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A bibliometric assessment of scientific productivity and international collaboration of the Islamic World in science and technology (S&T) areas

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Abstract This case study analyzes scientific research landscape of the Islamic World in order to access the research productivity, scholarly impact and international collaborations across all Science and Technology (S&T) areas over the time period of 2000–2011, using the Scopus database. While Turkey is clearly leading among the Islamic countries, Iran takes 2nd rank in terms of publication output. All S&T subject areas show annual increase in publications by more than 10 %. The highest percentage of publications of the Islamic World falls into the area of Veterinary with respect to the world. Dentistry is the top area with 7 % share of the world's top 25 % publications with respect to citation count. This undoubtedly shows that the impact of the scientific research of the Islamic World is very less as compared to the other developed nations. We also find that top collaborators of the Islamic World are mainly within Islamic countries. The findings of this case study provide an insight to the research landscape of the Islamic World and useful information to the scientific community as well as to the technology and innovation policy makers.

Keywords Scientific research productivity · Islamic World · International collaborations · Bibliometrics

Background

Scientific research is extremely important for the economic growth, industrial innovation, quality improvement, cost reduction and measurement of educational level of a country (Sharma and Thomas 2008). It plays an integral part in driving the world's economy.

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Scientific research positively impacts the economy in many ways by increasing productivity and improving the quality of available goods (Abdullah and Wee 2011). In the last decade, the Islamic World has experienced tremendous change in the scientific research landscape. The level of research maturity and activity in the Islamic World is varied and has been changing rapidly in last decade. In recent years, there are more international collaborations taking place in the Islamic World which exchanging knowledge with the world-class research (Kumar and Jan 2014).

Historically, Muslims in Arabia, North Africa and Spain were at the peak of their evolution. While the libraries in the Islamic World preserved a lot of classic learning, Christian Europe was in the Dark Ages (Zewail et al. 2011). The Islamic scholars in Medicine, Astronomy, Mathematics and other Science and Technology (S&T) areas created an impressive platform of knowledge in middle ages. In recent years, the progress of two Islamic countries namely Turkey and Iran is particularly very impressive to study. The enhancement of Turkey's scientific performance in recent decade has taken place at a very impressive rate that virtually rivals that of China. The Turkish government's gross expenditure on R&D has increased, nearly, sixfold in the last decade. This rapid development happened together with the dispatch of a National Science and Technology Innovation Policy, and a method, which incorporates the Turkish Research Area (TARAL) program that intends to tie every stakeholder of its science and advancement into a solitary institutional structure. It is expected that these determinations will contribute towards building a solid and viable National Innovation System (Royal Society 2011). Iran has made rapid progress in all subject areas and particularly in medical science over the past several decades. In addition, the growing inclination of most of the Iranian authors to publish their articles in journals has increased the international visibility of Iranian research (Moin et al. 2005). Not to forget that an Iranian mathematician, Maryam Mizakhani is the first woman ever to receive the fields medal in Mathematics (Carey 2014).

In Saudi Arabia, the King Abdullah University of Science and Technology (KAUST), a generous investment of US$ 20 billion by Saudi Arabian Royal Family, is intended to hire 250 faculty members and 2000 post graduate students from all over the world. The policy of KAUST is to develop and protect freedom of research, provide attractive environment for research and freedom to be experiment and creative. Abu Dhabi, the capital state of United Arab Emirates is following a different path: capitalizing on its energy resources to have a sustainable economy. The Masdar Institute is at the core of this planning which is attracting powerful partner enterprises like Siemens and Credit Suisse and will attract 50,000 peoples. In Abu Dhabi, the plan is to reduce the long-term dependency on hydrocarbons and maintain status in energy sector (Zewail et al. 2011). Pakistan is making progress in S&T areas as well. By analyzing bibliographic data, we find that the number of scientific research publications is increasing every year in Pakistan and after 2002 we see an exponential increase in the number of publications in the country. One of the reasons behind this exponential growth is the establishment of Higher Education Commission (HEC) in 2002 and increasing expenditure on research and development as a percentage of GDP.

Energy is essential to the way we are living. Whether it is in the form of electricity, gasoline or the form of oil, a countries economy, welfare and prosperity depends on having access to energy on affordable price. Malaysia is doing impressive research in energy sector. Development and economic growth in Malaysia is highly dependent on energy sector. In order to attain sustainability in energy sector, Malaysia is exploring alternative energy resources like Solar, Biomass, Mini Hydro and Wind Energy. Malaysia has the high

potential to become one of the major suppliers of renewable energy in palm oil biomass and become a role model for other huge biomass feedstock countries (Ong et al. 2011).

All the scientific organizations under Organization of Islamic Cooperation (OIC) are playing a major role in encouraging the development of S&T cooperation and networking among the Islamic countries for socio-economic progress (http://www.oicun.org/). One of the key initiatives of OIC is the establishment of The Islamic Educational Scientific and Cultural Organization (ISESCO), which is one of the largest international Islamic organizations in the world to increase the coordination and cooperation in S&T among the Islamic World. The ISESCO has established a large number of programs to increase coordination between universities, research institutions and scientific community. The ISESCO has addressed the necessity to initiate bilateral, multilateral and regional cooperation programs in the Islamic World (http://www.isesco.org.ma/). Another initiative of the Islamic World to promote S&T is the ISESCO Centre for Promotion of Scientific Research (ICPSR). The center was launched in the second Islamic conference of "Ministers of Higher Education and Scientific Research" in September 2003, in Tripoli, Libya in order to subsidize the promotion of scientific research, technological development, innovation and strengthening the foundations of scientific research. Similarly, another initiative of the Islamic World to promote S&T research is the initiative of Islamic Development Bank (IDB), the bank has been functional since 1975. The IDB grants loans for productive projects, assist in promotion of trade between Islamic countries, gives S&T prizes and provide scholarship for PhD and post-doctorate programs (http://www.icpsr.org.ma/).

The OIC Standing Committee on Scientific and Technological Cooperation COMSTECH was launched by third Islamic summit conference held in Islamabad, Islamic Republic of Pakistan, in 1981. The COMSTECH aims to promote collaboration between the Islamic countries in the fields of science and technology, build up the homegrown capability of the Islamic World in the fields of S&T through mutual assistance and cooperation and creation of thematic S&T networks in Islamic countries. The Federation of the Universities of the Islamic World (FUIW) is an organization working within the framework of ISESCO, aims at consolidation contacts between the Federation's General Secretariat and the Islamic world Universities, develop partnership, establish links, strengthening contacts among the Islamic World universities, provide research findings, promote joint scientific research between universities, facilitate degree certification mechanisms, exchange of researchers and publish scholarships available to students (http://www.fuiw.org/).

Despite the huge investments being made in S&T areas in the Islamic World, we do not find any comprehensive study that assesses the scientific research landscape of the Islamic World. Therefore, we believe that it is extremely important to assess the scientific productivity of the Islamic World. In the lieu of this, the followings are the objectives of this case study:

1. To study the scientific progress of the Islamic World in S&T.
2. To evaluate the relative research effort of the Islamic World devoted to S&T.
3. To explore trends and features S&T of the Islamic World.
4. To identify top S&T research area of the Islamic World.
5. To explore the structure of landscape of the Islamic World.
6. To study the S&T research impact of the Islamic World.
7. To study the patterns, dimensions and trends of intentional collaboration of the Islamic World across S&T.

Table 1 Publication output of Islamic World in S&T areas during 2001–2011

	Iran	Turkey	Malaysia	Egypt	Saudi Arabia	Pakistan	Tunisia	Algeria	UAE	Jordan	Indonesia
Agricultural and Bio Sciences	14,108	21131	6254	5613	2241	6804	3203	1213	723	1469	2793
Veterinary	2091	6387	298	863	285	396	204	78	175	207	187
Biochemistry, Genetics and Molecular Biology	12,786	20,906	4821	6308	2941	3175	3299	933	1063	981	1311
Chemistry	23,770	20,949	8253	12,019	4096	5465	2923	2885	776	1533	982
Computer Science	9581	10,601	4564	2552	2141	1381	1835	1878	1271	1320	484
Earth and Planetary Sciences	3539	6642	1122	2205	1042	592	726	583	544	512	876
Decision Sciences	1118	1548	311	299	346	133	232	139	212	150	74
Economics, Econometrics and Finance	341	1808	1177	137	178	369	312	34	352	182	298
Chemical Engineering	9486	8212	3204	3835	1889	954	1288	1343	603	802	465
Energy	3570	4958	1403	1744	1246	617	350	645	530	460	341
Engineering	25,503	27,218	9790	9631	4966	3455	3911	4615	2106	2310	1401
Environmental Science	6867	12,172	3426	3299	1502	1438	1623	1032	688	1079	1309
Nursing	884	1997	584	476	207	498	130	54	108	314	199
Health Professions	818	2776	378	216	162	123	308	54	80	123	23
Materials Science	17,259	20,317	9584	9236	3324	3180	3573	4084	784	1255	911
Mathematics	11,937	12,946	2994	4548	3330	2285	2648	2584	1143	1318	510
Medicine	31,002	104,783	10,654	13,811	12,643	13,777	9188	1050	3038	2944	2745
Dentistry	857	3766	221	400	633	55	74	2	91	357	62
Immunology, Microbiology	3734	6053	1694	2084	836	1370	1404	307	258	299	714
Neuroscience	1547	5306	341	620	327	161	244	53	227	132	75
Pharmacology, Toxicology and Pharmaceutics	6226	6800	1691	3731	1824	1760	600	245	431	603	503
Physics and Astronomy	17,918	21,421	9163	8957	3938	4642	3687	4849	866	1530	1094

Table 2 Indicators used in bibliometric analysis

Dimension	Indicator	Description
Productivity	Total publications	Total number of publications during 2000–2011 indexed in the Scopus
	Growth (CAGR)	The annual compound growth rate is calculated as $\sqrt[(2011-2000)]{P2/P1} - 1$ where P1 and P2 denote the number of publications made from subject area during in 2000 and 2011 respectively
Relative research effort	Activity Index	$\mathrm{AI} = \frac{\text{the Islamic World's share of the world's publication output in the given field}}{\text{the Islamic country's share of the world's publication output in all science fields}} \times 100$
Impact	Citation volume	Total number of citations within 2005–2011 to papers published in the same period
	% PnC	Ratio of number of publications not cited at all and total number of publications of a country during 2005–2011
	% Publications in Q_1	% Publications of Islamic World that exist in top 25 % publications of World with respect to citation volume
International collaboration	% International collaboration	Ratio of number of publications produce by an Islamic country with an international co-authorship in a given research area to the total number of publications produced by that Islamic country in that research area
	Salton's measure	$C_{ij} = \frac{P_{ij}}{\sqrt{(P_i \cdot P_j)}}$ where i, j entities represent the countries to be compared, P_{ij} denotes the co-authored publication of two countries, P_i and P_j denotes the publication of i and j country respectively
Collaboration pattern	Co-authorship Index (CAI)	$\mathrm{CAI} = \frac{C_i}{C_o} \Big/ \frac{W_i}{W_o}$ where C_i denotes the number of publications in a given field of a specific country in the ith year, C_o denotes the number of publications in a given field of a specific country during research period, W_i denotes the number of publications in a given field of the whole world in the ith year, W_o denotes the number of publications in a given field of the whole world during research period
	Top collaborators	The country with highest number of co-author publications with the Islamic World

In order to meet the objective of this case study we use variety of bibliometric indicators. Scientific progress can be studied with publication volume as an indicator of scientific productivity, citation volume as a measure of scientific research impact (Guan and Ma 2007). In addition, we can calculate the density and research collaboration between two countries with internationally co-publications (Royal Society 2011; Beaver 2011). This study presents two types of analysis. First, we conduct bibliographic analysis to explore the trends and features of the Islamic World in S&T and identify top research areas as well as to explore the structure of the Islamic world research landscape. Secondly, we also try to understand the patterns and trends of international collaboration of the Islamic World by exploring co-authorship network graphs. In order to see the collaborative research of the Islamic World with respect to rest of the world we retrieved scientific publication data that has at least with one author from the selected Islamic country and one from the rest of the world country.

Data collection and methodology

This study covers top eleven countries from the Islamic World that have the highest publication count during 2000–2011: Turkey; Iran; Malaysia; Egypt; Pakistan; Saudi Arabia; Tunisia; Algeria; Jordan; Indonesia and United Arab Emirates. Publications data is taken from the Scopus. We utilize Scopus All Science Journal Classification (ASJC) mapping to get relevant publications in the areas of S&T. Table 1 shows the statistics of the bibliography data of the selected countries of the Islamic World. In order to measure the research performance of the Islamic World a variety of bibliometric indicators are used in terms of publication, co-publication volume, citation, research internationality and research collaboration (see Table 2).

To measure the research productivity, we use publication volume and growth rate. The Activity Index is used to measure the relative research effort of the Islamic World devoted

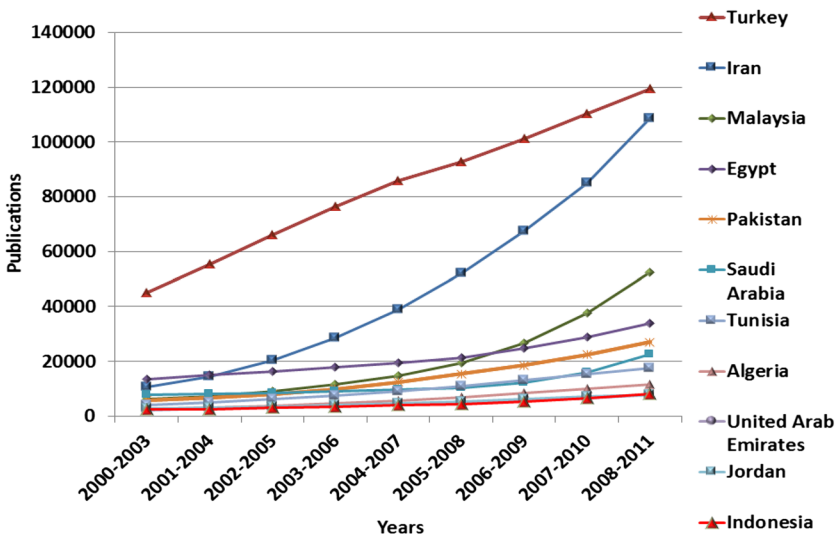

Fig. 1 Research strengths of Islamic World in terms of publication output during 2000–2011

to S&T, to explore trends and features S&T of the Islamic World and to identify emerging S&T research area of the Islamic World. The indicators we used (see Table 1) to measure the research impact includes citation counts, percentage of paper not cited during the selected time period and the Islamic World's share of the World's top publications in the given field with respect to the number of citations. The internationalization indicators include % int'l collaborations, top collaborators and co-authorship index. In order to quantify the collaboration strength between the Islamic World and other countries, a well know Salton's measure is used (Salton and Bergmark 1979). The Salton's measure considers publication volume of both countries in order to study the collaboration strength between two countries. While analyzing the Islamic World and rest of the World's publications, we use standard double counting approach to give the equal publication credit to all participating counties in collaboration.

Result and discussion

Publication productivity of the Islamic World

This section presents the research productivity of the selected Islamic countries. Figure 1 shows the publication output during 2000–2011. We find that Turkey is clearly leading in terms of publication output, Iran takes 2nd rank in terms of publications, Malaysia, Egypt, and Pakistan takes 3rd, 4th and 5th rank respectively. We find a big gap between Turkey and Iran, followed by a big gap between Iran and rest of the selected Islamic countries. The result shows that Turkey has significantly increased its publication output in recent years. Iran has been focusing hard in energy sector. According to the planning of 4th socioeconomic and cultural development planning, private sector was expected to gain the share of at least 270 MW in renewable energies (Ghobadian et al. 2009). We further analyze the

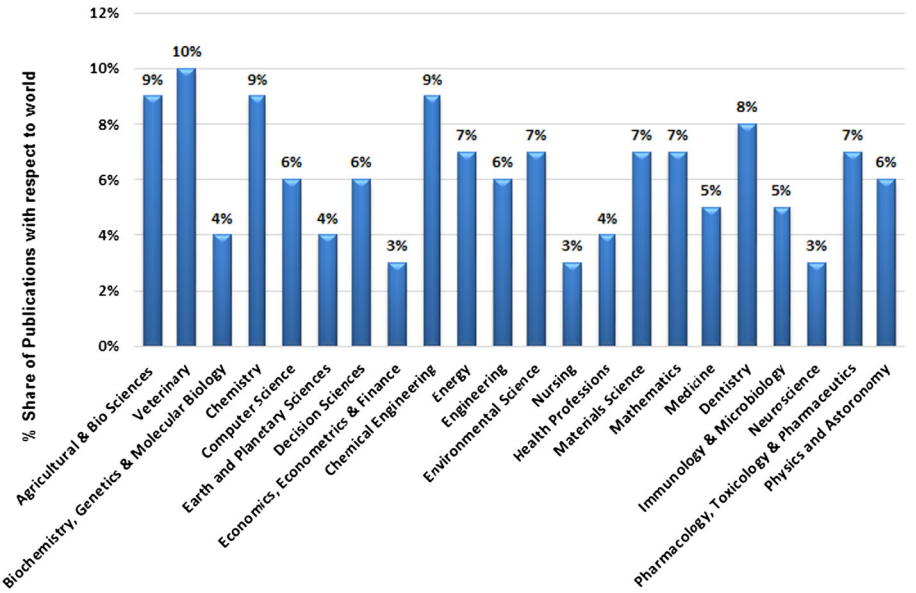

Fig. 2 Publication share of the Islamic World in S&T areas with respect to the World during 2000–2011

research strength of the Islamic World in all S&T subject areas in order to understand the strengths of the Islamic World across the fields. The highest publication falls into major areas of Veterinary followed by Chemical Engineering, Chemistry, Dentistry, Agricultural and Biological Sciences followed by Mathematics, Pharmacology Toxicology and Pharmaceutics, Material Science and Environmental Sciences (see Fig. 2).

During 2000–2011, all the selected subject areas in the Islamic World show increase in annual number of publications by more than 10 %. The Islamic World has produced 5925 publications in the field of Economics, Econometrics and Finance averaging 496 publications per year increasing its annual number of publications by 24 % per year and 29,293 publications in the field of Immunology and Microbiology averaging 2441 publications per year increasing its annual number of publications by 18 % per year, and 107,675 publications related to Agriculture and Biological Science averaging 8972 publications per year increasing its annual number of publications by 17 % per year (see Fig. 3).

The number of publications doesn't reveal much about the productivity of scientific research (Narin and Frame 1989). In doing so, we use the concept of Activity Index (Garg and Padhi 2001) which is used to evaluate the relative research effort of a country. Mathematically Activity Index has been defined as follows:

$$\text{Activity Index} = \frac{\text{country's share of he world's publication output in the given field}}{\text{country's share of the world's publication output in all science fields}} \times 100.$$

We use transformative expression to calculate Activity Index in order to study the development of research activities of the Islamic World during the period 2000–2011. This Transformative Activity Index (TAI) can be expressed as follows:

$$\text{TAI} = \frac{C_i}{C_o} \Big/ \frac{W_i}{W_o}$$

where C_i denotes the volume of publications in a given field of a specific country in the ith year, C_o denotes the volume of publications in a given field of a specific country during research period, W_i denotes the volume of publications in a given field of the whole world

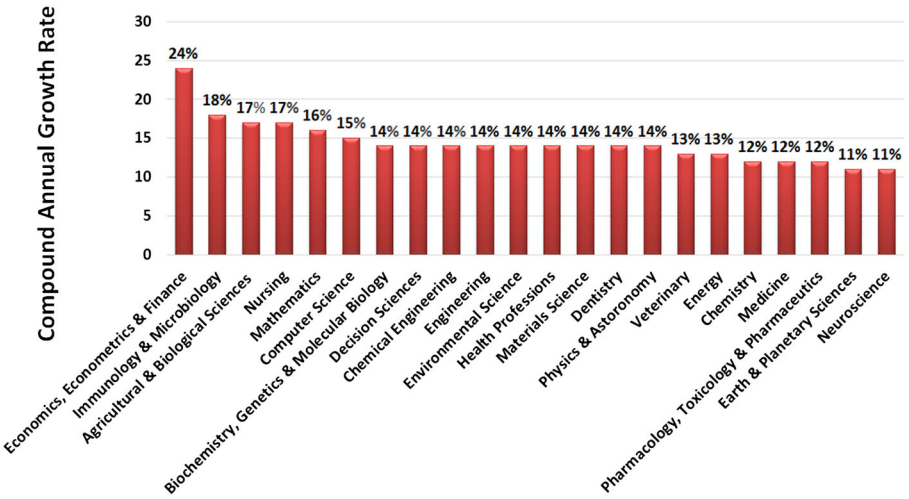

Fig. 3 Annual growth of Islamic world in terms of publication output in all Subject areas during 2000–2011

in the *i*th year, and W_o denotes the volume of publications in a given field of the whole world during research period.

If the TAI value is equal to 100 it indicates that country's research effort correspond precisely to the world average, if the transformative activity index value is greater than 100 then it reflect the country's research effort higher than average and if its below 100 then lower than the world average. The values of TAI during the period 2000–2011 for the countries considered are calculated and shown in Fig. 4. The Fig. 4 shows relative research efforts of the Islamic World. After 2008 the Islamic World has relative research effort above the world average. We can conclude by referring to the meaning of TAI that relative research effort of Malaysia has got really remarkable improvement in last 8 years. Malaysia is doing impressive research in Energy. Development and economic growth in Malaysia is highly dependent on energy sector. A similar finding has been reported by Kumar and Jan (2014).

Material Sciences

Figure 5 shows the TAI of the selected countries in Material Sciences. It indicates that the relative research effort of all other countries in the Islamic World is greater than the world average after 2008. In 2011 the relative research effort of Saudi Arabia is much higher than any other selected Islamic country. Saudi Arabia has shown impressive growth in terms of publications. In Saudi Arabia, the King Abdullah University of Science and Technology (KAUST), a generous investment of US$ 20 billion by Saudi Arabian Royal Family, is intended to hire 250 faculty members and 2000 post graduate student from all over the world. The policy of KAUST is to develop and protect freedom of research, provide attractive environment for research and freedom to be experiment and creative. Iran has been working hard on energy sector, according to the planning of 4th socioeconomic and Cultural development planning, private sector was expected to gain the share of at least 270 MW in renewable energies (Ghobadian et al. 2009).

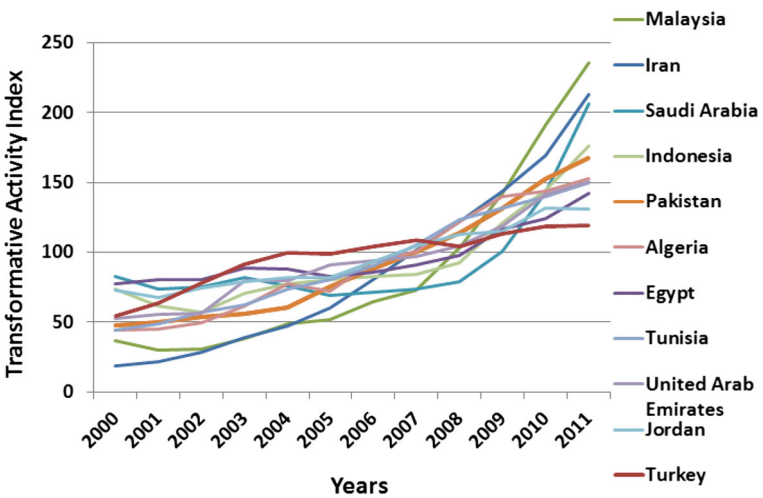

Fig. 4 Trends of TAI in Islamic World during 2000–2011

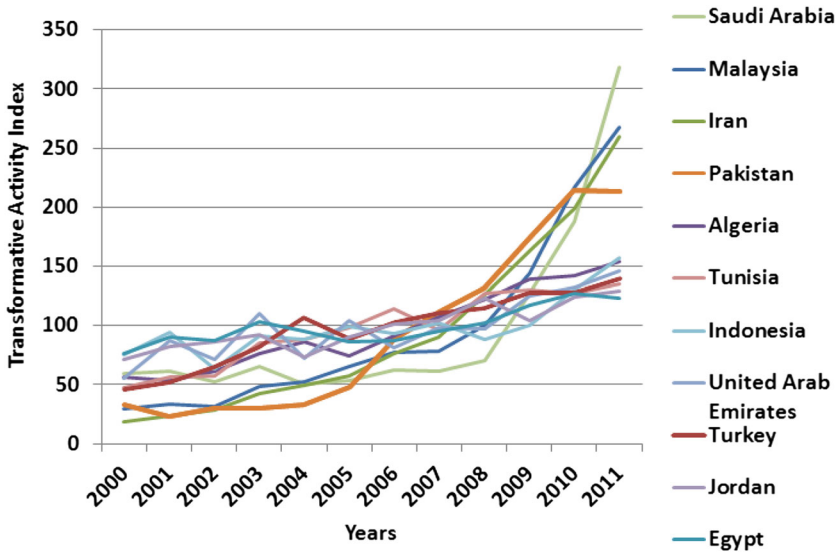

Fig. 5 Trends of TAI in Material Sciences during 2000–2011

Energy

Figure 6 presents relative research efforts in Energy of the selected countries. We find that except for Egypt and Saudi Arabia, relative research effort in Energy of the Islamic World is greater than the World average after 2008. Relative research effort of Iran and Malaysia has remarkably increased in the Islamic World. Malaysia is doing impressive research in

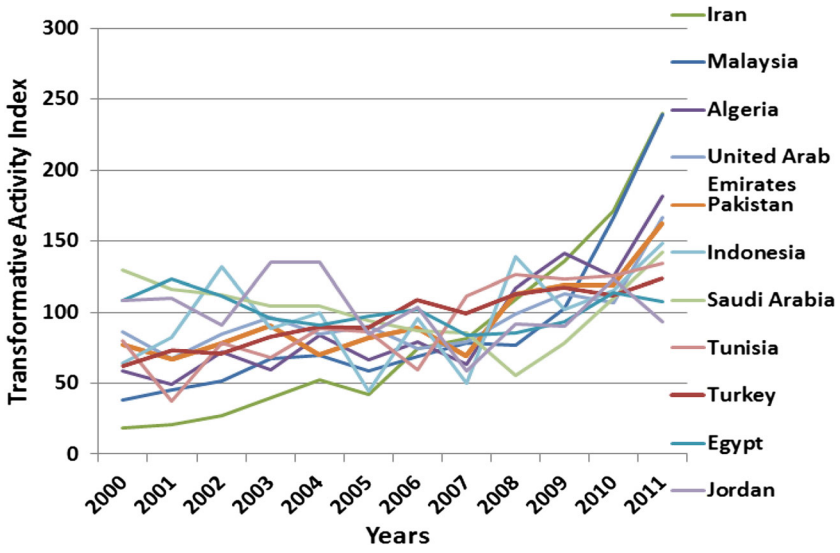

Fig. 6 Trends of TAI in Energy during 2000–2011

energy sector. Development and economic growth in Malaysia is highly dependent on energy sector. In order to attain sustainability in energy sector, Malaysia is exploring alternative energy resources like solar, biomass, mini hydro and wind energy. Malaysia has the high potential to become one of the major suppliers of renewable energy in palm oil biomass and become a role model for other huge biomass feedstock countries (Ong et al. 2011). We can conclude by referring to the meaning of TAI that relative research effort of Iran and Malaysia in Energy has got remarkable improvement in last decade.

Mathematics

Figure 7 presents relative research efforts of the selected countries in Mathematics. We find that except for Turkey, relative research effort of other ten selected Islamic countries is below than the world average before 2006. After 2008 the Islamic World has relative research effort above the World average in Mathematics. Relative research effort of Pakistan has remarkably increased than any other Islamic country. We can conclude by referring to the meaning of TAI that relative research effort of Pakistan in Mathematics has got remarkable improvement in last 8 years. There could be a lot of reason behind this improvement of relative research effort like leadership of the country, HEC was established in 2002 and if we look at the stats of UNESCO we come to know that Gross Expenditure on Research and Development as of percentage of GDP started increasing by 2002 in Pakistan.

Computer Science

Figure 8 presents relative research efforts of the selected countries in Computer Science. After 2008 the Islamic World has relative research effort above average in Computer Science. Relative research effort of Pakistan and Malaysia has remarkably increased than

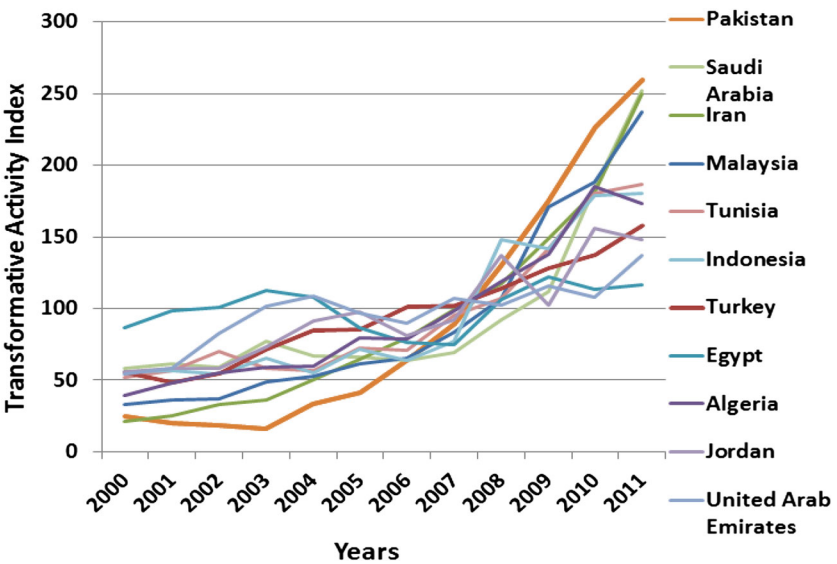

Fig. 7 Trends of TAI in Mathematics during 2000–2011

any other Islamic country. We can conclude by referring to the meaning of TAI that relative research effort of Pakistan and Malaysia in Computer Science has got remarkable improvement in last 8 years.

Impact of scientific research

The publication serves to disseminate the result of the study and invite other scientist to use the finding in his or her own research (McClellan 2003). Other authors use these finding in their own research by means of formal citations. The impact of a piece of research is the degree to which it has been useful to other researchers. The effective way of comparing impact of scientific research is citation analysis (Borgman and Furner 2002; Moed 2002; Van Raan and Van Leeuwen 2002). Citations should not be arithmetically averaged because citation distribution is highly skewed (Mishra et al. 2010), with the help of quartiles the citation of paper can be rated in terms of its percentile in the distribution of citation, so we have considered only the quartile one, top 25 % papers. Dentistry, Energy, Engineering are the top three areas of the Islamic World which have 7, 6 and 5 % publications share in World's top 25 % publications in their respective areas with respect to number of citation. The top 25 % publications of the Islamic World are show in Fig. 9. Moreover, Neuroscience with 1 %, Nursing, (Biochemistry, Genetics and Molecular Biology), (Economics, Econometrics and Finance) and (Earth and Planetary Sciences) with 2 % publication share in world's top 25 % publication are the four subject areas with least % of publication in the Top 25 % publications of the world with respect to citations count. The reason behind this could be that the United States and European Union have higher % of publications in these subject areas (Fig. 10).

The facts and figures show that the publication share of (Biochemistry, Genetics and Molecular Biology) and Neuroscience in European Union's total publications is 37 and 39 % respectively. Moreover, the publication share of (Earth and Planetary Sciences),

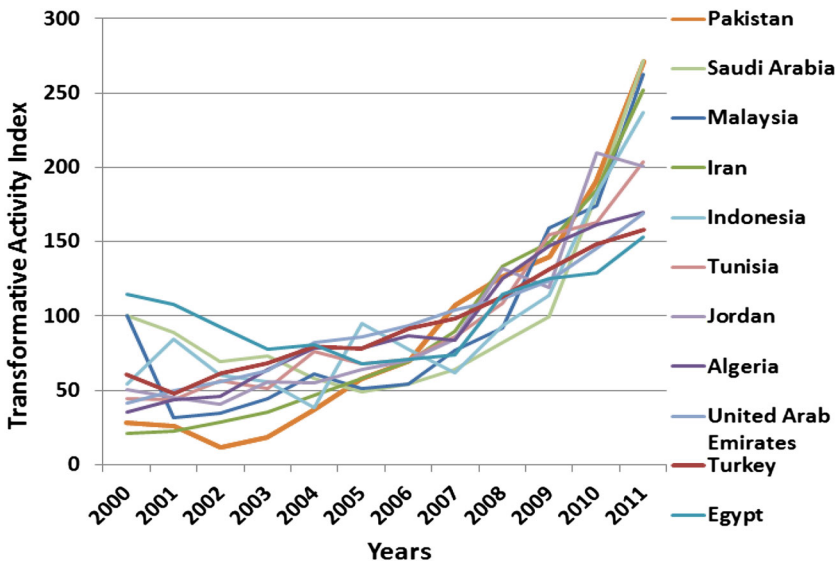

Fig. 8 Trends of TAI in Computer Science during 2000–2011

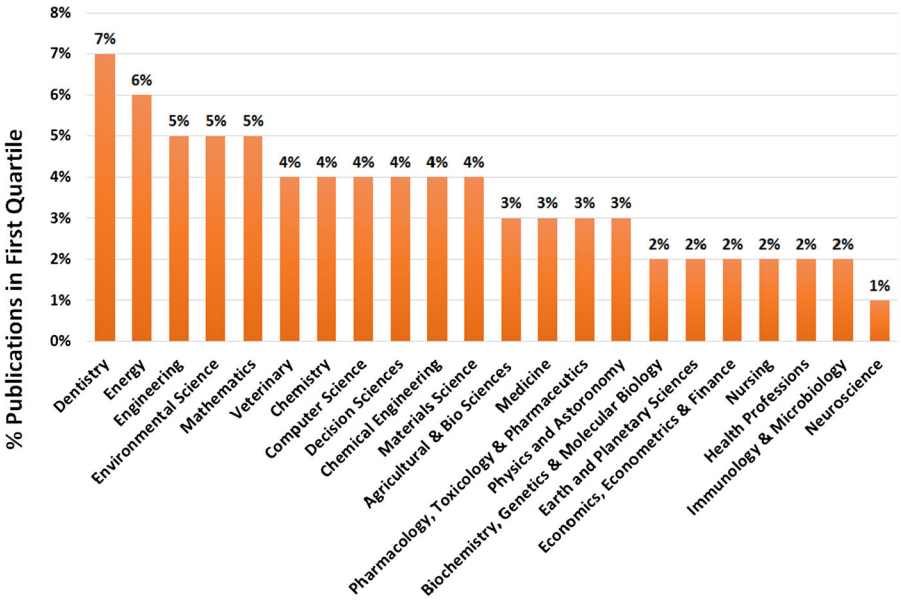

Fig. 9 Islamic World publications in first quartile of World's publications with respect to citations in S&T areas during 2005–2009

(Biochemistry, Genetics and Molecular Biology), (Economics, Econometrics and Finance) and Neuroscience are the top four areas of the United States with highest % world's share of publications with 36, 37, 38 and 39 % respectively. We found that the publications share of the Islamic World in the world's top 25 % publications with respect to the citations is very less as compared the other developed nations. This undoubtedly shows that the impact

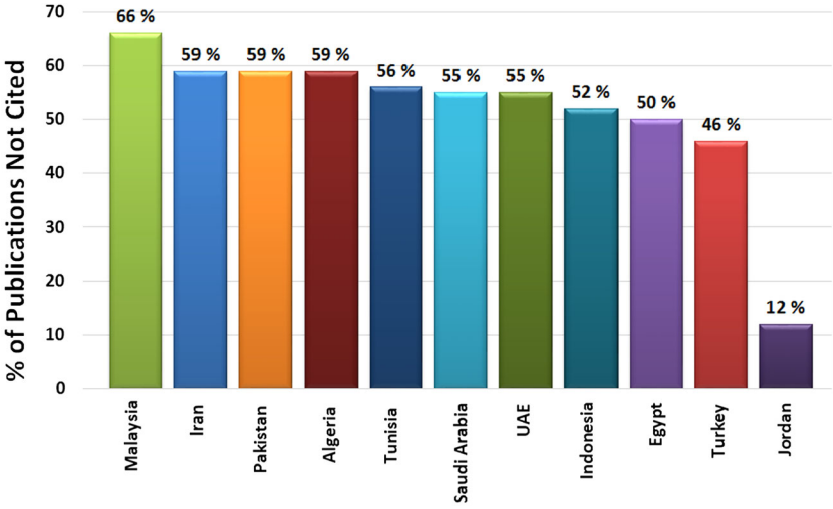

Fig. 10 % of publications not cited at all

of the scientific research of the Islamic World is very less as compared to the other developed nations. The impact of research can be enhanced by cooperating with the top research groups in the world and by working on the real world problems. In order to obtain percentage of the number of publications of the selected countries, which are not cited at all during the selected time period, we divided volume of papers not cited during selected time period by total number of papers in the country (Rinia et al. 1998). Malaysia has 66 % publications, which are not cited at all followed by Iran, Algeria and Pakistan with 59 % publications. This undoubtedly shows that the scholarly impact of the scientific research of the Islamic World is very less as compared to the other developed nations.

International collaboration

In this era scientific research is no longer a matter of individual scientist. A large number of projects are completed by group of scientists. International research collaboration is defined as the share of articles published together with at least one author from another country anywhere in the world (Jung 2012). These international research collaborations could be the result of government or individual interest, motivation of scientist or bilateral agreement between institutions. The factors that affect the international research collaboration include size of the country, economic and political reasons, as well as different aspects of migration and mobility at individual level. Figure 11 shows the number of publications and co-authored publications of the selected countries during 2000–2011. Interestingly, all the publication of Indonesia are written with at least one international co-author followed by United Arab Emirates with 85 % publications written with one international author followed by Algeria, Jordan and Saudi Arabia with 68, 64, 63 % publications written with international authors respectively.

The increase in the international collaboration could be the reflection of the efforts of OIC and all other organizations under the OIC which are playing a major role in strengthening the development of S&T, cooperation and networking among the Islamic countries for socio-economic progress (Fig. 12).

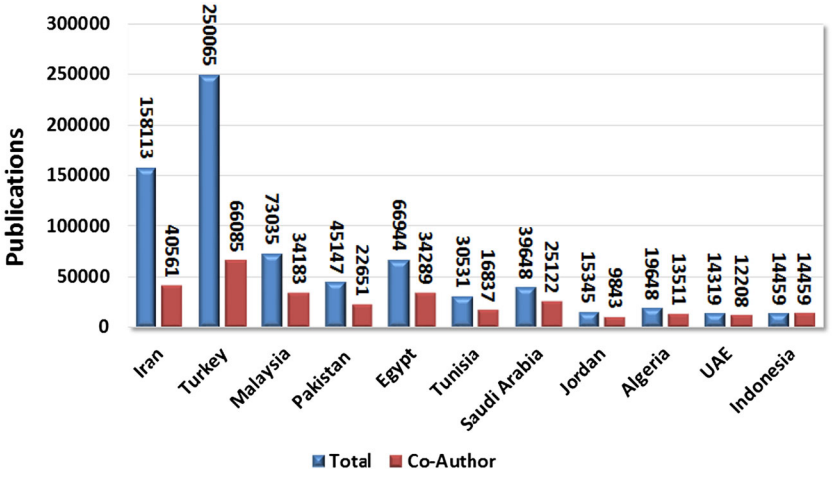

Fig. 11 Total and co-authored number of publications during 2000–2011

Collaboration pattern

Further, we analyze the authorship pattern of the publications produced by the selected Islamic countries. We present the collaboration profile of Islamic World by using Co-Authorship Index (CAI). The CAI index has been proposed by Schubert and Braun (1986) to study the collaboration patterns. The mathematical representation of Co-authorship index is calculated as follows:

$$\mathrm{CAI} = \frac{C_i}{C_o} \Big/ \frac{W_i}{W_o}$$

where C_i represents the volume of papers co-authored in the ith country, C_o represents the volume of papers in the ith country, W_i represents the number of papers co-authored in all countries, and W_o represents the total volume of papers in all countries.

CAI = 100 represents that the number of co-authored publications corresponds to the world average, CAI > 100 indicates higher than the world average, and CAI < 100 reflects lower than the world average. Figure 13 clearly indicates that CAI of Islamic world is more than the average except for Iran and Turkey. It means that authors of the Islamic World except for Iran and Turkey desired to work with international groups. The CAI for Iran and Turkey is different from other Islamic World countries they work within the country. Indonesia has the highest the co-authorship index value among Islamic countries. After Indonesia, The United Arab Emirates, Algeria, Jordan, Saudi Arabia, Tunisia, Egypt, Pakistan are the countries having co-authorship index value 183, 145, 137, 136, 118, 110 and 108 % respectively which are more than 100, it means that authors of these countries collaborate with international groups.

Co-authorship network graph

Co-authorship network graph is well documented and the most tangible form of scientific collaboration. By analyzing co-authorship network, every aspect of scientific collaboration

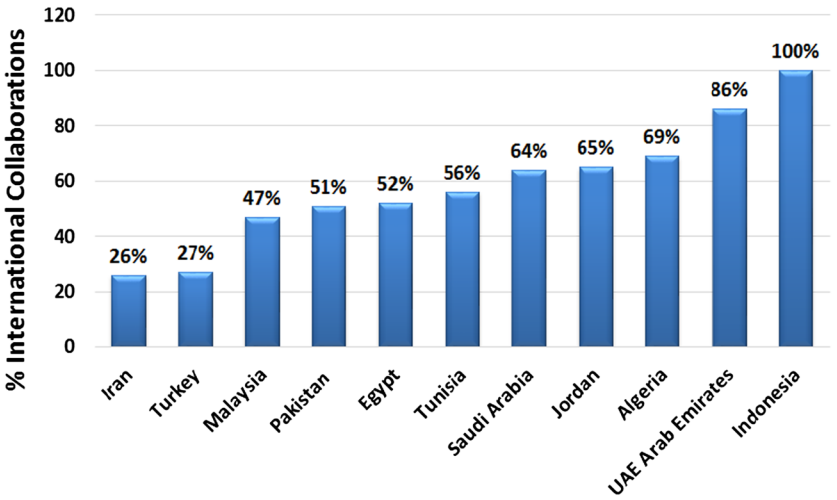

Fig. 12 Percent international collaboration during 2000–2011

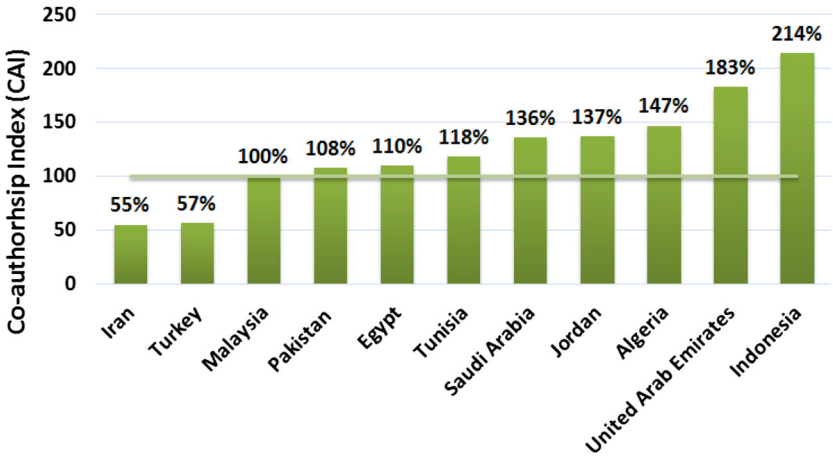

Fig. 13 CAI during 2000–2011

can be tracked reliably by using bibliometric methods (Erfanmanesh et al. 2012). Figure 14 presents the co-authorship network graph of the selected countries and their top four collaborator countries in S&T subject areas during 2001–2011 using Pajek package. The vertices, with green color, represents the Islamic World countries taken into consideration for this case study and vertices having blue color represents the countries which are top collaborators with the Islamic World countries. The less distances between vertices depicts strong collaboration between two countries, a large distance between vertices indicates week collaboration between countries and size of the vertices depicts the weight of countries in terms of publications volume. We use a well known Salton's measure (Salton and Bergmark 1979) to quantify the collaboration strength. Figure 14 shows that the

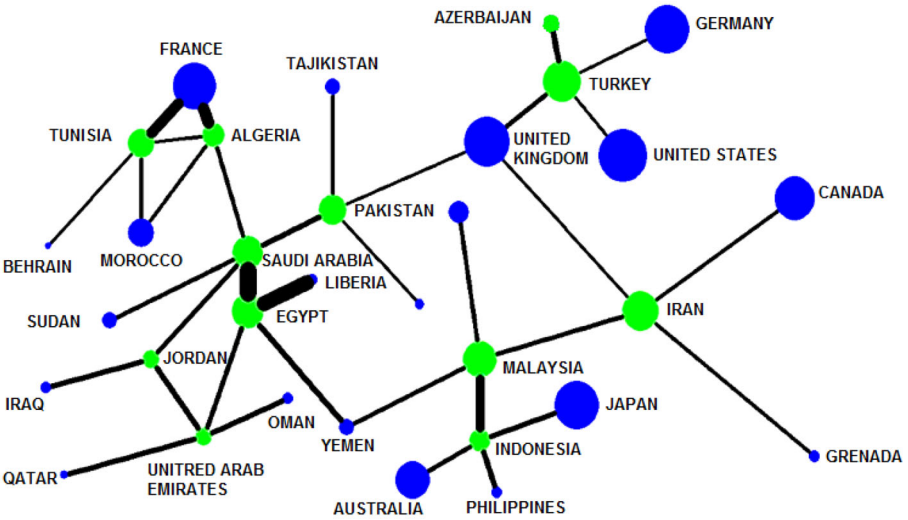

Fig. 14 International collaboration network graph during 2000–2011 using Pajek

Azerbaijan, Malaysia and Indonesia are top collaborator of the three most progressive countries of Islamic World, i.e. Turkey, Iran and Malaysia respectively. Moreover, we can clearly see the effect of same cultural and geographical background on the research collaborations form Fig. 14. We find that Middle East countries have strong collaboration with each other e.g. Saudi Arabia, Yemen, United Arab Emirates, Egypt, Iraq, Jordan, Oman and Liberia highly collaborate with each other. Similarly, Philippines, Malaysia Indonesia, and Japan show strong bonding due to same cultural background. Similarly, Tunisia and Algeria, Turkey and Azerbaijan, Pakistan and Tajikistan respectively show the effect of cultural background on research cooperation.

The Islamic World countries Algeria and Tunisia have top collaboration with France. The Azerbaijan, Tajikistan, Indonesia are the neighbors and top collaborators of Turkey, Pakistan and Malaysia respectively. From Fig. 14 we can see that most of the Islamic world countries have top collaborator within the Islamic world, it may be due to the efforts of OIC which is playing a major role in encouraging the development of S&T, cooperation and networking among the Islamic countries for socio-economic progress.

Conclusions

In this case study we have explored the research developments and features across S&T subject areas to access the research productivity, impact and collaboration pattern of the Islamic World. The bibliographic data over the time period of 2000–2011 was taken from the Scopus database to conduct this case study. Empirical data and all the information about the Islamic world can be concluded as follows:

1. In Islamic world Turkey is clearly leading in terms of publication output, Iran takes 2nd rank in terms of publications, Malaysia, Egypt, and Pakistan takes 3rd, 4th and 5th rank respectively in terms of number of publication.
2. After 2009 the research output of the Islamic World is above than average research output of the world in every subject area. Thus, it shows a clear visibility of the Islamic World contributing to the world class research.
3. In the Islamic World, Veterinary research output is at the top followed by Chemical Engineering, Chemistry, Dentistry, Agricultural and Biological Sciences followed by Mathematics, Pharmacology Toxicology and Pharmaceutics, Material Science, Environmental Sciences.
4. During 2000–2011, the Islamic World shows increase in its annual number of publications by more than 10 % across all S&T areas.
5. Top five subject areas of Islamic world with respect to the annual growth rate are Economics, Econometrics and Finance, Immunology and Microbiology, Agricultural and Biological Sciences, Mathematics and Computer Science.
6. Top collaborators of Islamic world are roughly within Islamic Countries except for Tunisia and Algeria have top collaboration with France, it is due to the efforts of OIC and all other organizations under the OIC which are playing a major role in strengthening the development of S&T, cooperation and networking among the Islamic countries for socio-economic progress. However, it is extremely important for the Islamic World to increase their international collaboration with outside world in order to welcome new ideas into their research.

7. Authors of the Islamic World except for Iran and Turkey preferred to work in large groups. The CAI for Iran and Turkey is diverged from other countries of Islamic world as they work in relatively small groups.
8. Except for Indonesia, Islamic world have average two author per paper and Indonesia have average three authors per paper, We can say that Islamic world has a trend of more people working together rather than individual scientist.

The Islamic World states are spread over four continents. We found that the Islamic World states of the same cultural zone or geographic region have strong research collaboration bond. In order to maximize the research productivity, the Islamic World must come up with long term and short term plans to facilitate this existing research network sharing same cultural zone or geographic region. Moreover, the most advanced Islamic World states in terms of scientific research, such as, Turkey, Iran and Malaysia should offer their skills to less advanced Islamic World states. Moreover, the Islamic World has numerous shared and common problems. It is very important for Islamic World states to make stronger the coordination and cooperation with each other, in both private and public sectors. Furthermore, the Islamic World states rich in natural resources and low in human resources, for instance, United Arab Emirates, Qatar, Saudi Arabia and Kuwait should collaborate with the states whom the revers applies e.g. Bangladesh, Pakistan and Indonesia.

We found that the publications share of the Islamic World in the world's top 25 % publications with respect to the citations is very less as compared the other developed nations. This undoubtedly shows that the impact of the scientific research of the Islamic World is very less as compared to the other developed nations. The impact of research can be enhanced by cooperating with the top research groups in the world and by working on the real world problems.

The current position of the Islamic World is greatly lower than desired in the global research landscape. We find an increasing gap between the Islamic World and developed nations in terms of scientific research productivity that is dependent on a number of factors. For instance, the developed nations have been investing substantial amount on scientific research that has caused in betterment of economic strength. On the other hand, unfortunately, this tendency has been mission in the case of Islamic World. The Islamic World encompasses one-fourth of the total world populace with only 2.4 % of the gross expenditure on research and development (GERD) that is very low as compared to the other developed nations of the world (Nabil and Kenan 2014). Therefore, it is obligatory for Islamic World to formulate policies aims to increase GERD as a proportion of GDP. Moreover, academic programs based on merit, incentives for the encouragement of commercialization of scientific research, vigorous peer review system and research valuation programs should be established and/or continued across the Islamic World to guarantee that further funding leads to high quality research.

The Islamic World required more investment in terms of human capital. Nabil and Kenan (2014) show that Islamic World comprises only a small share of the world's researchers relative to its population, which is only 10 %. Moreover, the reason behind the low high technology exports of the Islamic world is the less investment by private sector in R&D. By studying the research landscape, we find that the Islamic World is making an impressive progress in S&T but it is still low as compared to the other developed nations. The Islamic World must draw out long-term and short term plans to become more active and competitive in scientific research in the World. Special attention needs to be given to improve the status of international collaboration with outside world.

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