed to bring scientific progress to Muslim countries:

A. Promotion of human resources by eliminating illiteracy, ensuring the participation of women in society, and improving education.
B. Reform of national constitutions to guarantee freedom of thought, minimize bureaucracy, develop an achievement-oriented system, and develop an enforceable code of laws.
C. Establishment of centers of excellence in science and technology that will bring back to Muslims the confidence that they too can achieve and compete successfully in the globalized world.

The third condition is perhaps the easiest to implement, because it does not require a deep cultural change. To start the process, all that is needed is financial resources and to bring top scientists from developed countries. Indeed, in this area, widespread activity is occurring in several countries in the Middle East. Saudi Arabia is building a technological scientific university named after King Abdullah (King Abdulla University of Science and Technology - KAUST), to which a fund of $20 billion was awarded for recruiting 250 scientists and 2000 graduate students (male and female), by 2020. The university ensures its researchers' academic freedom, and its faculty will include leading scientists from Western countries. In the Education City in Qatar, which spreads over 10,000 hectares, seven U.S. university extensions are being established (including Carnegie Mellon and Texas A&M). In the Science and Technology Park, which was built nearby, companies such as Shell and Rolls Royce operate. Nearby, the Sidra Medical and Research Center will be built by 2012, with an investment of $8 billion. Abu Dhabi is focusing on the “Masdar Initiative”, which will in due course encompass about 1500 businesses and 50,000 employees, focusing on renewable energy. Six universities are in partnership with the Masdar research network, including MIT, Imperial College and Columbia University.

2. Evaluating Research by Quantitative Indicators

As a result of improvements that took place over the last decades in the databases and in bibliometric methods, the use of quantitative metrics to measure scientific output and quality became common practice. These metrics allow simple, well-defined measurements of scientific output and research impact of an individual scientist, a university or a country. These measurements provide objective information, and are accepted by a large number of scholars and influence policy makers. They are used for such important and diverse goals as rating, budgeting, and funding of academic institutions.

In the present study, as well as in other earlier studies [6-8], quantitative metrics were used to evaluate the development of research and the scientific-technological level of countries. The main indicators used for this purpose are based on number of publications and average citations of the publications. The importance of these indicators stems from their ability to measure, over time, the productivity and impact of the scientific enterprise in a country. Moreover, it is argued that there is a correlation between the number of citations and peer review and other indicators measuring scientific excellence. The two main indicators used in the present study are:

- Number of publications which provides an estimate of the research output or productivity.
- The average citations per publication, indicating the number of times a certain publication was cited by other papers during a given period.

Together, these two indicators provide a good measure of the scientific enterprise of a country. Figures that describe the most cited publications and most cited researchers are displayed later. These indicators have a special significance, because unlike the former indicators, they reflect excellence in scientific accomplishments, which set the upper standards for scientists and universities. Additional measures can be used, such as the H index of the country (indicating the number of publications that have at least H citations).

Despite all the above, it should be recognized that the citation indicators cannot provide a full and complete picture on the quality of research of a country. A study conducted recently at the Samuel Neaman Institute [7] presented the limitations and shortcomings of these measures, because there are biases in these indicators and many scientific subjects are too complex to be evaluated in such basic terms. For example, scientific fields and subfields in the data base are defined by the formal definition of the scope of the selected journals in which they are published. As a result, some papers belonging to a certain field that are published in a journal classified as belonging to a different field, will be associated with that other field. In addition, in certain fields, the innovative papers are published mainly at conferences, which are not necessarily included in the database. Not all areas of research are covered in journals. Furthermore, there are significant differences between the various fields in terms of citation practices, the numbers of citations, and the size of the scientific community. The well-known databases cover the fields of science and medicine better than those of the social sciences and humanities, where books constitute a considerable part of the publications. In addition, better coverage is given to basic fields than to applied fields, such as engineering. Differences in citation practices that exist even between the sub-fields of the major disciplines may lead to bias and distortions. There are various methodological flaws related to citations, expressed, for example, in ignoring self-citations, not setting a reasonable minimum for the number of papers in a country, and including inappropriate platforms and editors' articles. In addition, it is argued that most authors do not cite most of the sources that influenced them, and certainly not all the sources. There are biases in citations in that credit is often given not to the originator of an idea but to its users or to a review paper on the subject. There is no distinction between different types of citation (positive or negative), and no consideration of informal influences that are not cited.

In conclusion, however, it is important to reiterate that, despite the known faults and failings, using the indicators of number of papers and citations have many advantages. They constitute a major tool for measuring scientific productivity and quality and for evaluating research development and the scientific-technological level of countries.

3. The Research Status of Middle Eastern Countries

The study by Thomson Reuters mentioned above [6] analyses the many changes that are taking place in the last decade in research activities in the Muslim countries in the Middle East, as reflected in their database the ISI Web of Knowledge [9], which is the largest of its kind. The report based on the study is part of a series of publications on the changes occurring in different geographic regions worldwide. The fourteen countries that were included in the study are Turkey, Iran, Egypt, Saudi Arabia, Jordan, Syria, Iraq, Lebanon, Oman, Qatar, Bahrain, Kuwait, Yemen and United Arab Emirates. The report presents the development of scientific productivity and scientific quality in the years 2000-2009. Scientific productivity was assessed based on the annual numbers of scientific publications, and the scientific quality was assessed based on the average number of citations per paper.

The report [6] highlights the impressive developments in terms of research policy, investments in research, and research outputs in the countries analyzed. According to this report, the total research output in the fourteen countries it addresses grew from 760,000 to more than 1.16 million publications during the past decade (2000-2009), which reflects a growth from 2% to 4% of total global output. Although the scientific output of all the 14 countries together has grown faster than that of any other region, the rate is not the same in all the countries. The process occurs mainly in five countries, including (in this order) Turkey, Iran, Egypt, Saudi Arabia, and Jordan, in which the countries' scientific output (number of publications) constitutes 90% of the output of all fourteen. Of these, Turkey produces about half of the output of the countries in the region, with the largest output being in medicine. The output of Turkey has increased from 5000 articles in 2000 to 22000 articles in 2009, with a sharp increase identified since 2004. Turkey's share in global output grew from 0.7% in 2000 to 1.9% in 2009. Iran produces one quarter of the output of the states in the region. Iran's output has grown from 1300 articles in 2000 to 15000 articles in 2009, with a sharp increase identified since 2004. Iran's share in the global output grew impressively – from less than 0.2% in 2000 to 1.3% in 2009. Egypt produces less than an eighth of the output, Saudi Arabia about half that of Egypt, and Jordan less than half that of Saudi Arabia. The growth in output in these countries occurs at a similar rate.

The increase in the scientific output is not immediately expressed by the scientific quality and the impact that the scientific publications have, as measured by the average number of citations per publication. However, this aspect also has improved significantly in the five leading countries. The main areas in which the figures exceed the global average are mathematics (especially applied mathematics, in Egypt and Saudi Arabia) and engineering (in Turkey). According to the report [6], all five countries focus, more or less in the following order, on the fields of engineering, agricultural science, chemistry, pharmacology, materials science, and mathematics. In addition, Egypt and Iran focus on the physical sciences, and Saudi Arabia and Turkey on medicine. When considering the 1% of the most cited papers in a given year and field, it seems that the fields in which each of the five countries excels are mathematics and engineering. The average citations per publication in mathematics, mainly applied mathematics, in Egypt and Saudi Arabia exceed the world average, and the same holds true for engineering in Turkey. Finally, it should be noted that there is a high degree of collaboration between researchers in these countries and those in developed countries, mainly the United States. Moreover, in several countries, some of the most senior researchers come from developed countries.

4. Qualitative Aspects in Comparison with Israel

Recent comprehensive studies conducted at the Neaman Institute [7, 8] examined the research status of Israel in comparison with developed countries. One study [7] analyzed the entire scientific activity over the last 12 years, based on the two best-known databases, ISI Web of Science [9] of Thomson Reuters Corporation, and Scopus [10] of Elsevier. The data, according to the two databases, indicate that Israel holds very respectable positions among the top countries in many areas and according to different measures. In these areas, Israel is among the top 10 countries in the world according to average citations per publication, and among the top 20 countries in the world according to number of citations, which is also affected by the volume of the activity. The comprehensive study [8] examined the changes in the status of Israel's research over the years and indicated that there was a decline in some areas. In conclusion, it was found that, despite Israel's respected position among the developed countries, over the past decade there has been stagnation, and even regression in some areas [7, 8].

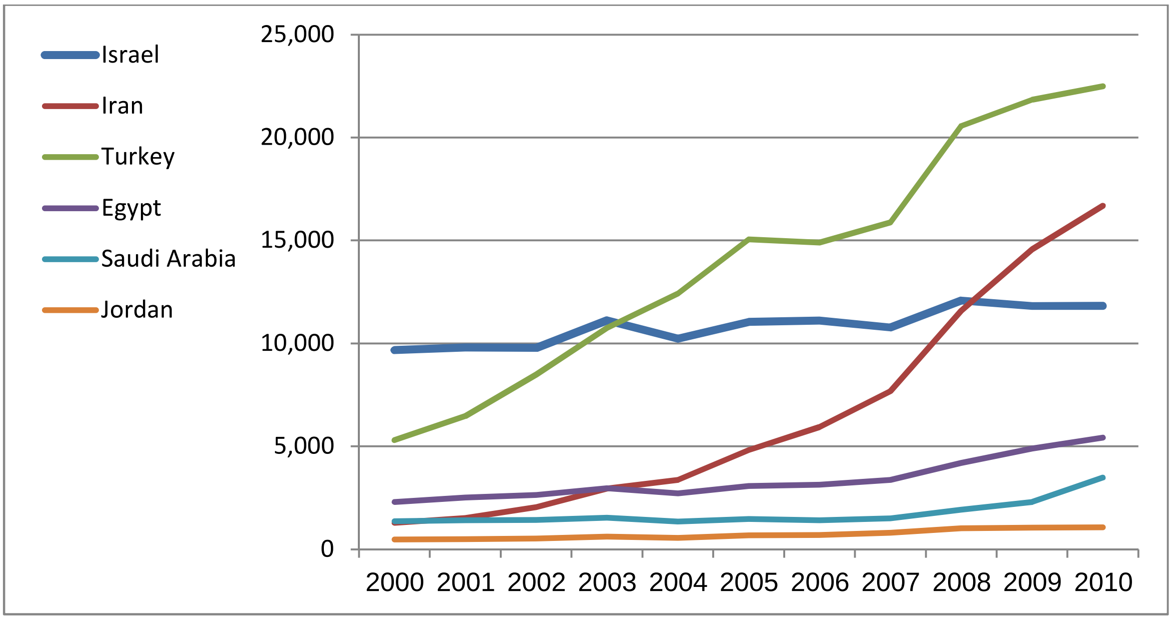
The current chapter presents a comparison between Israel and Iran, Turkey, Egypt, Saudi Arabia, and Jordan, which are the most scientifically productive countries among the 14. Also, data relating to most cited publications and researchers is presented.

The data presented are based on the best-known databases of Thomson Reuters Corporation [9, 11, 12, 13, and 14][1].

Figure 1 shows the number of scientific publications per year in all fields combined in the years 2000-2010, for Israel and Iran, Turkey, Egypt, Saudi Arabia, and Jordan. The Figure shows that the number of publications per year in Israel remains almost unchanged during this period, while it increases significantly in Iran and Turkey, and more moderately in Egypt, Saudi Arabia and Jordan.

[1] The data were retrieved using software developed by Prof. Gideon Czapski, "International Science Indicators".

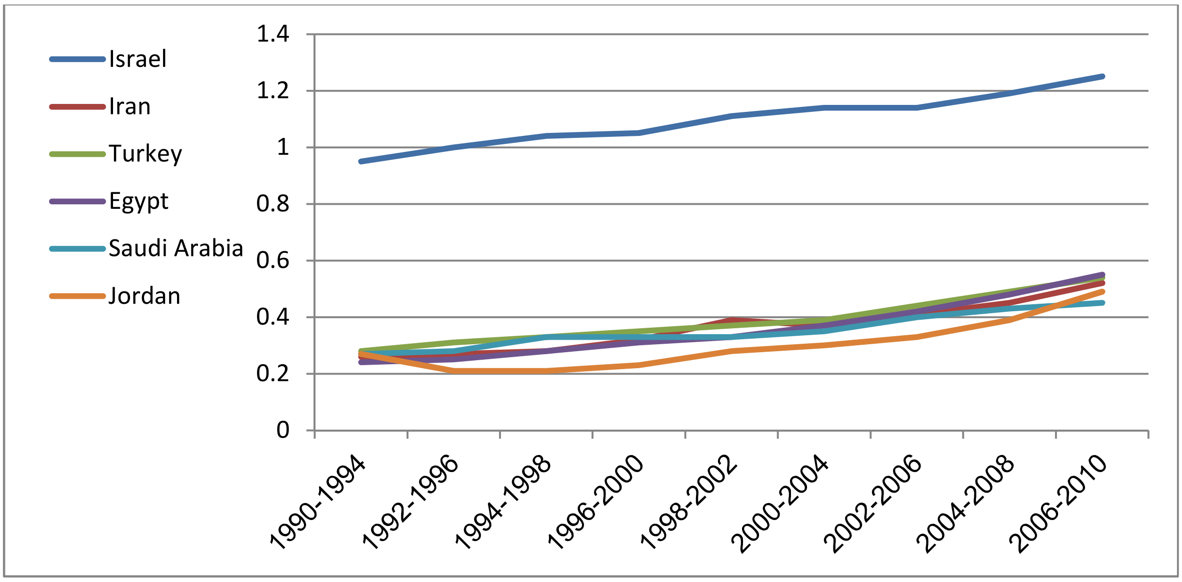
Figure 1. Number of scientific publications per year in all areas, for each of the years 2000-2010, in Israel and in the five most scientifically productive countries in the Middle East.



Source: processed from the data of Thomson Reuters [6, 9]

Figure 2 shows the citations per publication in all fields combined, normalized to the global average (divided by it), for successive periods of five years during the twenty years from 1990 to 2010. Each period reflects articles published during this period and the average citations per publication. According to this indicator, the gap in quality between Israel and other countries remains approximately constant; however, it seems that the picture changes in individual fields of activity.

Figure 2. Average citations per publication in all fields, normalized to the global average.



Source: processed from the data of Thomson Reuters [6, 11, 13]

An examination of the North African countries (Algeria, Morocco and Tunisia) reveals a similar relative increase in the number of publications in recent years, although the number of publications in these countries is still relatively small. Likewise, no significant increase is seen in the average citations per publication in these three North African countries, in contrast to the significant increase that occurred in the Middle East, which is described in Figure 2.

In order to understand the processes that occurred over time and in order to obtain the best possible comparative general view, data are presented below for Israel and for other most scientifically productive countries in the Middle East, which, as mentioned above, are: Iran, Turkey, Egypt, Saudi Arabia, and Jordan in specific scientific fields. The data are for successive periods of five years during the twenty years from 1990 to 2010; each period presents the numbers of publications during this period and the averages citations per publication, normalized to the global average. Figures 3-5 present data for the major areas of *mathematics*, *computer science* and *engineering*. The main field of engineering is a very wide one, including many sub-fields with significant variations in citation practices; therefore, several subfields of engineering should be considered. Figures

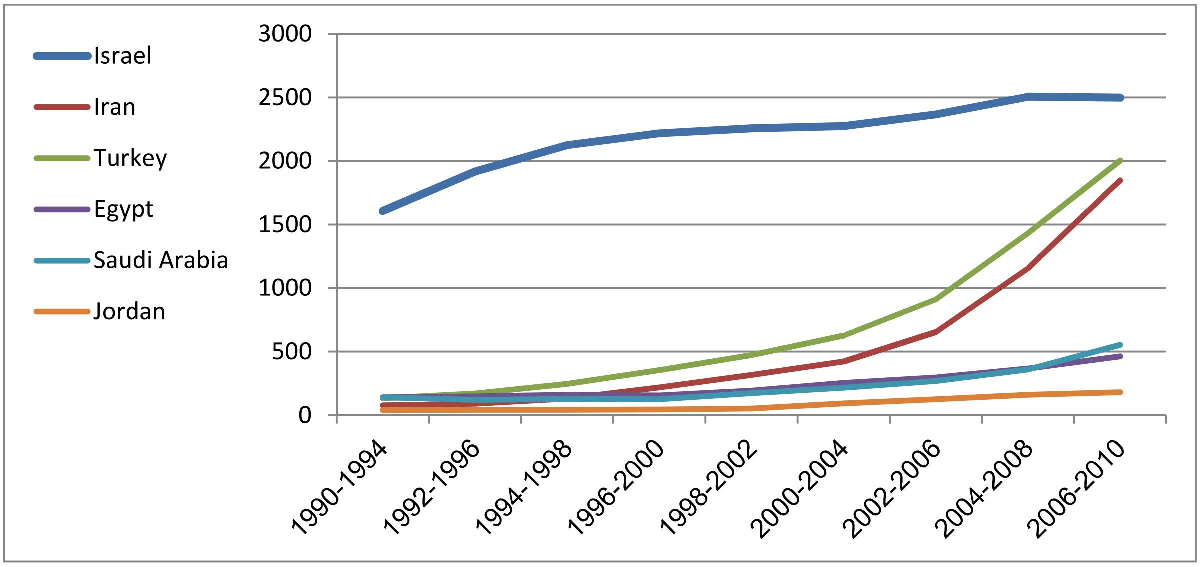
6-10 present the data for five major sub-areas in the field of engineering: *software engineering, biomedical engineering, electrical and electronic engineering, mechanical engineering* and *chemical engineering*. The data presented in Figures 11-20 apply to the main fields of science: *physics, chemistry, materials science, biology and biochemistry, molecular biology and genetics, clinical medicine, earth sciences, pharmacology and toxicology, space science* and *neuroscience.*

It should be noted that there are fields where the number of publications in a particular country is very small, but at the same time, the average citations per publication is relatively high due to the significant contribution of outstanding individual researchers. Such data do not reflect, of course, the scientific quality of the country, so it is customary to set a lower limit for the number of articles, to prevent possible distortions in such cases. For this reason, some of the countries were dropped from the Figures of average citations per publication.

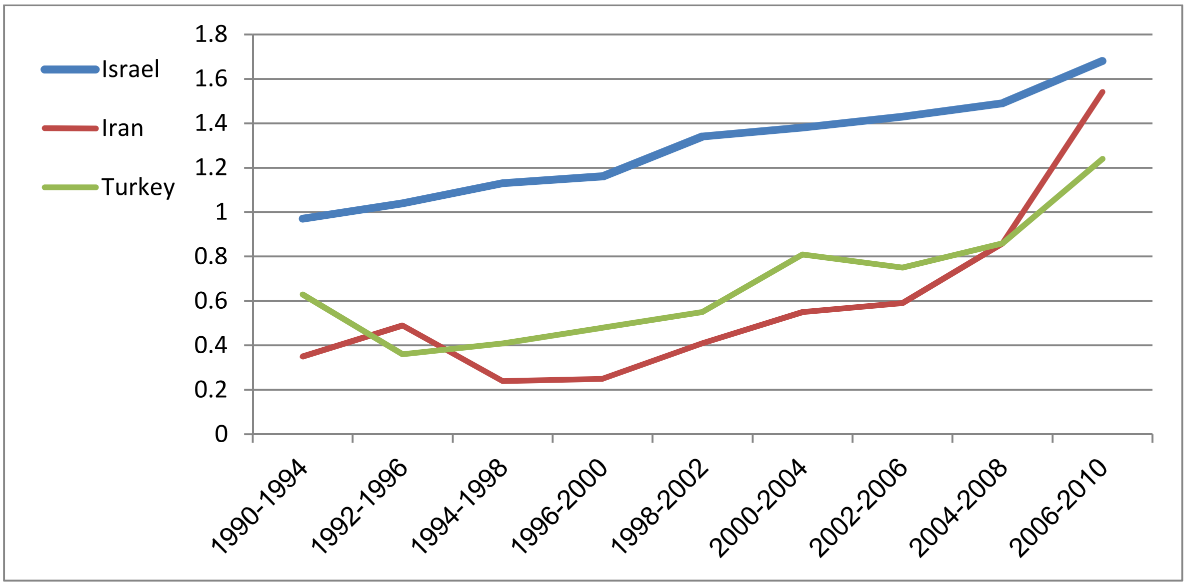
Figure 3 describes the field of mathematics. Thomson Reuters' database [11, 13] defines mathematics as a field that includes also the sub-field of applied mathematics. Due to the nature of the work and the number of those who are involved in the field of mathematics, even an excellent article has a relatively small number of citations. However, this is not the case in the domain of applied mathematics. Therefore, presenting citations of papers on mathematics together with applied mathematics does not properly represent excellence in mathematics per se.

Figure 3. The field of mathematics (mainly applied mathematics)

Number of publications



Average citations per publication, normalized to the global average

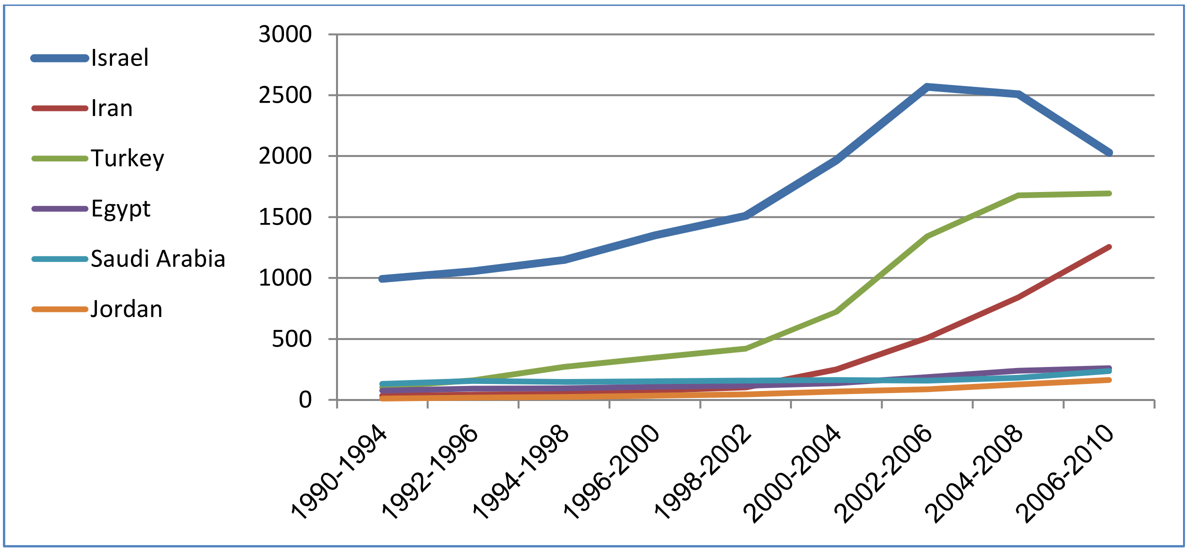


Source: processed from the data of Thomson Reuters [11, 13]

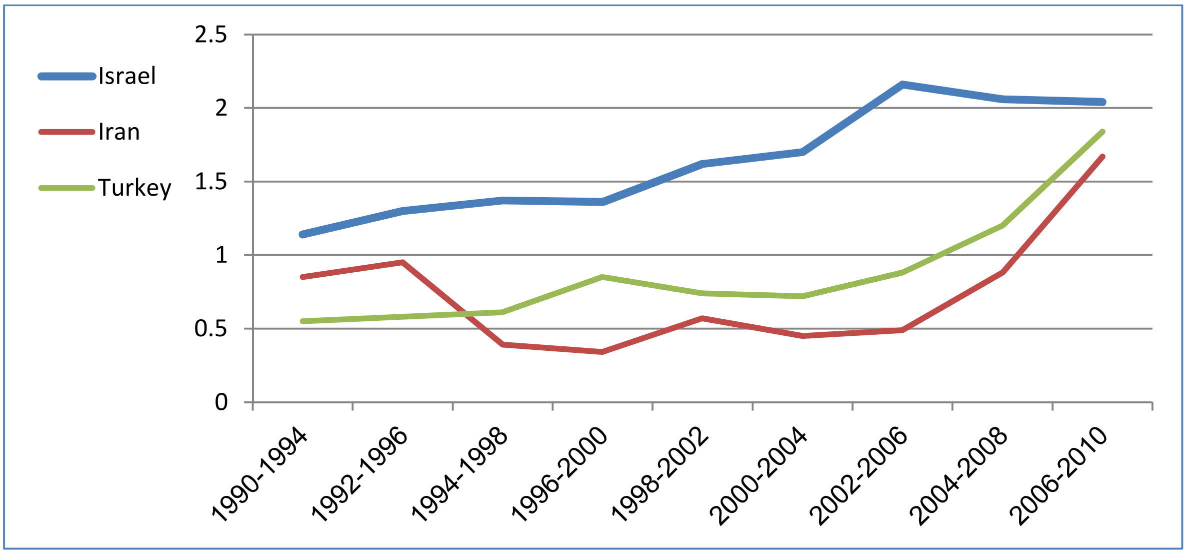
Figure 4 illustrates the field of computer science. It should be noted that the ISI database is not quite suitable for measuring excellence in this field, because most of the outstanding articles in computer science are given at leading conferences. The percentage of articles accepted for publication, of the total articles submitted to these conferences, is relatively low. The database that reflects well the articles of the leading conferences in computer science is CiteSeerx, but unfortunately this database is not sophisticated enough to analyze differences between countries as is done in the Thomson Reuters database.

Figure 4. The computer science field

Number of publications



Average citations per publication, normalized to the global average

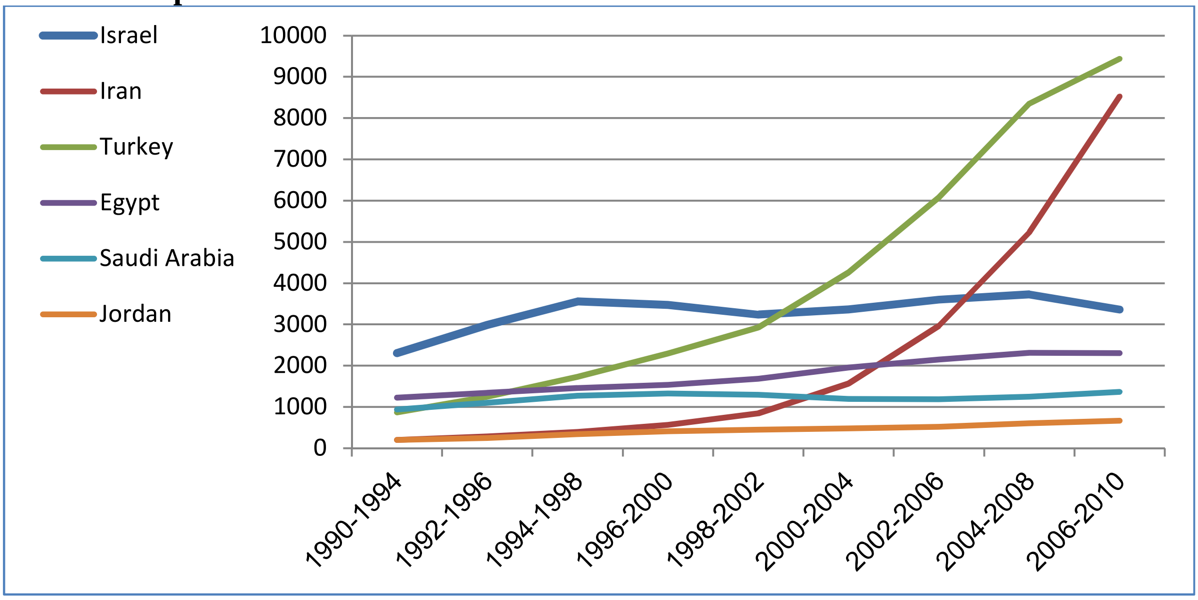


Source: processed from the data of Thomson Reuters [11, 13]

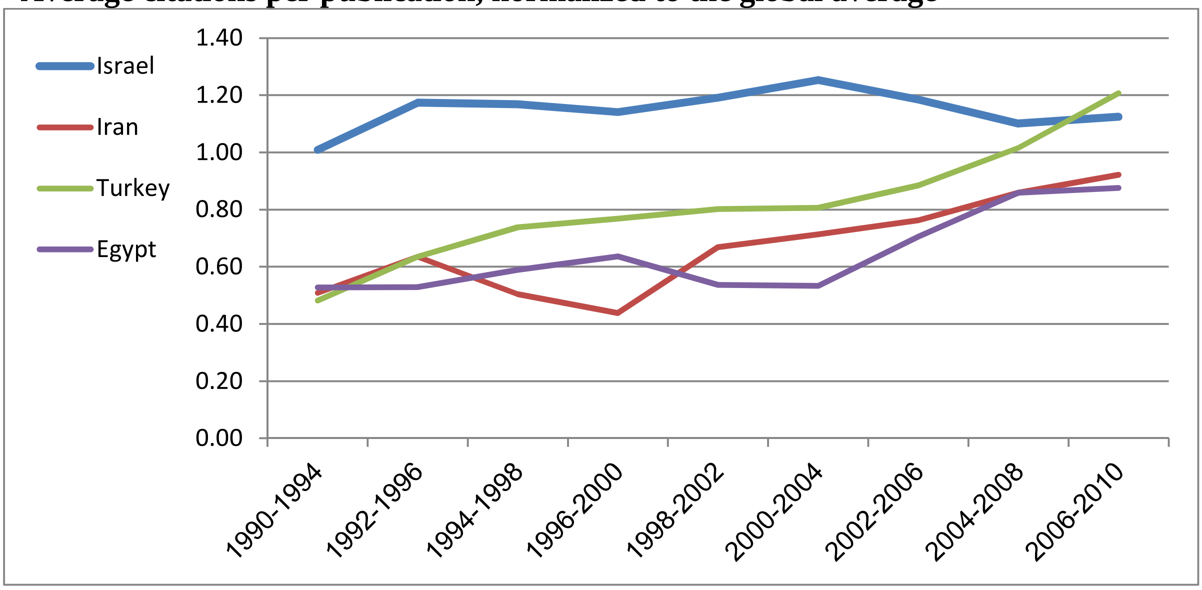
Figure 5 describes the field of engineering. As stated above, because it is a very wide field with many sub-fields, Figures 6-10 present the data for five major sub-fields of the main field of engineering. Of these, Israel's average citations per publication is the highest in four sub-fields: software engineering, biomedical engineering, electrical and electronic engineering, and mechanical engineering. In chemical engineering, however, Turkey's average number of citations per publication exceeds that of Israel. Also, Turkey and Iran's number of publications is particularly high in this subfield, compared to Israel and compared to other subfields of research. One reason for this is that Israel almost does not deal with classical chemical engineering but with other fields, such as nanotechnology, biotechnology, biochemistry, etc. These phenomena affect the entire field of engineering. As a result of the vast variance between the sub-fields, extensive activity in sub-fields with high average citations per publication, e.g., biomedical engineering, causes an increase in the status of the entire engineering field. In contrast, extensive activity in sub-fields with a lower average citations per publication, e.g., industrial engineering and manufacturing, will reverse the effect, even if the country's international status in this area is high.

Figure 5. The field of engineering

Number of publications



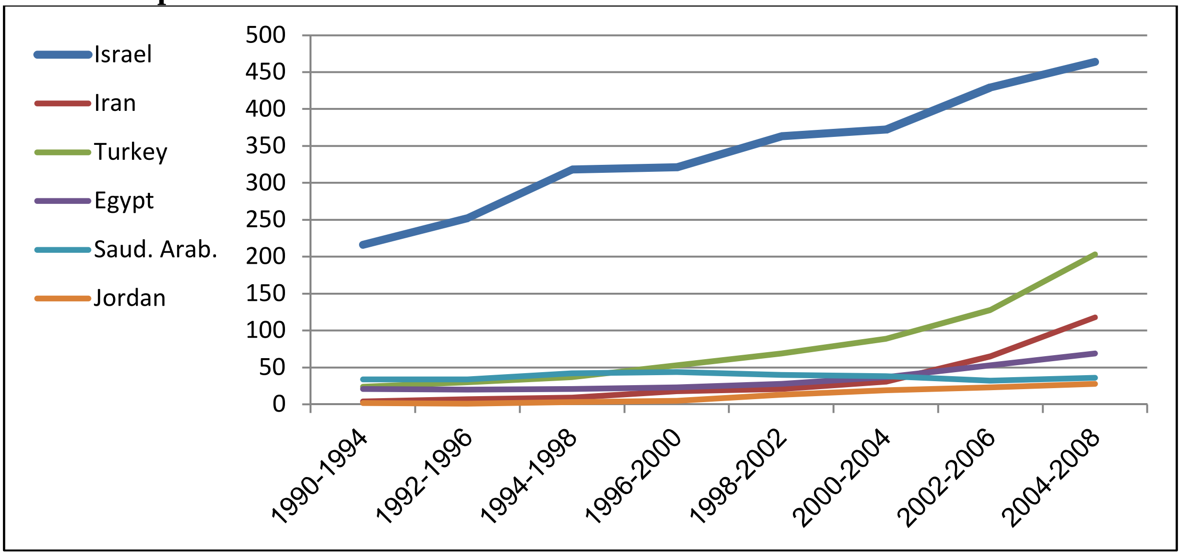
Average citations per publication, normalized to the global average



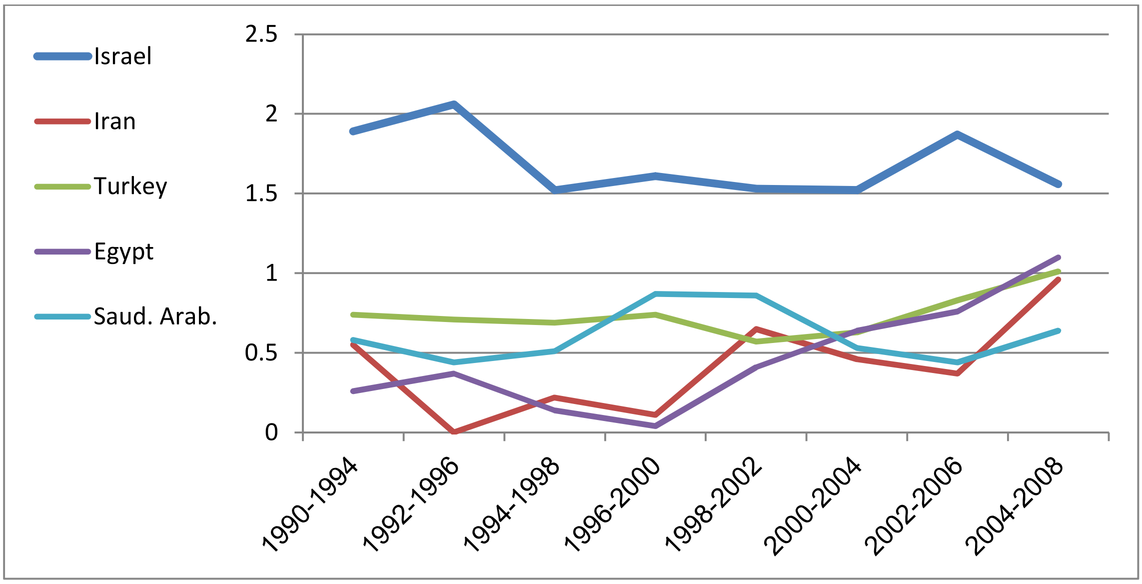
Source: processed from the data of Thomson Reuters [11, 13]

Figure 6. Sub-field – software engineering

Number of publications



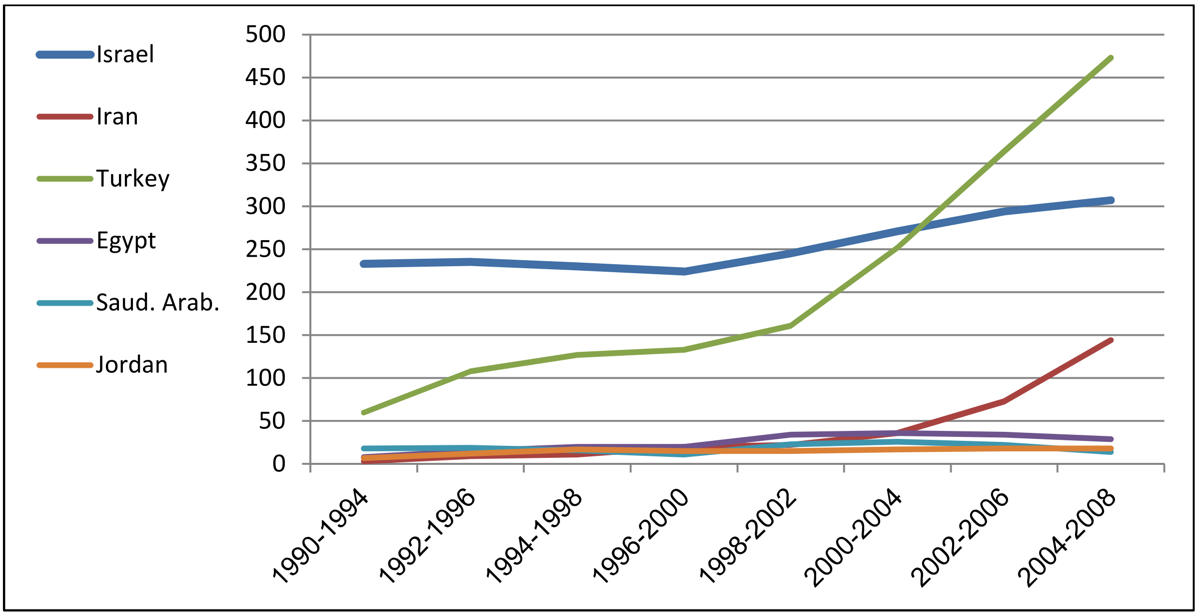
Average citations per publication, normalized relative to the global average



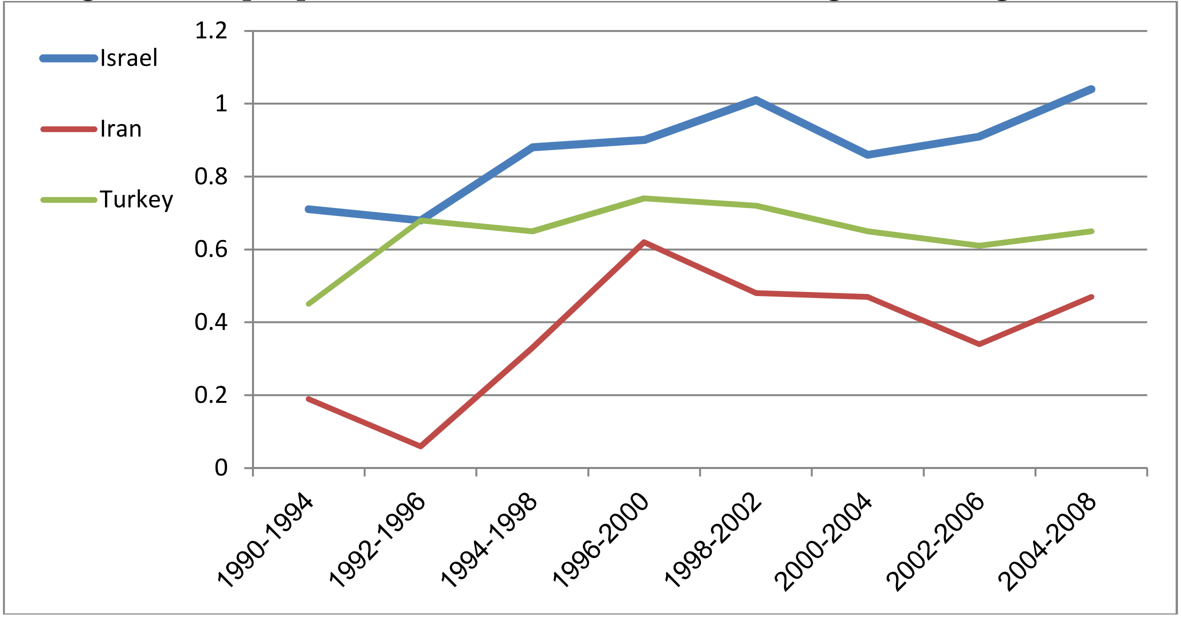
Source: processed from the data of Thomson Reuters [12]

Figure 7. Sub-field – bio-medical engineering

Number of publications



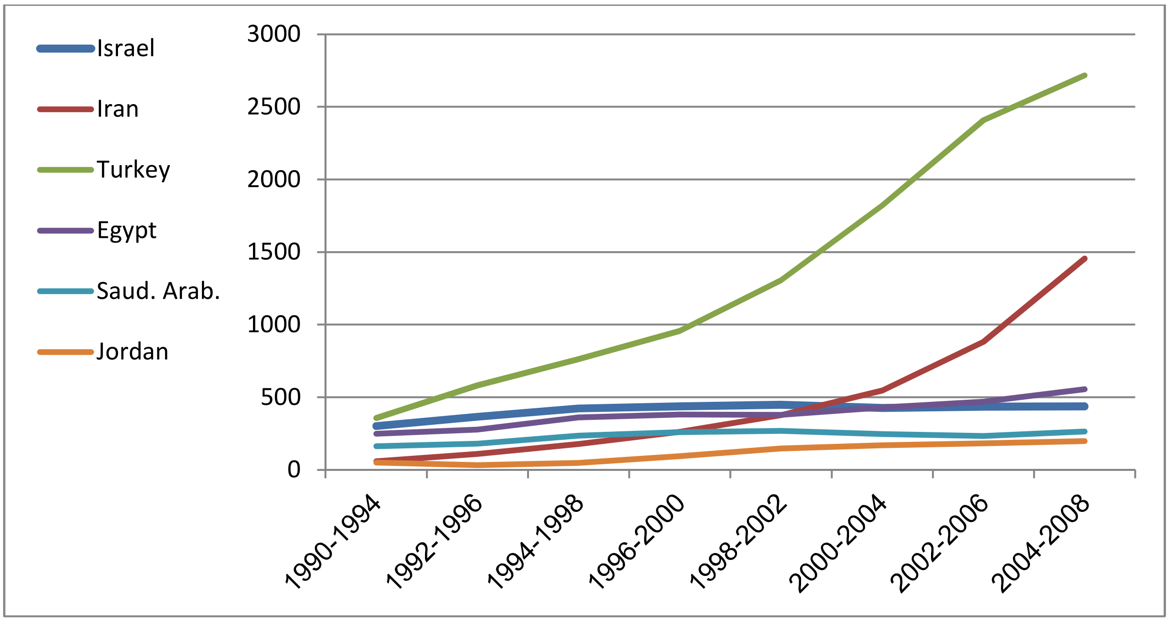
Average citations per publication, normalized relative to the global average



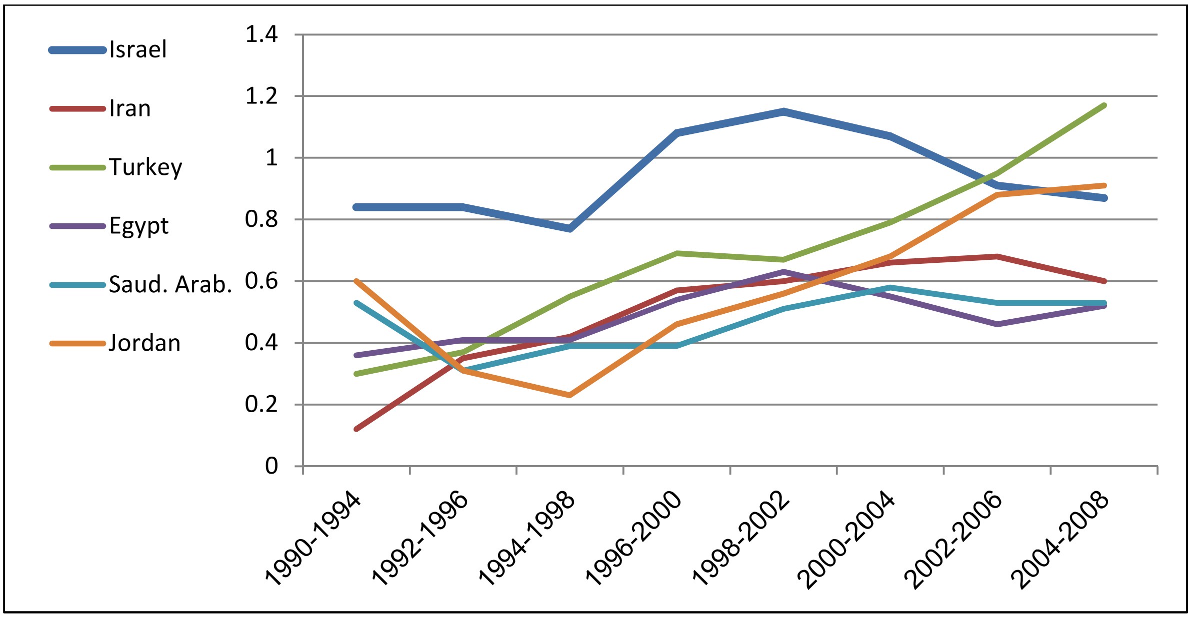
Source: processed from the data of Thomson Reuters [12]

Figure 8. Sub-field – chemical engineering

Number of publications



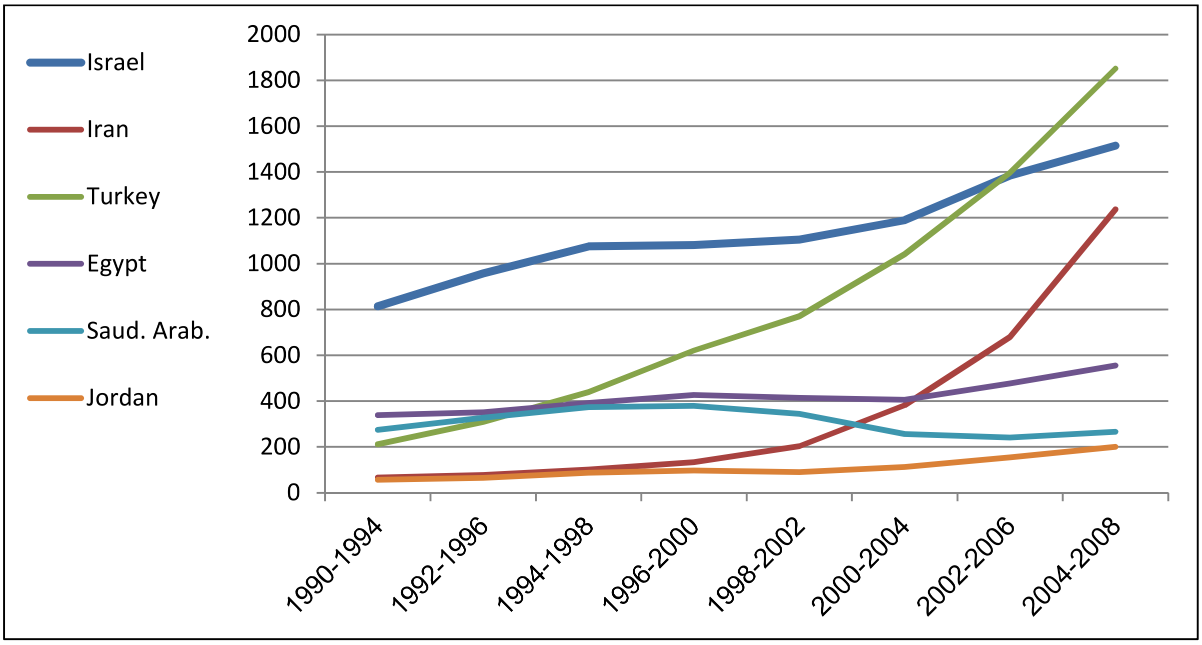
Average citations per publication, normalized to the global average



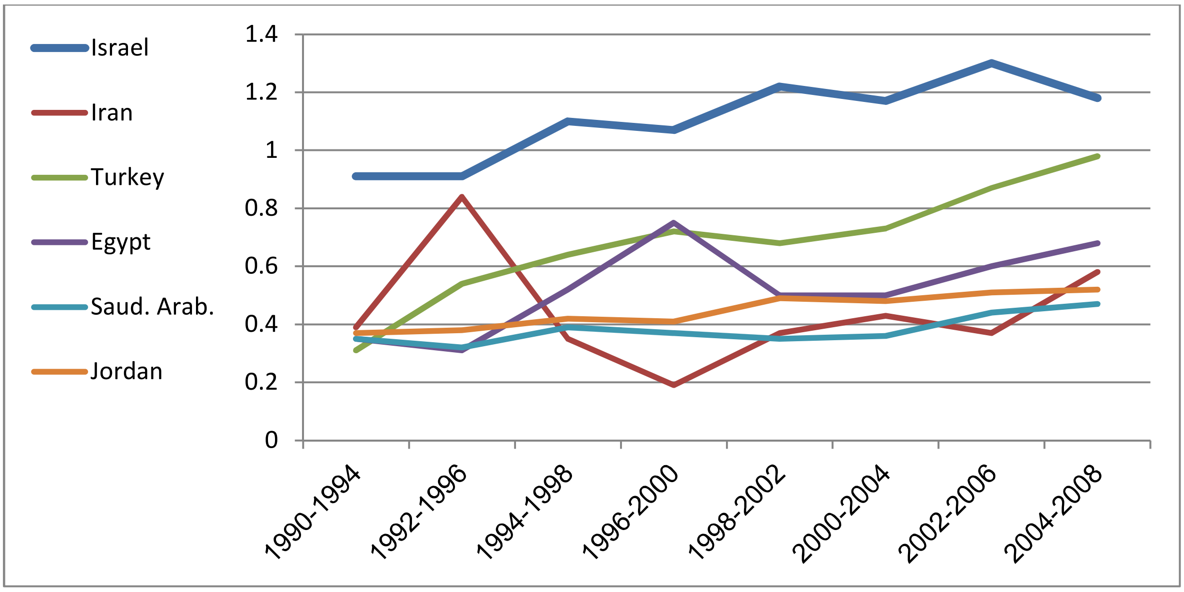
Source: processed from the data of Thomson Reuters [12]

Figure 9. Sub-field – electrical and electronic engineering

Number of publications



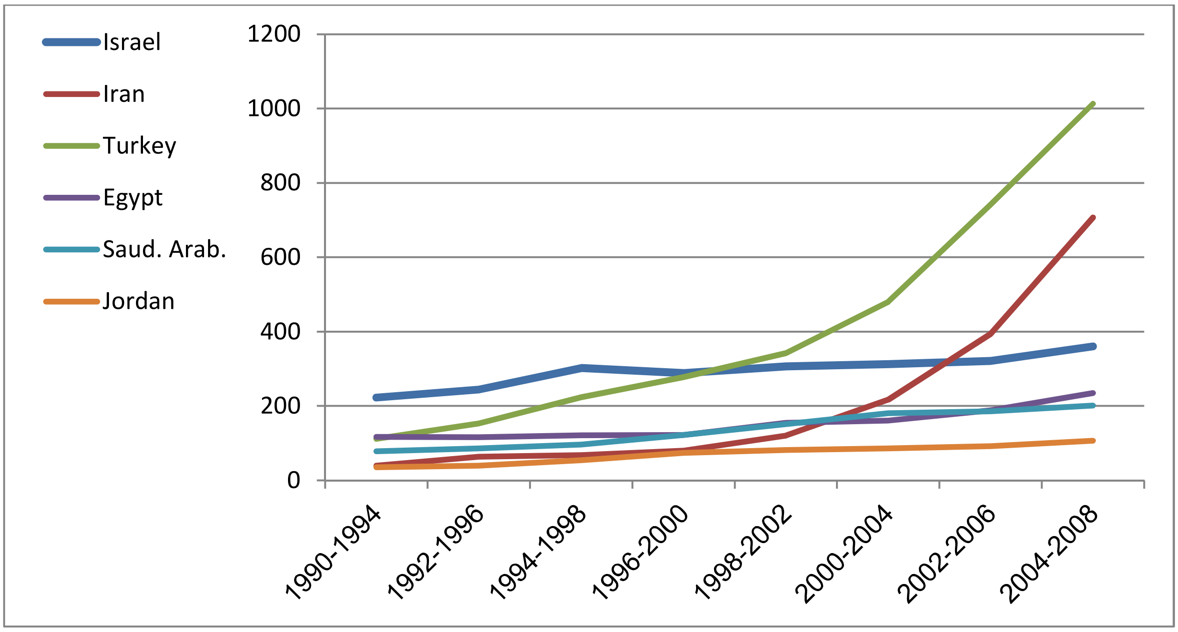
Average citations per publication, normalized to the global average



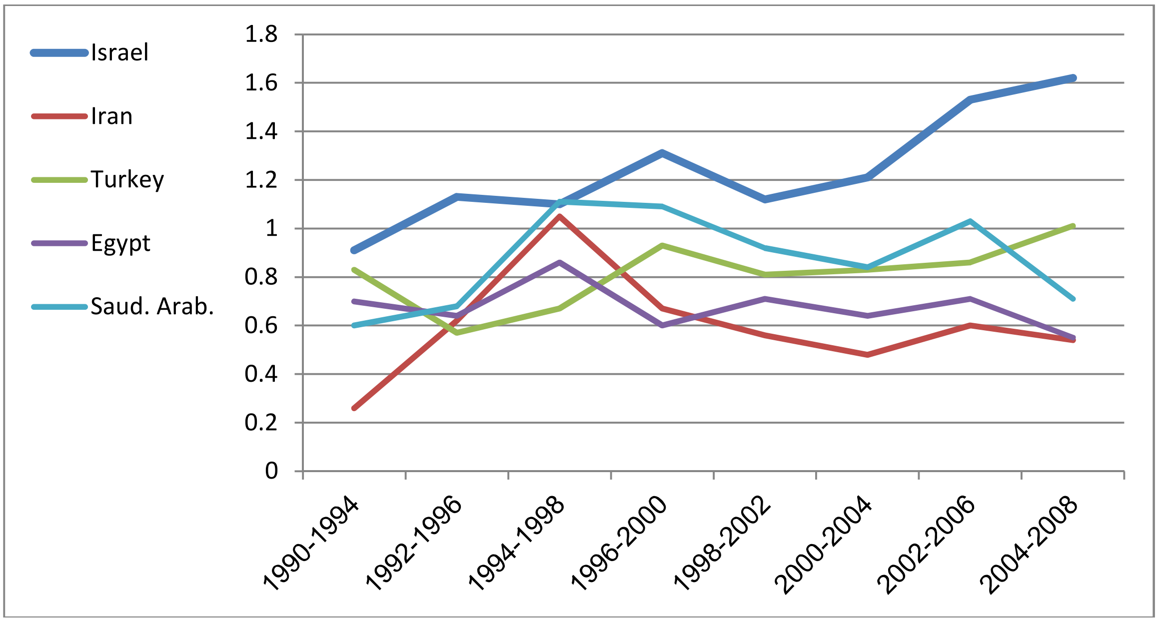
Source: processed from the data of Thomson Reuters [12]

Figure 10. Sub-field – mechanical engineering

Number of publications



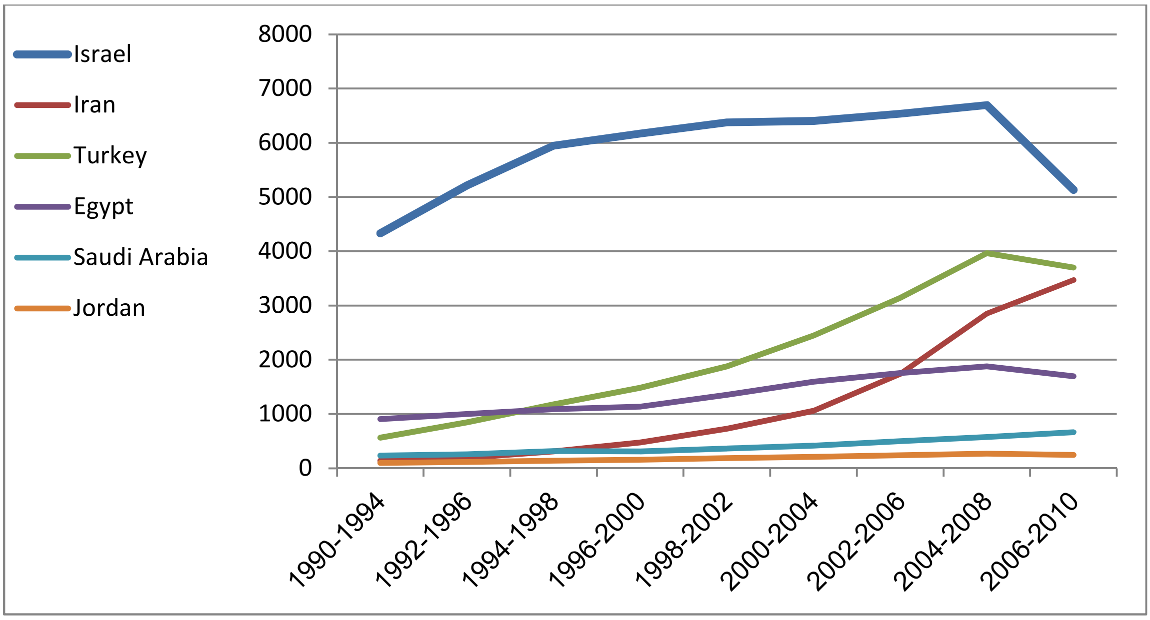
Average citations per publication, normalized to the global average



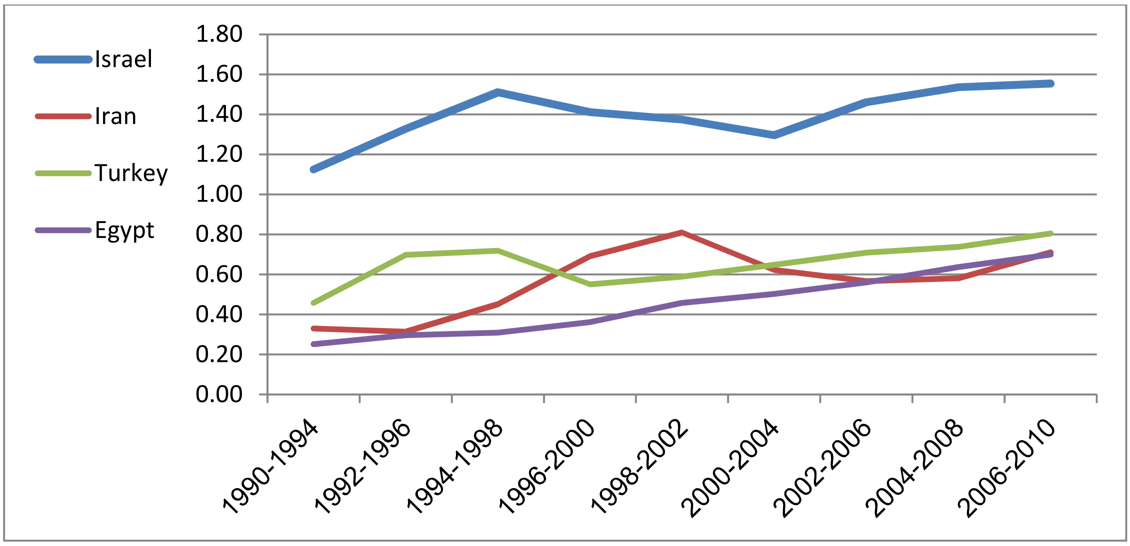
Source: processed from the data of Thomson Reuters [12]

Figure 11. Physics

Number of publications



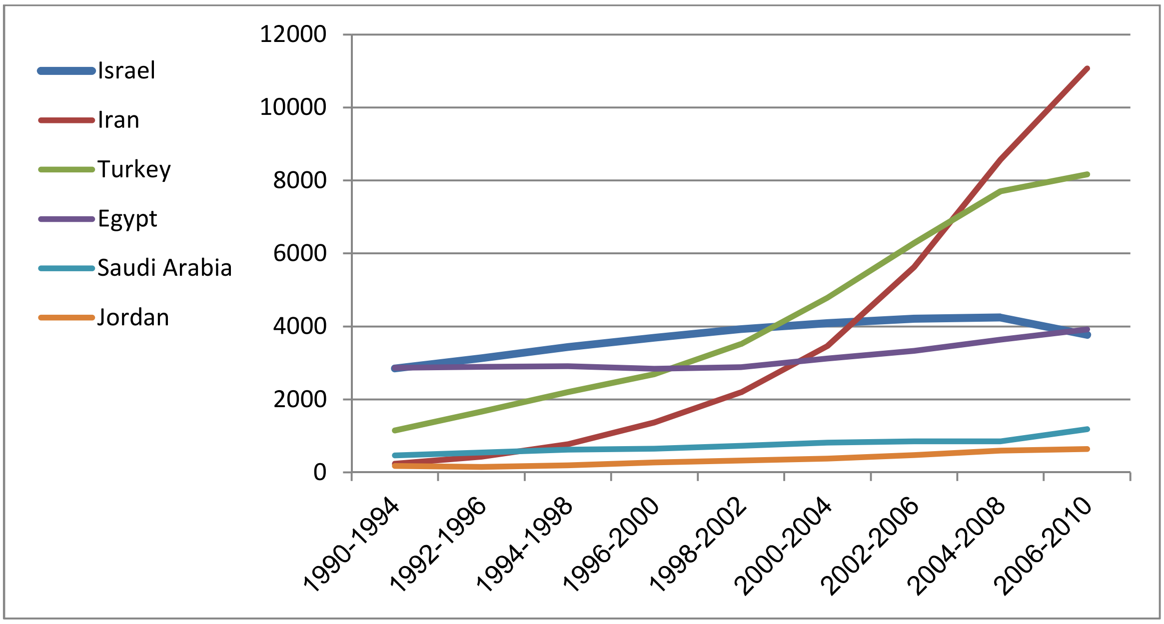
Average citations per publication, normalized to the global average



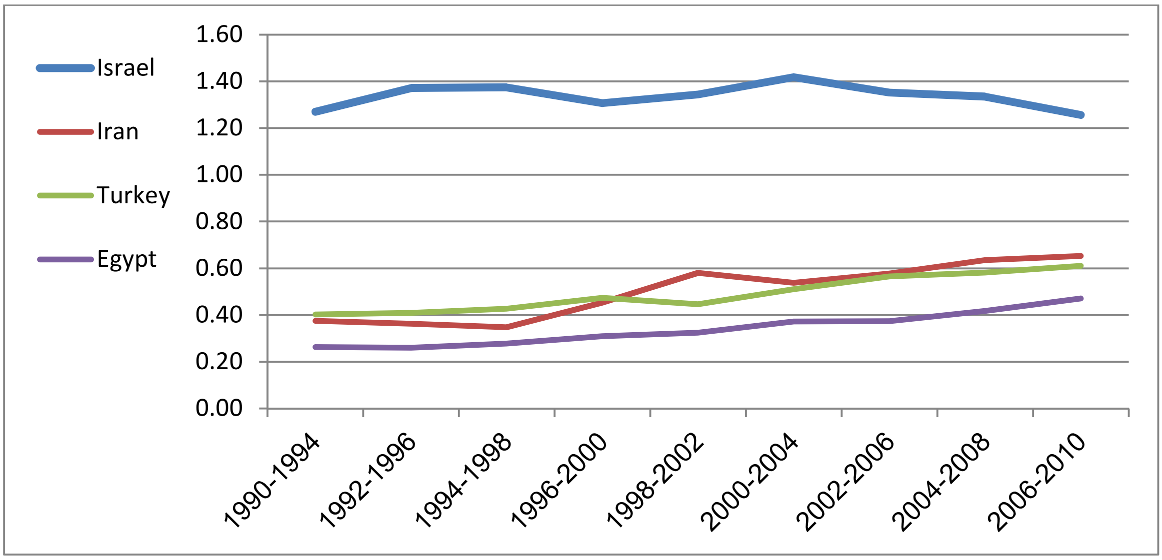
Source: processed from the data of Thomson Reuters [11, 13]

Figure 12. Chemistry

Number of publications



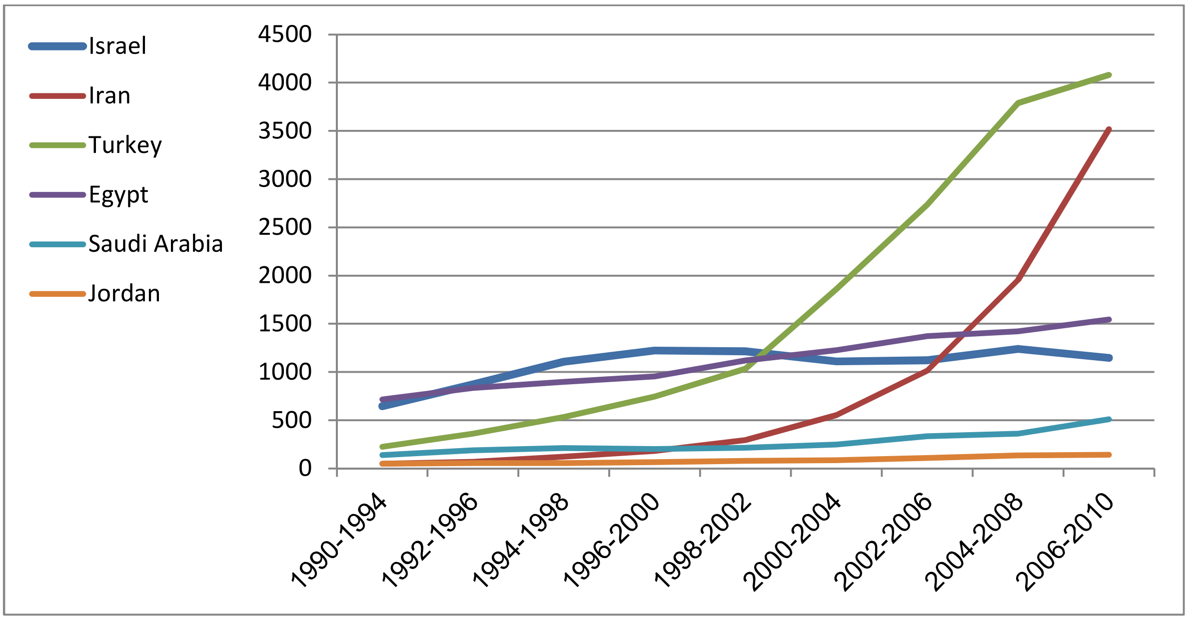
Average citations per publication, normalized to the global average



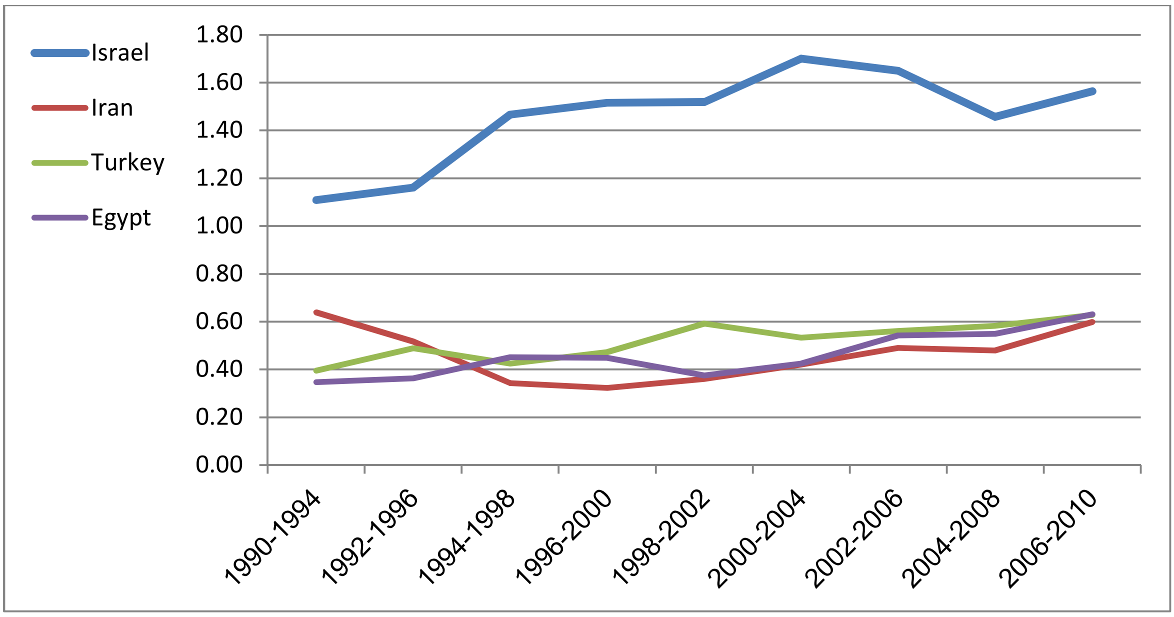
Source: processed from the data of Thomson Reuters [11, 13]

Figure 13. Materials science

Number of publications



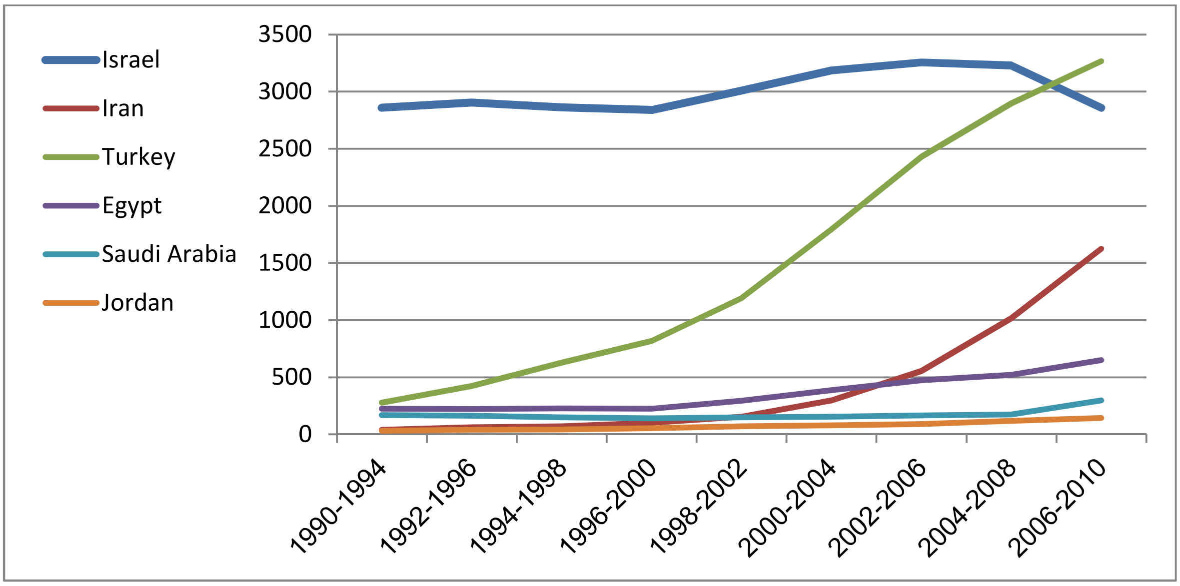
Average citations per publication, normalized to the global average



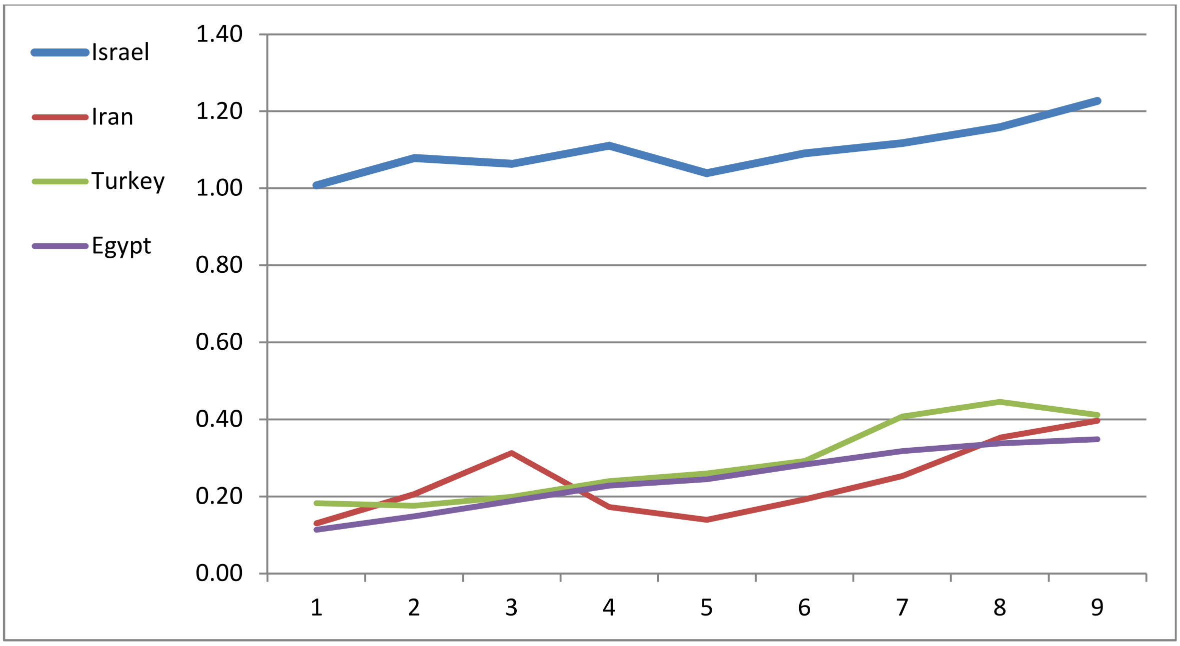
Source: processed from the data of Thomson Reuters [11, 13]

Figure 14. Biology and Biochemistry

Number of publications



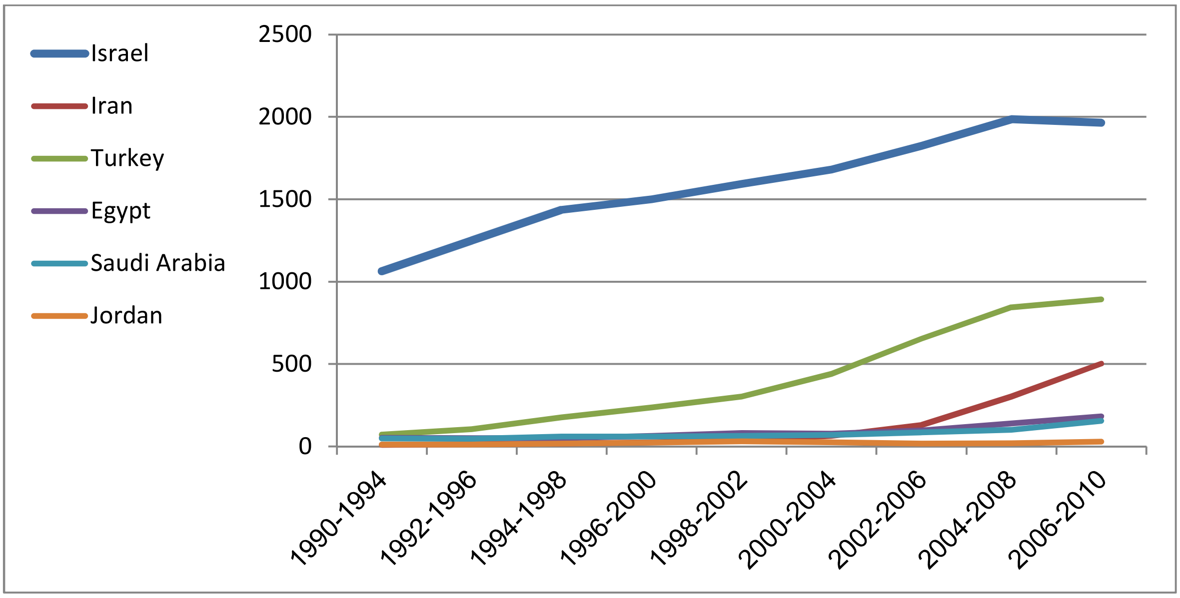
Average citations per publication, normalized relative to the global average



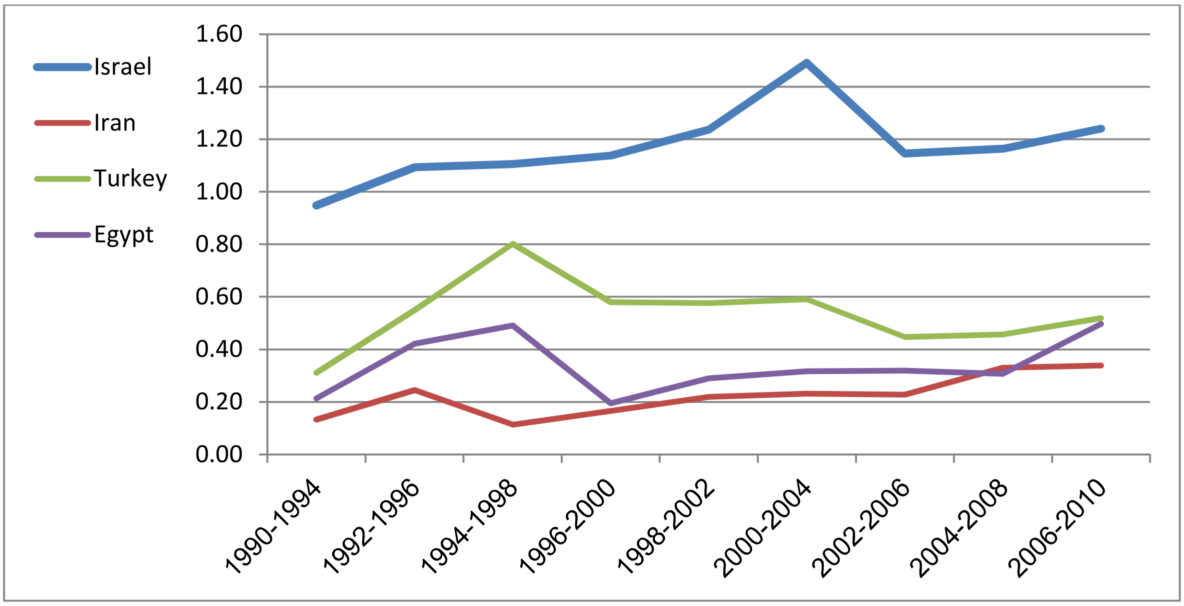
Source: processed from the data of Thomson Reuters [11, 13]

Figure 15. Molecular biology and genetics

Number of publications



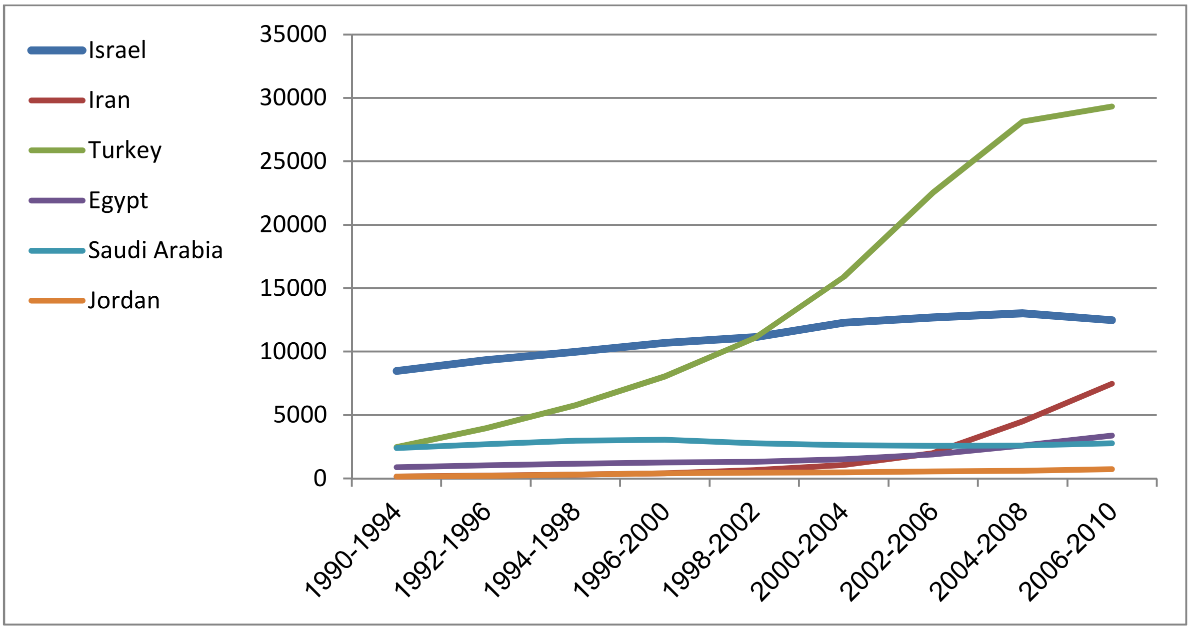
Average citations per publication, normalized to the global average



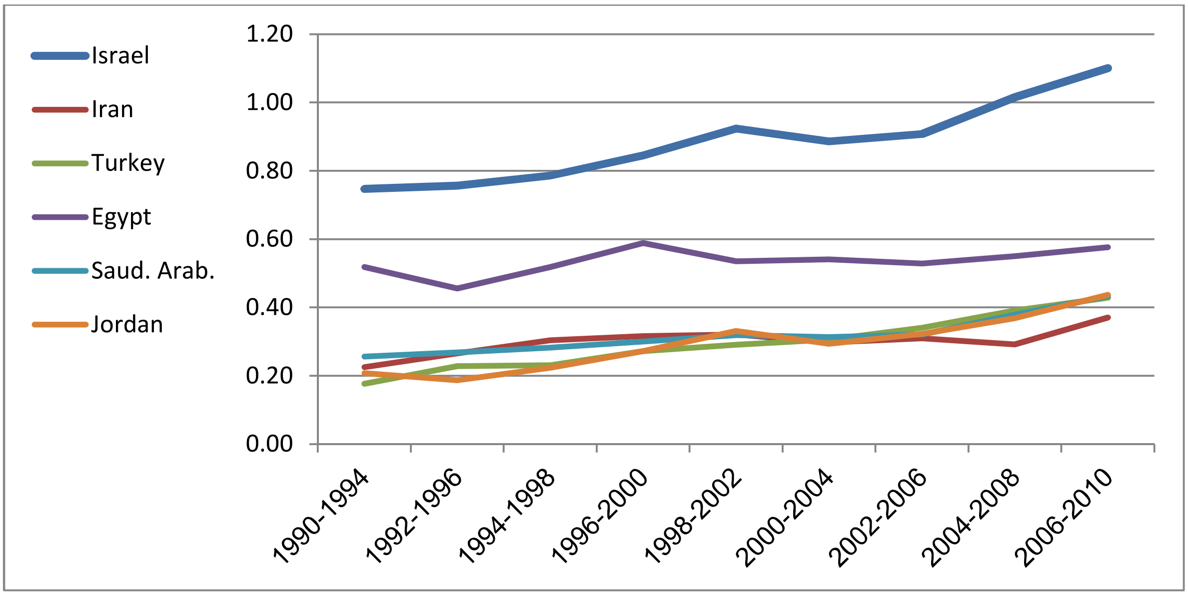
Source: processed from the data of Thomson Reuters [11, 13]

Figure 16. Clinical medicine

Number of publications



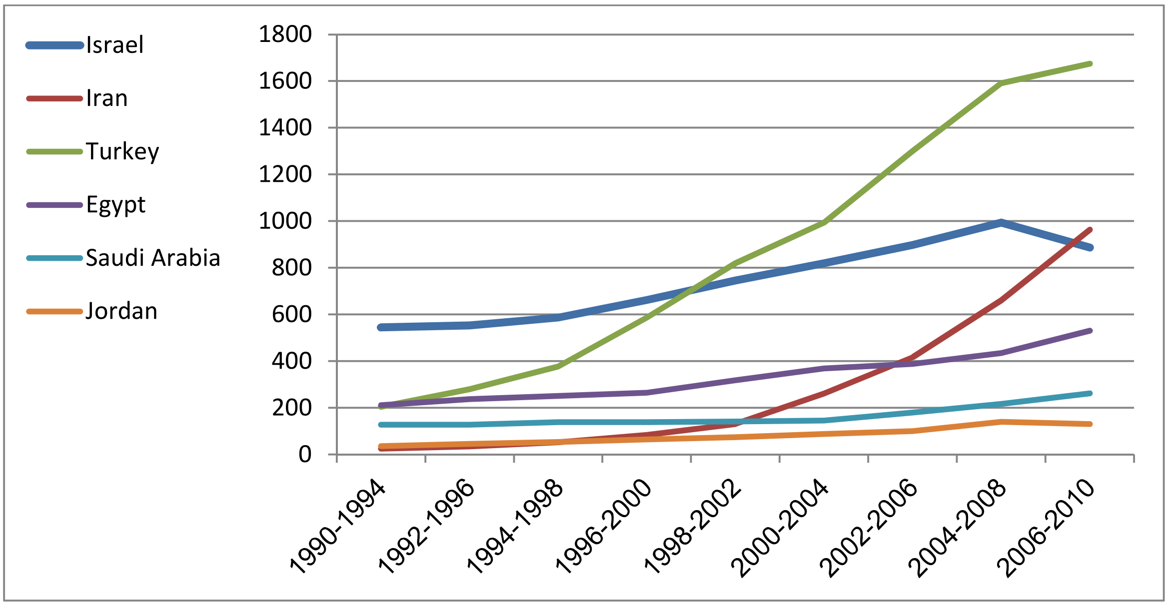
Average citations per publication, normalized to the global average



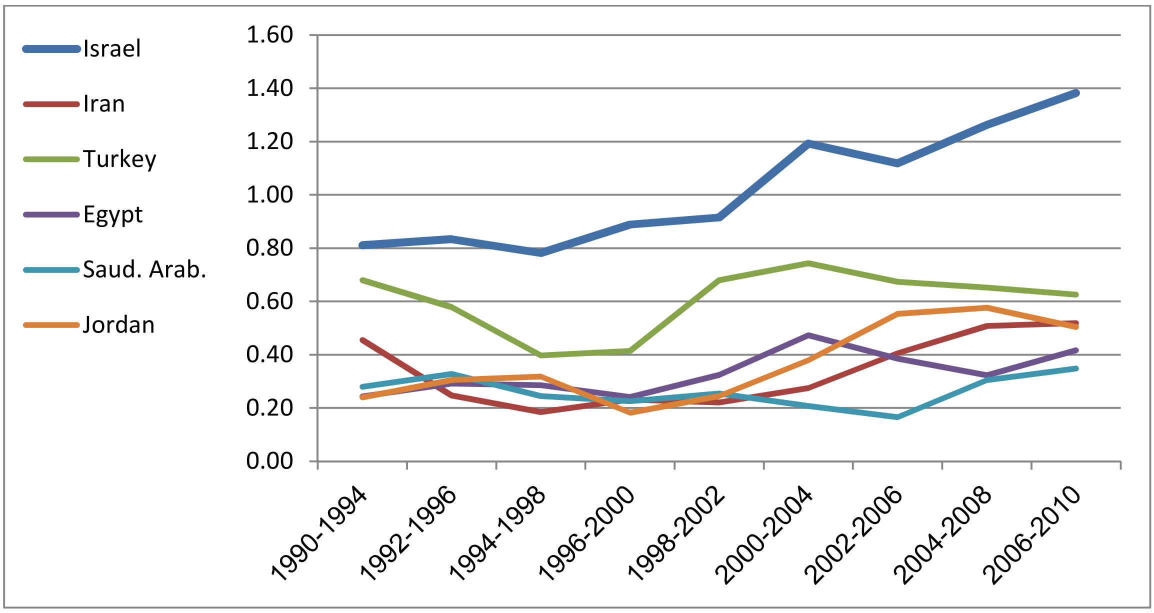
Source: processed from the data of Thomson Reuters [11, 13]

Figure 17. Geoscience

Number of publications



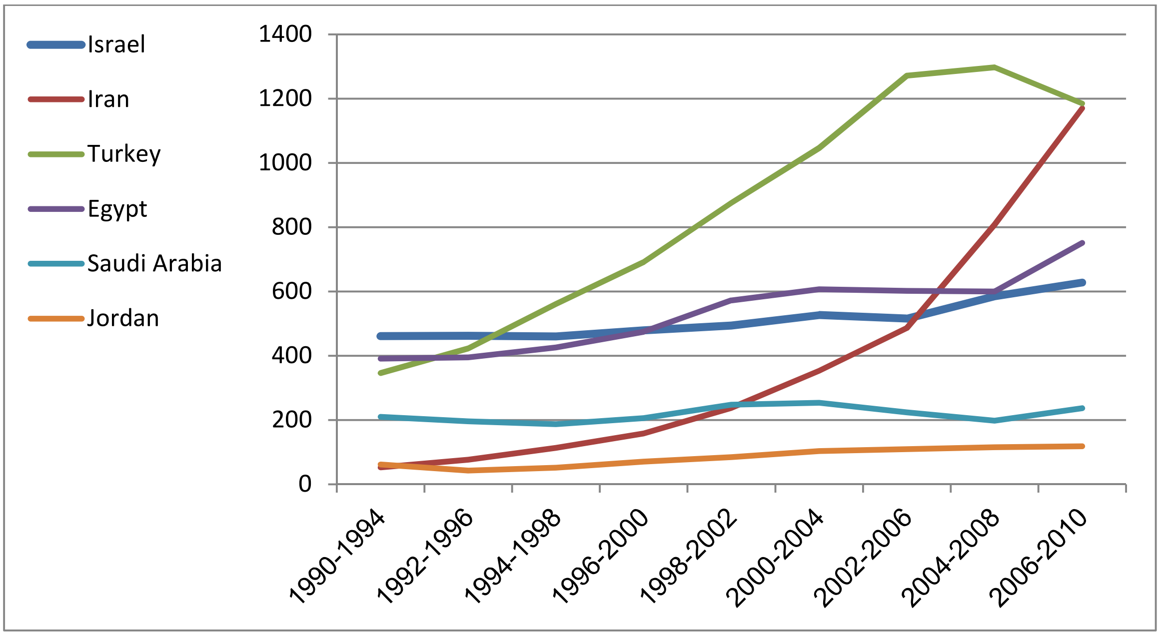
Average citations per publication, normalized to the global average



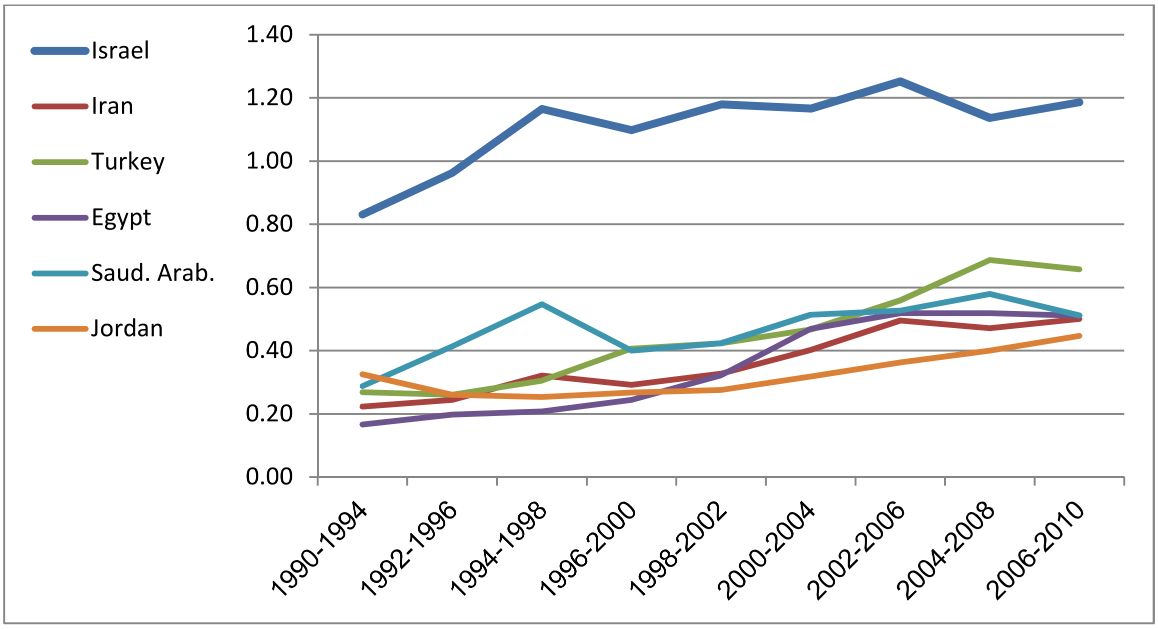
Source: processed from the data of Thomson Reuters [11, 13]

Figure 18. Pharmacology and toxicology

Number of publications



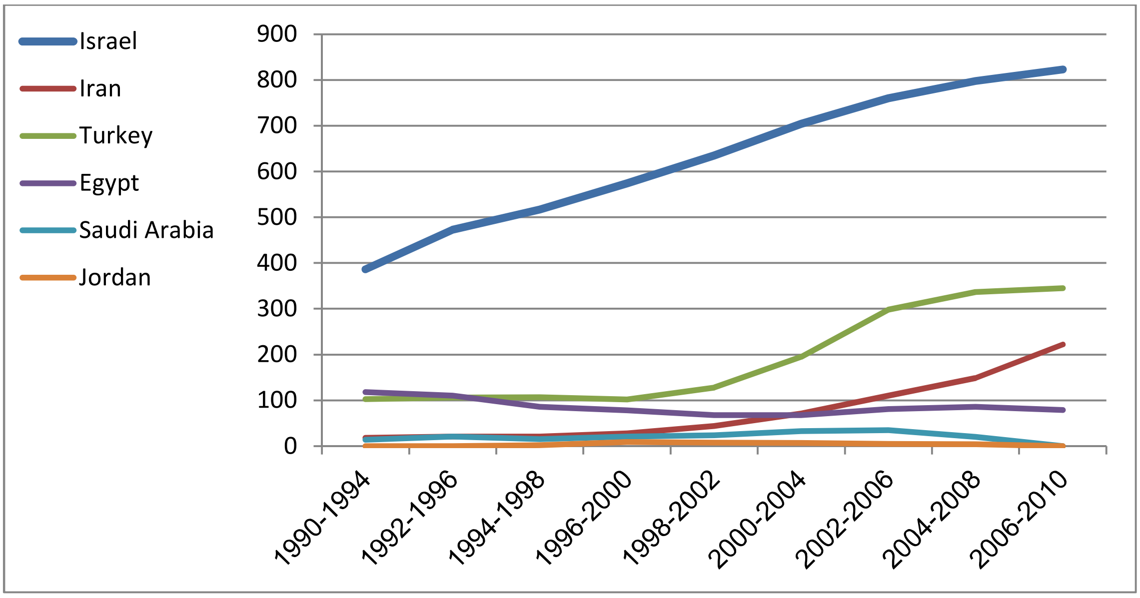
Average citations per publication, normalized to the global average



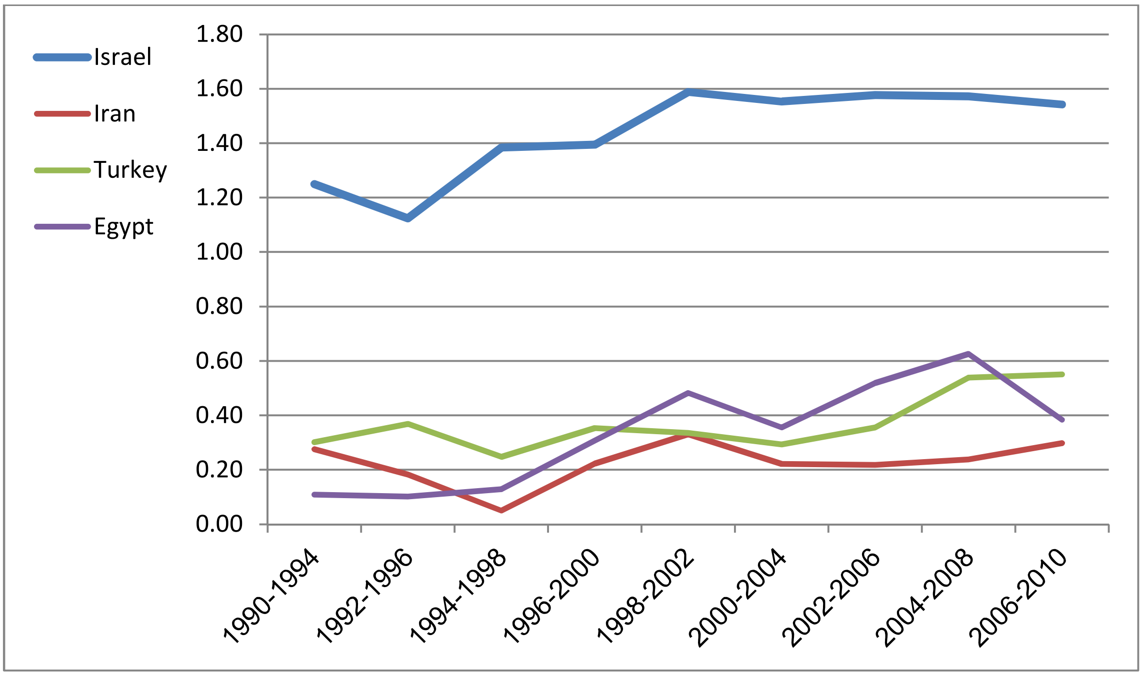
Source: processed from the data of Thomson Reuters [11, 13]

Figure 19. Space science

Number of publications



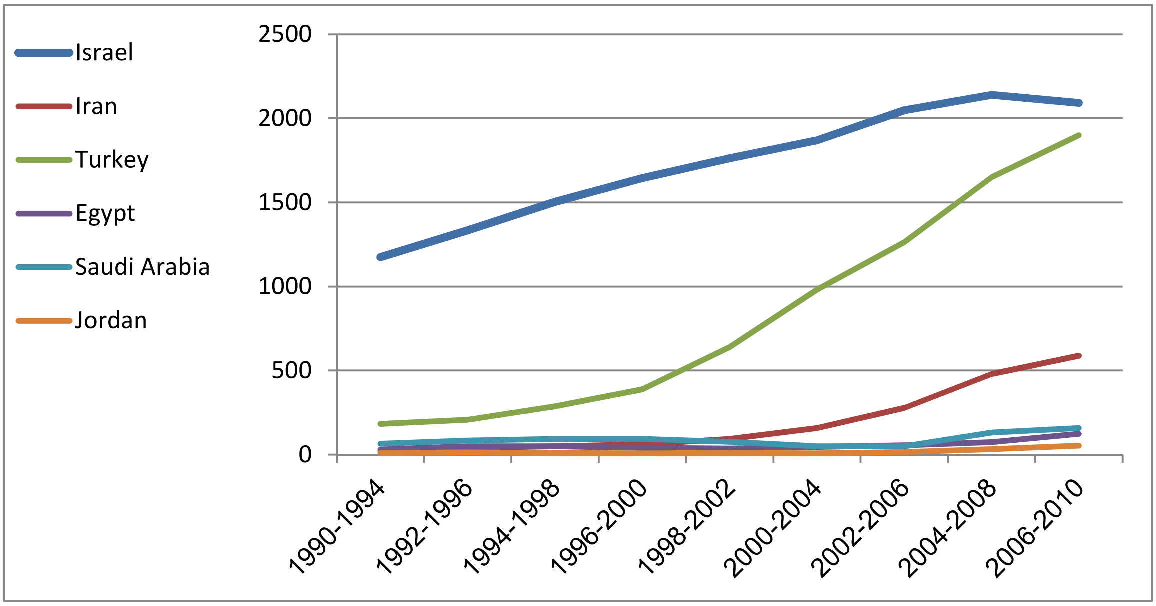
Average citations per publication, normalized to the global average



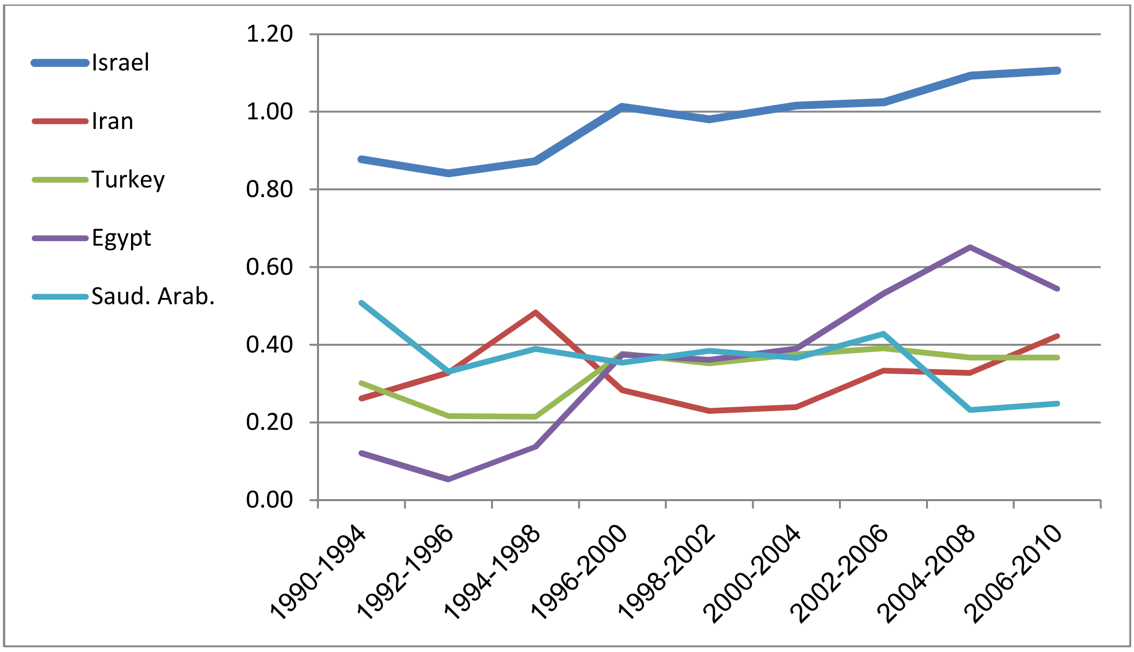
Source: processed from the data of Thomson Reuters [11, 13]

Figure 20. Neuroscience

Number of publications



Average citations per publication, normalized to the global average



Source: processed from the data of Thomson Reuters [11, 13]

5. Major findings

The most striking phenomenon is the rapid development and significant advance of Iran and Turkey in many fields in recent decades, in comparison with the relatively moderate progress (and sometimes even regression) of Israel in these fields, as reported in former Samuel Neaman Institute reports [8, 9]. In an attempt to focus the discussion on these developments, a comparative summary of the processes that occurred in Israel, Turkey and Iran will be presented below. It should be noted that the above is only a preliminary summary of the data. A thorough and detailed analysis, which will take into consideration the limitations of the indicators as they relate to each field separately, is a subject for a future study.

The results indicate a gradually shrinking gap between Israel and Iran and Turkey in the number of publications as well as in the average citations per publication. Despite the distinguished research status of Israel among the developed countries, in certain fields and indicators Iran and Turkey are already ahead. Tables 1 and 2 present data on the number of publications and averages citations per publication for Israel, Iran and Turkey, demonstrating the processes and developments that have occurred during the past twenty years. The main findings are as follows.

- **Number of publications**
  - Between the years 1990-1994 and 2006-2010, the number of publications in the various fields has grown as follows: Israel - tens of percent, Turkey and Iran - hundreds to thousands of percent.
  - During 2006-2010, the number of publications in Turkey exceeded those of Israel in the following fields: all fields combined, chemistry, engineering, materials science, biology and biochemistry, medicine, geosciences, pharmacology and toxicology. The number of publications in Iran exceeded those of Israel in the following areas: chemistry, engineering, materials science, geoscience, pharmacology and toxicology.

- **Average citations per publication**
  - Between the years 1990-1994 and 2006-2010, the average citations per publication in various fields increased as follows: Israel - tens of percent, Turkey and Iran - hundreds of percent.
  - During 2006-2010, the average citations per publication in Turkey, in engineering, exceeded that of Israel.

The data presented above are based on two main commonly used indicators, namely, number of publications and the average citations per publication, together portraying a preliminary general picture. To examine other aspects, the following data will be presented relating the indicators of the most cited publications and most cited researchers, comprising an indicator of the publications' quality and importance.

Table 1. The number of publications in Israel, Iran and Turkey, during 1990-1994 and 2006-2010.

Source: processed from the data of Thomson Reuters [11, 13]

Field	Period	Israel	Iran	Turkey
All Fields	1990-1994 2006-2010	36,099 50,984	1,261 50,242	7,643 86,905
Mathematics	1990-1994 2006-2010	1,606 2,498	79 1,848	134 2,003
Physics	1990-1994 2006-2010	4,331 5,130	138 3,469	565 3,700
Chemistry	1990-1994 2006-2010	2,849 3,769	234 11,067	1147 8,168
Computer Science	1990-1994 2006-2010	992 2,026	34 1,255	106 1,693
Engineering	1990-1994 2006-2010	2,302 3,364	198 8,520	867 9,440
Material Science	1990-1994 2006-2010	647 1,145	48 3,518	226 4,081
Biology & Biochemistry	1990-1994 2006-2010	2,858 2,857	40 1,623	278 3,267
Mol. Biology & Genetics	1990-1994 2006-2010	1,063 1,963	10 502	71 892
Clinical Medicine	1990-1994 2006-2010	8,477 12,467	142 7,448	2,468 29,325
Geosciences	1990-1994 2006-2010	544 886	24 964	204 1,674
Pharmacology & Toxicology	1990-1994 2006-2010	460 627	52 1,170	346 1,185
Space Science	1990-1994 2006-2010	386 823	18 222	103 345
Neuroscience & Behavior	1990-1994 2006-2010	1,174 2,092	21 589	183 1,899

Table 2. The average of citations per publication in Israel, Iran and Turkey, during 1990-1994 and 2006-2010.

Source: processed from the data of Thomson Reuters [11, 13]

Field	Period	Israel	Iran	Turkey	World
All Fields	1990-1994	3.1	0.8	0.9	3.2
	2006-2010	6.2	2.6	2.7	n/a
Mathematics	1990-1994	1.0	0.3	0.6	0.9
	2006-2010	1.7	1.5	1.2	1.6
Physics	1990-1994	3.7	1.1	1.5	3.3
	2006-2010	6.8	3.1	3.5	4.7
Chemistry	1990-1994	3.8	1.1	1.2	3.0
	2006-2010	7.3	3.8	3.5	5.8
Computer Science	1990-1994	1.1	0.8	0.5	0.9
	2006-2010	2.0	1.7	1.8	1.9
Engineering	1990-1994	1.1	0.6	0.5	1.1
	2006-2010	2.7	2.2	2.9	2.4
Material Science	1990-1994	1.6	0.9	0.6	1.5
	2006-2010	5.9	2.2	2.4	3.7
Biology & Biochemistry	1990-1994	6.6	0.8	1.2	6.5
	2006-2010	9.2	3.0	3.1	7.5
Mol. Biology & Genetics	1990-1994	9.3	1.3	3.0	9.8
	2006-2010	14.2	3.9	5.9	11.4
Clinical Medicine	1990-1994	2.4	0.7	0.6	3.3
	2006-2010	6.6	2.2	2.6	6.0
Geosciences	1990-1994	2.2	1.2	1.9	2.7
	2006-2010	6.1	2.3	2.8	4.4
Pharmacology & Toxicology	1990-1994	2.9	0.8	0.9	3.5
	2006-2010	7.1	3.0	3.9	6.0
Space Science	1990-1994	5.3	1.2	1.3	4.2
	2006-2010	12.2	2.4	4.4	7.9
Neuroscience & Behavior	1990-1994	5.1	1.5	1.7	5.8
	2006-2010	9.5	3.6	3.2	8.6

Most cited publications. Thomson Reuters' database of the most cited publications [11] contains the most cited publications per year in each of the 22 main fields. These publications passed a high threshold of citations, which is determined separately for each field every year. The database includes publications in journals, review articles, notes, and conference proceedings. It also includes journals and other sources covered only by the ISI. The publications are classified into fields according to the fields of the journals in which they appeared (each journal is classified into one field only). A publication associated with a country is a publication in which at least one of its authors was affiliated to this country according to the address he has provided. The number of publications included in the database of the most cited publications for six Middle Eastern countries, during a period of 10 years (since January 2001 until the end of April 2011) are as follows: Israel - 1346 publications, Turkey - 642 publications, Iran - 370 publications, Egypt - 93 publications, Saudi Arabia - 62 Publications, Jordan - 25 publications.

Most cited researchers. Thomson Reuters' database of the most highly cited researchers [14] lists the researchers that were identified as being the most cited in their fields, the list of their publications, and additional information. From each area, about 250-350 researchers were selected, whose publications, since 1981, received the highest number of citations above a threshold that was set for each field separately. The number of researchers included in the database for six Middle Eastern countries (as of July 2011) are as follows: Israel - 50 researchers, Saudi Arabia – 40, Turkey – one, Iran - one, Egypt and Jordan - none. Examining individually the most cited researchers of Saudi Arabia reveals that most of them are veteran researchers whose main academic career evolved mainly in universities outside that country, most of them served in senior positions at Western universities, and received an appointment in the universities of Saudi Arabia in recent years.

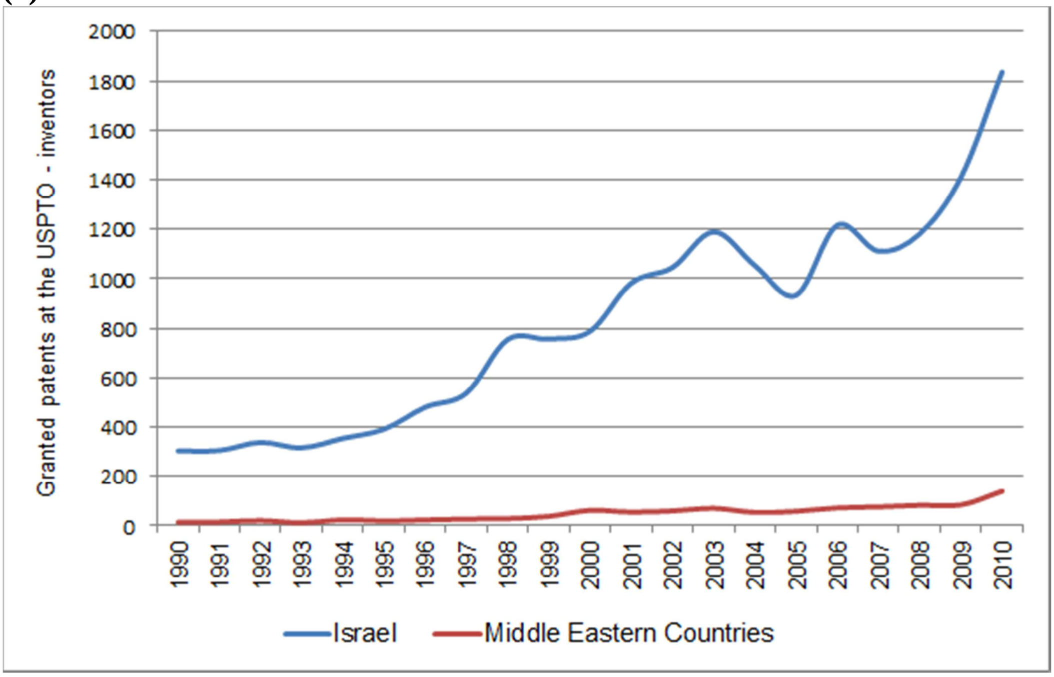
Patents

Patents comprise a unique source for technological knowledge. They are considered to be a good proxy for invention skills, R&D activities and for the scope of technological innovation of countries, regions, sectors and firms. Figure 21 (a,b) presents the number of patents granted by the USPTO to inventors from Israel and from middle-Eastern countries[2].

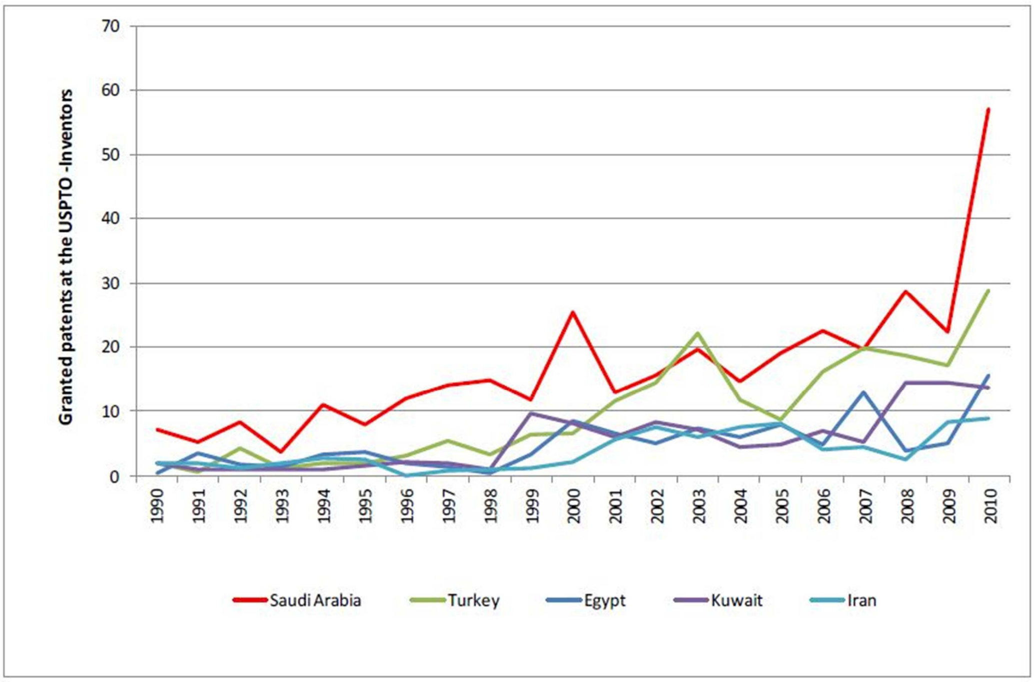
[2] Turkey, Algeria, Egypt, Iran, Jordan, Kuwait, Lebanon, Saudi Arabia, Tunisia, United Arab Emirates

Figure 21. Granted patents at the USPTO, by inventors' country of residence[3]

21 (a)



21 (b)



[3] Source: OECD.Stat Extracts

The data reveals significant differences in the scope of inventive outputs between Israel and Middle-Eastern countries (Figure 21a). In 2010, 1836 patents were granted to Israeli inventors, compared to 140 patents granted to inventors from Middle-Eastern countries. In contrary to the findings on publications and citations, data analysis shows no evidence regarding gap mitigation in inventive outputs between Israel and her neighboring countries over the past decade. When Middle-Eastern countries are compared to each other (Figure 21b), a significant growth trend in Saudi patents (the number of patents of inventors has nearly tripled in the past five years). Caution should be exercised in this analysis as the absolute number of Saudi patents is still very small. The data should be examined again in a few years to see whether the current growth rate continues.

6. Summary

The data presented in this study indicate that the following processes occurred during the past few years:

- A significant and rapid progress of Iran and Turkey in many fields, relative to a moderate progress (and sometimes, regression) of Israel in these areas.
- The gradually shrinking gaps between Israel and Iran and Turkey are expressed initially in the number of publications, and then in the average citations per publication.
- Israel leads in most of the fields examined, but Iran and Turkey are already ahead of Israel in some fields in the number of publications, and in a few areas even in the average citations per publication.
- There is no evidence regarding gap reduction in inventive outputs between Israel and her neighbors during the past decade.

The rapid progress in the Middle East is the result of a number of factors including high investments, new initiatives for the establishment of research centers, collaborations with high-quality universities in developed countries, and more. All these indicate an active policy that is oriented toward the advancement of science. The narrowing of the gap in science, between Israel and some Middle Eastern countries may raise some concerns.

As for Israel, over the past decade there have been troubling developments [15]. A process that jeopardizes the State of Israel's academic - scientific-technological resilience is taking shape. This is a direct result of the ongoing cuts in government budgets, leading to a reduced number of faculty members, to an increase in their average age, to the migration abroad of young scientists and of renowned scientists, closure of departments, and more. All these adversely affected scientific output and its quality. It is important to note that the time constant for achieving excellence in research is very long, that is, investments are expressed only after many years and present achievements are the fruit of past investment. Therefore, the processes that have occurred in Israel in recent years will be seen and felt only in a few years.

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