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A Framework for Description and Measurement of National Scientific Wealth with a Case Study on Iran

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ABSTRACT
A sustainable development in science, innovation, and technology requires a balanced distribution of scientific wealth in sub-country regions. This paper addresses the issue of geographical distribution of scientific wealth and its goal is to offer a framework to describe and measure the share of provinces in national scientific wealth. Our proposed model divides the indicators of scientific wealth into two groups, production and the use of scientific wealth. To evaluate this model, the scientific wealth of Iran was studied using recorded data on IRANDOC databases. Rich, average, and poor provinces were identified and the results showed that 70% of the scientific wealth belongs to 20% of the provinces. The findings can facilitate planning for a sustainable science and technology policy.

Keywords: Scientific wealth, Iran, Geographical distribution, Regional development, Science productivity

1. INTRODUCTION

Scientific growth is one aspect of development that demonstrates how competitive each nation is regarding its science and technology achievements. Different indicators have been developed in order to show the scientific and scholarly competency of nations, including what follows: (a) quantity of contribution

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in production of scholarly literature on a global level, such as what appears in Scimago (Guerrero-Botea & Moya-Anegón, 2012) and Web of Science; (b) innovations and registered patents, especially if registered by international authorities; (c) access to and utilization of new technologies such as access to high speed Internet; and (d) the amount of investment in technology and research, especially compared to the whole of expenditures in a single country. Details on science and technology indicators on a national level can be found in Grupp and Mogee (2005).

Research and development (R&D) intensity refers to the expenditures on R&D as a proportion of GDP and can indicate the relative amount of investment for generating new knowledge (OECD, 2012). Since the 1990s, in many developing countries governments started adopting new knowledge-based economies, paying attention to R&D strategies, science and technology (S&T) infrastructures, and foreign investments in science, research, and technology (U.S. Census Bureau, 2011). The global pattern on expenditure on R&D shows a 6.7 percent increase each year during the first decade of the 21st century; though 2011 statistics revealed that the main countries spending on research and science are limited to North America, Europe, and East Asia. In contrast, the countries in Central America, South America, Central Asia, the Middle East, Australia/Oceania, and Africa have accounted for only 10 percent of global expenditures on R&D in 2011 (International Comparisons of R&D Performance, 2014).

Regarding international movements for scientific development, the developing country of Iran has included science and technology development policies in its socioeconomic plans such as the continuing *Five-Year Social and Economic Development Plan* (PMO, 2003). Paying more attention to science, technology, and innovation as well as increases in higher education has resulted in a rapid increase in the number of Iranian domestic and international publications. For example, Iran has been recognized as the third fastest country in the world in growth of submitting scholarly papers to Web of Science during the period of 2005-2010 (Thomson Reuters, 2012).

In contrast to the quantitative growth of scientific output, there is little evidence about the global scientific impact of Iran. On the other hand, the effects of research activities have not been evident and visible in the social and economic development of the country. From the geographical viewpoint, the unbalanced regional development is an obvious issue in this developing country.

Focusing on the contribution of different provinces of Iran toward the production and use of scholarly publications, the goal of this research is to study the geographical distribution of the scientific wealth in Iran. The main problem addressed in this research is how to calculate and measure the distribution of the scientific wealth among Iranian provinces. The following questions are studied in this research:

1. What is the contribution of Iranian provinces in production of national scientific wealth?
2. What is the contribution of Iranian provinces in the use of national scientific wealth?
3. How can the distribution of scientific wealth be measured at a sub-country level?
4. How are the Iranian provinces ranked according to their share in the country's national scientific wealth?

2. A MODEL FOR PRESENTATION OF SCIENTIFIC WEALTH

Science production and use has been a topic of research for years. Inhaber and Alvo (1978) offered an approach to measuring science with paying attention to the inputs and outputs of a scientific activity. The term *scientific wealth* has appeared in the research entitled "The scientific wealth of nations," in which the scientific publications of some countries were comparatively studied (May, 1997). The study assessed the scientific wealth of the countries along two items: the number of scientific products and the number of citations. Similar studies have been conducted using other terminologies, especially scientific impact (King, 2004; Belew, 2005; Poddly, 2005; Radicchi, Fortunato, & Castellano, 2008; Lebeau et al., 2008). However, it seems that scientific wealth is something more than the pure counting of scientific publications or citations as many other factors may influence this wealth. Therefore, we propose a more comprehensive model to illustrate the structure of scientific wealth and its components (Fig. 1). In our model, scientific wealth consists of two main categories: science production and use. Each part is di-

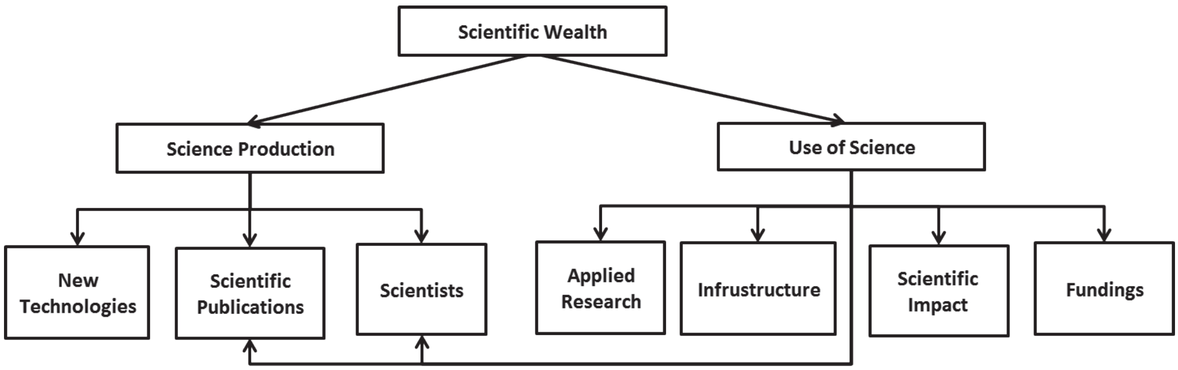


Fig. 1 Proposed model of the structure of national scientific wealth based on science production and use

vided into sub-classes presented as science indicators.

It is necessary to mention that the presented model can be challenged in two ways: comprehensiveness and reliability. Comprehensiveness means that the model of the scientific wealth should be able to reveal all the intervening aspects of the production and exploitation of the science. Reliability of the presented model also can be found out via common ways such as the feedback of the experts' view.

According to the amount of the contribution of the provinces in the production and the exploitation of scientific wealth, provinces have been classified into three groups: rich, average, and poor. It can be assumed that provinces with more than n publications are ranked as rich provinces from the viewpoint of the production of scientific wealth. Such thresholds have sometimes been used in other situations. For instance, Iranian families have been divided into two groups, of higher and lower than the poverty line, by the determination of the specific amount of income. We have modified this categorization as it is explained in the Methodology section. Using such categorizations in order to emphasize the inequity of the provinces in the case of science and technology can help to reach a sustainable national development. From a global view, adopting new technology and investments in infrastructures reduces the gap between North and South countries (UNESCO, 2010).

3. LITERATURE REVIEW

Scientometrics researchers have considered geography as a key item for analysis of scientific collaborations. The first steps were taken to illustrate world regions' contributions in the global citation indices. Frame, Narin, and Carpenter (1977) reported on the global coverage of ISI's SCI. The rate and inadequate coverage of developing countries' scientific productions in global citation indices was also considered by Garfield (1983), Moravcsik (1985), Frame (1985), and Shrum (1997).

Other research efforts show that the international contribution of the different regions and universities of a country follows different patterns. For instance, a study on the international contribution of different organizations and regions of Spain revealed that the older universities have more international contribution. In this country, the Catalonia region also has more international records according to its special autonomy (Olmeda-Gómez et al, 2008). Okubo and Zitt (2004) studied the scientific relationship of France with its neighboring countries and showed that France, Germany, and England had the best level of scientific contribution. From the researchers' point of view, language has been the key factor in the mentioned international contributions in the way that, for example, there has been more contribution between Finland and Sweden.

Navaro and Martin (2008) studied the patterns of domestic and international collaboration in some countries. The results show that the more a country produces scientific publications the more it has inner scientific cooperation among its regions and organizations; however, the amount of international contribution is not necessarily high. Instead, the most international collaboration is among countries where their scientific production is not as high. The European countries have paid more attention to scientific relationships with other European countries than for other countries, which probably is the result of geographic proximity.

Glanzel, Schubert, and Czerwon (1999) studied the scientific production of the Europe Union or other world regions. King (2004) studied the publications of 31 countries from the different regions of the world from 1993 to 2000. Osareh and Wilson (2000) focused on the international scientific collaboration of Iranian authors and found out that the most repeated joint papers happened with colleagues from the U.S. and U.K.

Anselin, Varga, and Acs (1997) studied the spatial spillover between university research and high-tech innovations and found spatial externalities between university research and high-tech innovations. Ponds, Oorta, and Frenkena (2007) showed that geographic proximity is important for scientific collaboration of academic-industrial sectors. This proximity is not effective for pure academic relations.

Another geographic feature of scientometrics studies can be found in the visualization of co-authorships around the world. Leydesdorff and Persson (2010), Leydesdorff and Rafols (2011), and Bornmann and Leydesdorff (2011) have studied the distribution of science production and scientific effectiveness in the world, with emphasis on Europe and the developed countries. A combination of GIS maps and social network analysis tools can result in interesting representations of knowledge around the world.

Science and technology (S&T) ties with economic development has led to different national and international measurements and indicators. *Statistical Abstract of the United States: 2011* contains different tables about the share of U.S. states in national R&D activities (U.S. Census Bureau, 2011). The National Science Board's *Science and Engineering Indicators 2012* reports on the decreasing amount of R&D in national GDP of the U.S. compared to Asian competitors i.e. Japan and South Korea (National Science Board, 2012). More global statistics are available from OECD Scoreboard (OECD, 2012).

The relationship between scientific outcomes and regional development has been studied by Asadi and Moradi (2014). The correlation between industrial indicators and the scientific productivity of 31 Iranian provinces was examined and the results showed strong correlation.

In summary, the previous work has compared the scientific productivity of different countries or citations among those countries. How the science is nationally distributed has not been carefully studied and this paper focuses on this topic.

4. METHODOLOGY

A survey was conducted on available research, science, and technology data on Iran as features of national scientific wealth in order to examine the practicability of the proposed model. Bibliometric techniques such as counting the number of publications co-authorship and citation analysis were used in order to make the components of the suggested model.

The dataset for this research was built using all of the publications indexed in seven databases of IRANDOC,[1] which consisted of 504,000. For any specific record in the databases of IRANDOC, there was at least one province affiliated as producer of that publication. Author, Organization, and University fields were looked at to find the producing provinces. For each record, it was possible to find one or more beneficiary provinces, i.e. the geographical entities

[1] Iranian Research Institute for Information Science and Technology (IRANDOC): www.irandoc.ac.ir

in Title, Subject, Keywords, and Location fields. The geographic names became uniform and sub-provincial names were replaced with the province name, because research granularity was limited to provinces. For instance, a thesis from the University of Tehran was titled as "Agricultural industries of Shiraz." The title refers to Shiraz, the provincial capital of Fars province, while it has been researched and written at the University of Tehran. As a result, Tehran province can be considered as the producer and Fars province as the beneficiary for this piece of work.

The number of hits for geographic names was considered as a weight for ranking the Iranian provinces for each single query. Based on the obtained weights, each province was classified in one of these groups: rich, average, and poor. Iran had 31 provinces in 2011 and for each query, these provinces were first looked up in the mentioned fields and then ranked according to the frequency of appearance. Twenty percent of the top and bottom provinces were tagged as *rich* and *poor* regions respectively, based on production or beneficiary in the national scientific weights.

5. EMPIRICAL RESULTS

The retrieved records from IRANDOC databases have been analyzed in order to get comparative results. Table 1 shows the distribution of scientific products retrieved from the mentioned databases. Tehran province with 77,674 records has the most number of the indexed records. Considering all of the databases, this province still allocates the first position. This is due to the scientific, political, and cultural centrality of Tehran Metropolis, which holds various research centers and large universities. With 18,570 records, Isfahan province is ranked the second productive province. Having about 100 cities and towns and locating various centers of higher education, Isfahan province has enough facilities for production of more scientific resources. Mazandaran, Fars, Guilan, and Sistan and Baluchistan provinces have been placed in the next rankings. In contrast, Qom, Northern Khorasan, and Alborz provinces had the least scientific products. Due to its new establishment, Alborz province has the least reserved records in the form of Alborz province.

Figure 2 compares the number of retrieved records for 31 provinces regarding the sum of retrieved records from six databases. The share of Tehran province in the retrieved records has obviously been much more than the other provinces – at least 4 times more than Isfahan, the second high ranked province. The overall average of the retrieved resources from the six studied databases is 5,905 titles for each province.

Table 2 shows the results of the scientific products retrieved from each field. The *title* field, with an average of 2,231 records, has the highest number of location names of Iranian provinces. The field of *university* with a subtle distance is located in the second ranking with the mean of 2,228 records for each province.

Table 3 shows the distribution and percent share of each province from three different aspects related to the scientific wealth of the country. The first and second columns reveal the share of each province as the *producer* of national scientific wealth. The next two columns indicate the share of each province as the *beneficiary* of the scientific wealth and the last two columns show the share of the provinces in the total scientific wealth of the country. Tehran province with more than 63% has the highest share and is ranked first for *production* of national scientific wealth. It also has the first ranking for the *use* of the scientific wealth. In total, Tehran shares 42% of the national scientific wealth of Iran and is absolutely a unique shareholder. Isfahan is the second province after Tehran again in all three aspects. Mazandaran province is the third province and Sistan and Baluchistan is forth in scientific *production*. The provinces of Fars and Mazandaran are ranked third and fourth in the use of national science. Mazandaran is the third province in the total share of scientific wealth of the country and Fars stands fourth. Neighboring Tehran province, the two provinces of Qom and Alborz with less than 500 records are located at the bottom of the list.

Table 4 shows the final rank of 31 provinces based on their share in the national scientific wealth. For instance, Guilan province with 2.8% of the science production has the fifth rank in the science production of the country and is a *rich* province from this aspect. Having 4.51% of the total records of *use*, this province is located in the eighth rank and is regarded as an *average* province; it means that it is neither rich nor poor. With 3.7% of the total, Guilan province is located in the fifth rank and is regarded a *rich* province regarding

Table 1. Distribution of Retrieved Records for Provinces With Separation of the Database

Province	Theses	Theses, Recently Added	Journal Articles	Con-ference Papers	Research Reports	Govern-ment Reports	Total
Alborz	182	46	92	34	84	39	477
Ardabil	213	66	86	112	314	80	871
Azarbayejan, E	928	198	306	356	1132	422	3342
Azarbayejan, W	898	195	351	305	1007	194	2950
Bushehr	588	224	347	238	1207	323	2927
Chaharmahal & Bakhtiari	291	67	124	116	454	109	1161
Fars	2224	653	1003	890	2756	588	8114
Guilan	2293	867	612	534	1964	530	6800
Golestan	322	135	227	155	458	53	1350
Hamadan	374	91	145	184	922	226	1942
Hormozgan	380	136	365	181	915	191	2168
Ilam	225	55	103	69	345	164	961
Isfahan	7361	3589	1494	1521	3878	727	18570
Kerman	1507	281	587	682	2163	353	5573
Kermanshahan	2836	538	221	275	938	407	5215
Khorasan Razavi	1625	586	513	729	1889	465	5807
Khorasan, N.	153	57	107	98	90	44	549
Khorasan, S.	173	75	59	77	160	60	604
Khuzestan	1194	306	705	533	2067	559	5364
Kordestan	525	466	294	96	821	190	2392
Kuhgiluyeh & Buyerahmad	125	41	56	25	558	58	863
Lorestan	452	282	154	160	628	116	1792
Markazi	363	149	135	120	614	136	1517
Mazandaran	4027	1423	830	715	2118	656	9769
Qazvin	348	32	120	110	266	25	901
Qom	106	26	47	48	109	129	465
Semnan	953	549	180	205	854	248	2989
Sistan & Baluchestan	3220	1047	461	250	1187	443	6608
Tehran	57517	4301	5024	1575	6229	3028	77674
Yazd	596	103	281	219	866	216	2281
Zanjan	180	58	86	110	474	154	1062
Total	92179	16642	15115	10722	37467	10933	183058

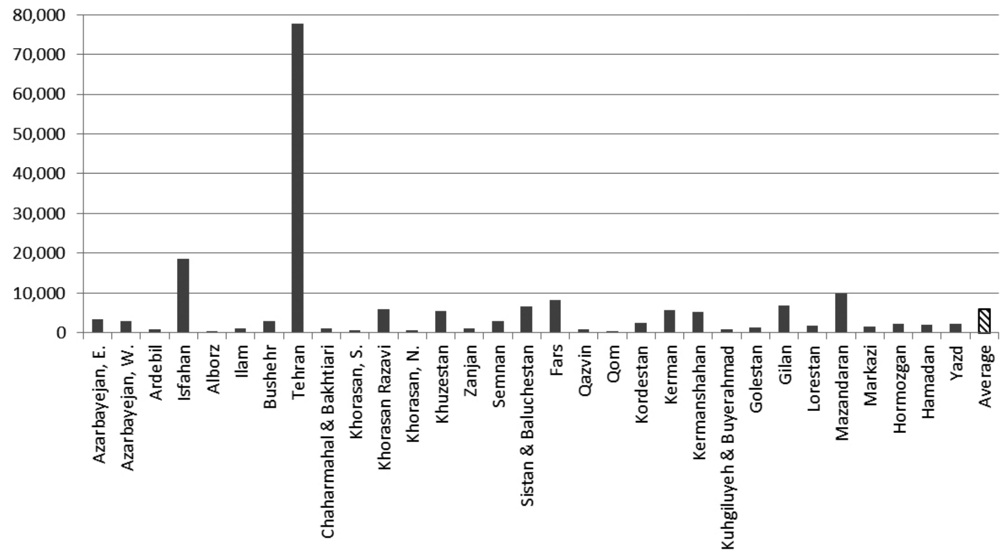


Fig. 2 Frequency of retrieved resources from the 6 databases of IRANDOC for each province

its share in the national scientific wealth in total.

Figure 3 shows the status of the rich, average, and poor groups of the provinces respectively from the aspects of *production*, *use,* and *total* share in the scientific wealth of Iran. In the production section, 90% of the scientific products of the country are produced by only 20% of the provinces of the country. From the aspect of science use, 20% of the provinces of the country have allocated 56% of the scientific subjects to themselves and in total, the share of the rich provinces from the scientific wealth of the country is 70%, the average provinces is 28%, and the poor provinces is only 2%. On the other hand, six rich scientific provinces of the country have allocated 70% of the scientific wealth of Iran to themselves; whereas, the other 25 provinces share only 30% of the scientific wealth of the country. Totally, the findings of the present research show a deep gap between rich provinces and the rest of the provinces from the aspect of the contribution in science production and use.

6. DISCUSSION AND CONCLUSIONS

Focusing on the concept of scientific wealth, a novel method was introduced and examined in this research to assess the distribution of scientific wealth at a sub-country level. By having a list of the inputs and outputs of the science cycle, it is possible to assess the amount of the contribution of the regions of a country in production or use of the national scientific wealth. In this research, the amount of the production or use of scientific products was paid attention to as indicators of scientific wealth. More studies are needed to determine the scientific wealth more carefully in each region and all over the country in regard to infrastructure, legislation, budgets, and human resources.

According to the Pareto principle (also known as "the 80-20 rule") most of the wealth is concentrated in a small proportion of the population (Sanders, 1987). This study revealed that the Pareto principle can be roughly applicable to the share of Iranian provinces in national scientific wealth. It means that a small 20% of Iranian provinces held a 70% share in the national scientific wealth. This can indicate the unbalanced distribution of scientific wealth in Iran, in coordinate with previous research such as Garfield (1983), Moravcsik (1985), Frame (1985), and Shrum (1997) which indicated the scientific production gap between developed and developing countries. Sustainable scientific devel-

Table 2. Frequency Distribution of Retrieved records for Each Province in Different Fields

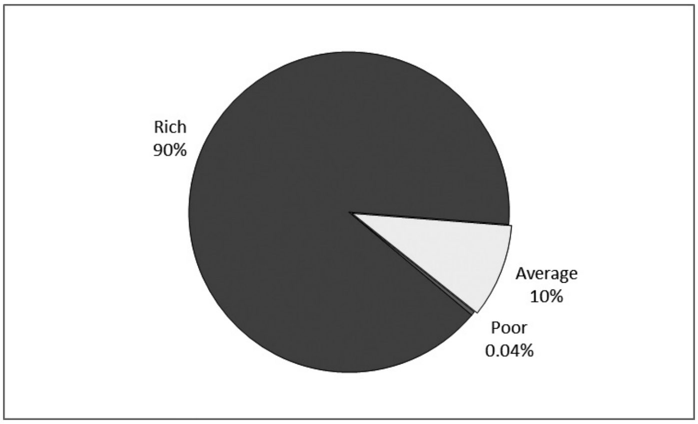
Province	Title	Subject	Keyword	University	Total
Alborz	330	77	70	0	477
Ardabil	547	244	79	1	871
Azarbayejan, E	1916	999	407	20	3342
Azarbayejan, W	1814	780	351	5	2950
Bushehr	1607	922	270	128	2927
Chaharmahal & Bakhtiai	660	367	134	0	1161
Fars	4681	2320	925	187	8113
Guilan	2886	1594	619	1701	6800
Golestan	835	396	116	3	1350
Hamadan	1156	638	144	4	1942
Hormozgan	1112	809	174	73	2168
Ilam	551	317	93	0	961
Isfahan	6766	3102	1454	7248	18570
Kerman	3352	1576	549	96	5573
Kermanshahan	2120	839	705	1551	5215
Khorasan Razavi	3345	1477	710	275	5807
Khorasan, N.	431	79	39	0	549
Khorasan, S.	418	114	69	3	604
Khuzestan	3060	1704	529	71	5364
Kordestan	1208	671	183	330	2392
Kuhgiluyeh & Buyer	417	389	57	0	863
Lorestan	969	470	165	188	1792
Markazi	862	441	117	97	1517
Mazandaran	3857	1777	876	3259	9769
Qazvin	546	199	109	47	901
Qom	304	129	32	0	465
Semnan	1272	636	216	865	2989
Sistan & Baluch.	2095	1184	592	2737	6608
Tehran	18097	4930	4487	50160	77674
Yazd	1341	669	264	7	2281
Zanjan	603	391	67	1	1062
Total	69158	30240	14602	69057	183057

Table 3. Frequency of Appearance of Provinces as *producer* or *beneficiary* in the Dataset

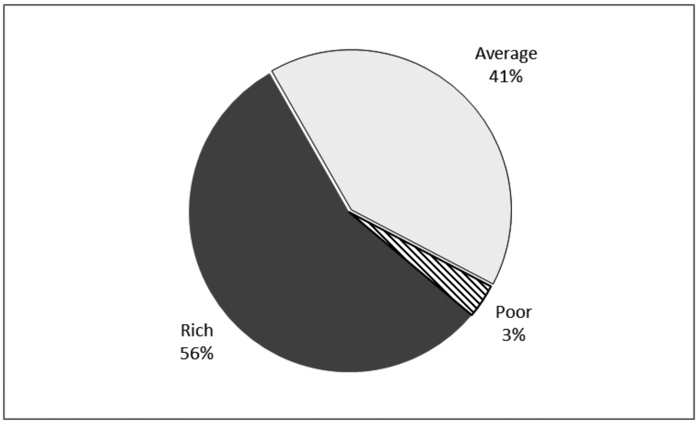
Province	Producer		Beneficiary		Total	
	Frequency	Percent	Frequency	Percent	Frequency	Percent
Alborz	70	0.1%	407	0.41%	477	0.26%
Ardabil	80	0.1%	791	0.80%	871	0.48%
Azarbayejan, E	427	0.5%	2915	2.93%	3342	1.83%
Azarbayejan, W	356	0.4%	2594	2.61%	2950	1.61%
Bushehr	398	0.5%	2529	2.54%	2927	1.60%
Chaharmahal & Bakh	134	0.2%	1027	1.03%	1161	0.63%
Fars	1112	1.3%	7001	7.04%	8113	4.43%
Guilan	2320	2.8%	4480	4.51%	6800	3.71%
Golestan	119	0.1%	1231	1.24%	1350	0.74%
Hamadan	148	0.2%	1794	1.80%	1942	1.06%
Hormozgan	247	0.3%	1921	1.93%	2168	1.18%
Ilam	93	0.1%	868	0.87%	961	0.52%
Isfahan	8702	10.4%	9868	9.93%	18570	10.14%
Kerman	645	0.8%	4928	4.96%	5573	3.04%
Kermanshahan	2256	2.7%	2959	2.98%	5215	2.85%
Khorasan Razavi	985	1.2%	4822	4.85%	5807	3.17%
Khorasan, N.	39	0.0%	510	0.51%	549	0.30%
Khorasan, S.	72	0.1%	532	0.54%	604	0.33%
Khuzestan	600	0.7%	4764	4.79%	5364	2.93%
Kordestan	513	0.6%	1879	1.89%	2392	1.31%
Kuhgiluyeh & Buyer	57	0.1%	806	0.81%	863	0.47%
Lorestan	353	0.4%	1439	1.45%	1792	0.98%
Markazi	214	0.3%	1303	1.31%	1517	0.83%
Mazandaran	4135	4.9%	5634	5.67%	9769	5.34%
Qazvin	156	0.2%	745	0.75%	901	0.49%
Qom	32	0.0%	433	0.44%	465	0.25%
Semnan	1081	1.3%	1908	1.92%	2989	1.63%
Sistan & Baluchestan	3329	4.0%	3279	3.30%	6608	3.61%
Tehran	54647	65.3%	23027	23.17%	77674	42.43%
Yazd	271	0.3%	2010	2.02%	2281	1.25%
Zanjan	68	0.1%	994	1.00%	1062	0.58%
Total	83659	100.00%	99398	100.00%	183057	100.00%

Table 4. Ranking the Provinces Based on Indicators of Scientific Wealth

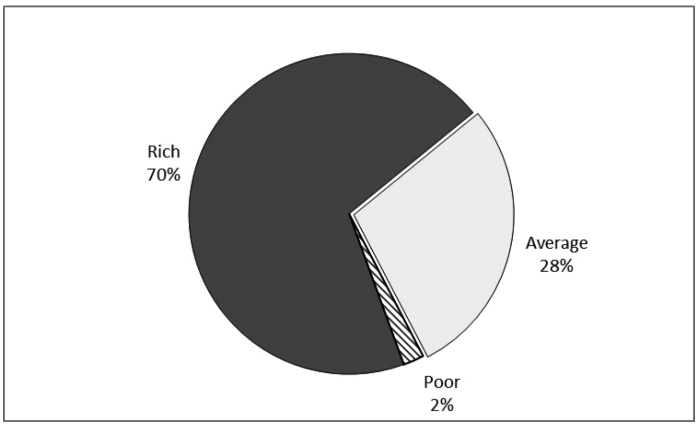
Province	Total			Production			Use		
	%	Indicator	Rank	%	Indicator	Rank	%	Indicator	Rank
Tehran	42.4%	Rich	1	65.3%	Rich	1	23.17%	Rich	1
Isfahan	10.1%	Rich	2	10.4%	Rich	2	9.93%	Rich	2
Mazandaran	5.3%	Rich	3	4.9%	Rich	3	5.67%	Rich	4
Fars	4.4%	Rich	4	1.3%	Average	7	7.04%	Rich	3
Guilan	3.7%	Rich	5	2.8%	Rich	5	4.51%	Average	8
Sistan & Baluchestan	3.6%	Rich	6	4.0%	Rich	4	3.30%	Average	9
Khorasan Razavi	3.2%	Average	7	1.2%	Average	9	4.85%	Rich	6
Kerman	3.0%	Average	8	0.8%	Average	10	4.96%	Rich	5
Khuzestan	2.9%	Average	9	0.7%	Average	11	4.79%	Average	7
Kermanshahan	2.8%	Average	10	2.7%	Rich	6	2.98%	Average	10
Azarbayejan, E	1.8%	Average	11	0.5%	Average	13	2.93%	Average	11
Semnan	1.6%	Average	12	1.3%	Average	8	1.92%	Average	16
Azarbayejan, W	1.6%	Average	13	0.4%	Average	15	2.61%	Average	12
Bushehr	1.6%	Average	14	0.5%	Average	14	2.54%	Average	13
Kordestan	1.3%	Average	15	0.6%	Average	12	1.89%	Average	17
Yazd	1.2%	Average	16	0.3%	Average	17	2.02%	Average	14
Hormozgan	1.2%	Average	17	0.3%	Average	18	1.93%	Average	15
Hamadan	1.1%	Average	18	0.2%	Average	21	1.80%	Average	18
Lorestan	1.0%	Average	19	0.4%	Average	16	1.45%	Average	19
Markazi	0.8%	Average	20	0.3%	Average	19	1.31%	Average	20
Golestan	0.7%	Average	21	0.1%	Average	23	1.24%	Average	21
Chaharmahal & Bakhtiari	0.6%	Average	22	0.2%	Average	22	1.03%	Average	22
Zanjan	0.6%	Average	23	0.1%	Poor	28	1.00%	Average	23
Ilam	0.5%	Average	24	0.1%	Average	24	0.87%	Average	24
Qazvin	0.5%	Average	25	0.2%	Average	20	0.75%	Poor	27
Ardabil	0.5%	Poor	26	0.1%	Average	25	0.80%	Poor	26
Kuhgiluyeh & Buyerahmad	0.5%	Poor	27	0.1%	Poor	29	0.81%	Average	25
Khorasan, S.	0.3%	Poor	28	0.1%	Poor	26	0.54%	Poor	28
Khorasan, N.	0.3%	Poor	29	0.0%	Poor	30	0.51%	Poor	29
Alborz	0.3%	Poor	30	0.1%	Poor	27	0.41%	Poor	31
Qom	0.3%	Poor	31	0.0%	Poor	31	0.44%	Poor	30



A. Share of scientific wealth production



B. Share of scientific wealth beneficiary



C. Total share of national scientific wealth

Fig. 3 Share of national scientific wealth of Iran among rich, average, and poor provinces opment requires planning for more normal distribution of science in a country. This can be examined for any other country in the world to find out how equally this wealth is distributed.

A careful assessment of the distribution of scientific wealth in the country, the amount of equality, and logical justice in accessing it can be a subject for further research. Besides the quantitative aspect of the scientific productions of a country, the study of the effectiveness of the costs and infrastructure will lead to more useful results.

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