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Synergy in the Iranian Innovation Systems at Regional and National Levels In the Triple-Helix Context

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Abstract

The synergies for the Iranian regional and national innovation systems among the geographical, technological and organizational distributions of firms were measured. Among the data of 87934 active industrial firms (December 2015), merely 46150 firms could be classified using NACE codes into high-tech, medium-tech and knowledge intensive sectors which in turn geographically divided into five regions. Accordingly, both the T_0 and ΔT_{GTO} of Iran at the national level had negative signs (-480.6 and -5.14 mbits, respectively), however all the ΔT_{GTO} s in each separate region was highly positive denoting that national agglomeration significantly adds to the synergy in the system and a highly integrated national innovation system was proposed in Iran. Regions 1 (including Tehran as the capital) as well as region 4 (including Khuzestan which contains enormous oil and gas resources and industries) caused less disturbance to the national synergy compared with the other three regions (ΔT_{GTO} s= +18.1 and +22.2 mbits, respectively). The decomposition of sectorial technologies showed that in contrast to many other countries, especially for west European countries, high-tech manufacturing and knowledge intensive services were the main drives of knowledge-based configuration in the regional economy of Iran, while medium-tech manufacturing tend to uncouple the economy from the regional configuration.

Keywords: Knowledge-Based Economy, Triple Helix, Iran, Probabilistic Entropy, Innovation Systems

Introduction

The concept of “knowledge economy”, KE, is based on the view that knowledge and information play the main role in economic growth and development. In today’s ever changing world, knowledge has become a key factor for sustainable economic development and competitive advantage. The best economic performance is observed in the countries that have used the KE properly and preserved the institutional knowledge management. The latter provides information of the highest quality which is both timely and easily accessible to facilitate and enhance decision-making, strategic planning, and assessment at the system.

Over the past several decades, economic models are undergoing a "knowledge revolution", driven by knowledge as an intangible public good and by the technologies for processing and communicating the knowledge, which refers to an obvious transition from traditional economy (source-based economy) to the KE as a source of innovation and creativity (Leydesdorff, 2001).

One of the most famous organizations related to the KE is OECD¹. The OECD is established in 1961 in Paris and today its 35 member developed countries span the globe, from North and South America to Europe and Asia-Pacific². Currently, OECD provides a forum in which governments can work together to share experiences and seek solutions to understand what drives economic, social and environmental change and also measures productivity and global flows of trade and investment. Another simple KE benchmarking tool, the knowledge assessment methodology, was designed by the World Bank Institute.³ It is an online interactive tool that produces the KE index (KEI). This KEI is based on a simple average of four sub-indexes, representing the four pillars of the KE including: i) economic incentive and institutional regime; ii) innovation and technological adoption; iii) education and training; iv) ICT⁴ infrastructure. An efficient innovation system made up of firms, research centers, universities, commissions, consultants, and other organizations that could tap into the growing stock of global knowledge, adapt it to local needs, and create new technological solutions.

Beyond the unavoidably advantages of KE in every country (Foray & Lundvall, 1996; Abramowitz & David, 1996), a big question and maybe the most challenging issue in this field is "can something as elusive as the knowledge base of an economy be measured and/or quantified its extent and composition (Carter, 1996; OECD, 1996)? Accordingly, much time and effort is expended by many national as well as international organizations in an attempt to measure and expand the definition of KE (Carter, 1996; Oxley et al., 2008; Bedford, 2013). Social, economic, and political research, driven by this challenge, resulted in development of some theoretical models and concepts, which became highly influential in recent years (for instance national systems of innovation (Lundvall, 1988; Nelson, 1993)), regional innovation systems (Cooke, 1992), "Mode 2" knowledge production (Gibbons et al., 1994), clusters (Porter, 1998), and triple helix model (Etzkowitz & Leydesdorff, 1995, 2000)). All of them, though from different perspectives and with different theoretical background, justify the important role of innovation and knowledge infrastructure for the development of economic systems at different levels (e.g. regional, national, supra-national, etc.).

In this study we choose the triple helix (TH) model which was firstly introduced by Etzkowitz and Leydesdorff in 1995. In spite of the theoretical backgrounds of TH model, our concentration herein is on the use of this model to measure the knowledge economy. Up to now, quite a large number of quantitative empirical studies in the stream of the TH model have been carried out by plenty of authors in several countries to elucidate the possible synergies between knowledge production, wealth generation, and political control in systems of innovation. The main goal of this study is the employment of TH model to assess the innovative system of Iran, as an important country in the Middle East, in comparison with the other countries reported in the literature. Achieving this aim will require solving the following queries:

- How is the distribution trend of industrial firms (including three levels of high-tech, medium-tech and knowledge intensive) change in different provinces of Iran?
- How much does the national level add to the sum total of synergy (negative entropy) generated at the level of regions.
- What is the synergy ranking of high-tech industrial firms in Iran?
- What is the synergy ranking of medium-tech industrial firms in Iran?
- What is the synergy ranking of knowledge intensive industrial firms in Iran?
- What are the characteristics associated with the knowledge-based economy of Iran from the national or regional viewpoints?

Literature review

The TH model of innovation has attracted considerable attention in both developed and developing economies as an integral policy making tool to enhance innovation and promote economic development (Etzkowitz & Leydesdorff, 1997). Specifically, it advocates the strengthening of the collaborative relationships between academia, industry and government to improve innovation and can be regarded as an empirical method of learning and solving problems (Leydesdorff, 2013). The triple helix model of university-industry-government relations has hitherto been developed mainly as a (neo) institutional model for studying the knowledge infrastructure in networks of relations (Etzkowitz & Leydesdorff, 2000; Powell & DiMaggio, 1991). From this perspective, a triple helix can be formulated dynamically as the interactions among three (or more) sub-dynamics of a system (Leydesdorff & Etzkowitz, 1998).

The analytical function of the TH model is to loosen the complex dynamics of a knowledge-based economy in terms of its composing sub-dynamics. The TH indicator measures the synergy as redundancy generated among the distributions of relations (Leydesdorff, Park & Lengyel, 2014). The formal model is not a grand super-theory: it builds on and remains dependent on appreciations of the phenomena at the level of the composing theories. Not incidentally, the TH model originated from the study of science and technology (Etzkowitz & Leydesdorff, 2000; Mirowski & Sent, 2008; Shinn, 2002; Slaughter & Rhodes, 2004). In the TH context, the knowledge-based overlay and the institutional layer operate upon one another in terms of frictions that provide opportunities for innovation both vertically within each of the helices and horizontally among them. The quality of the knowledge base in the economy depends on the locally specific functioning of the interactions in the knowledge infrastructure and on the interface between this with the self-organizing dynamics at the systems level. A knowledge base would operate by diminishing the uncertainty that prevails at the network level, that is, as a structural property of the system. The TH indicator measures whether uncertainty increases or decreases at the systems level and to which extent. Because this is an entropy measure, the results can be decomposed.

Using firms as units of analysis in a series of studies, Leydesdorff et al. decomposed a number of national systems of innovation. The knowledge base of Netherlands economy in terms of TH relations among 'technology, organization, and territory' was studied (Leydesdorff, Dolfsma & Van der Panne, 2006). In this extensive research, data consisting of records on more than 1 million firms in the Netherlands was used to validate the KBE indicator with four major findings: first, the knowledge base of a regional economy is carried by medium-tech manufacturing; second, medium-tech manufacturing provides the backbone of

the techno-economic structure of the country; third, non-high-tech knowledge-intensive services have an unfavorable effect on the territorial knowledge base of an economy; and finally, the Netherlands is highly developed as a knowledge-intensive services (KIS) economy.

The knowledge base of regional innovation systems in Germany in terms of a TH dynamics was studied (Leydesdorff & Fritsch 2006). They found that at the district level in Germany, medium-tech manufacturing is the main driver of the knowledge-based configuration in a regional economy, while KIS tend to uncouple the economy from the regional configuration. Moreover, at the level of regions (NUTS-2)⁵ Germany's knowledge-based economy was no longer structured in terms of the previous East-West divide of the country, while this divide has prevailed at the level of the states (NUTS-1) that constitute the Federal Republic. Finally, the configuration of medium-tech manufacturing was considered a better indicator of the knowledge-based economy than that of high-tech manufacturing.

Regional innovation systems in Hungary were studied in 2010 (Lengyel & Leydesdorff, 2011). They used entropy statistics to measure the synergies of knowledge exploration, knowledge exploitation, and organizational control in the Hungarian innovation system. They concluded that three regimes have been created during the Hungarian transition with very different dynamics. They also reported that the national level of Hungary no longer added to the synergy across the regional innovation systems.

Synergy in the Norwegian innovation system was studied using TH relations among technology, organization, and geography in 2013 (Strand & Leydesdorff, 2013). Accordingly, they aggregated the data at the NUTS-3 level for 19 counties, the NUTS-2 level for seven regions, and the single NUTS-1 level for the nation. Measured as in-between group reduction of uncertainty, 11.7% of the synergy was found at the regional level, whereas only another 2.7% was added by aggregation at the national level. The counties along the west coast were indicated as more knowledge-based than the metropolitan area of Oslo or the geographical environment of the Technical University in Trondheim.

Triple-helix synergy in the Russian innovation systems at regional, provincial, and national levels was measured in 2015 (Leydesdorff, Perevodchikov & Uvarov, 2015). Hence, half a million units of data at firm level were obtained from the *Orbis*TM database of Bureau Van Dijk. They stressed that the knowledge base of the economy was concentrated in Moscow region (22.8%) and Saint Petersburg (4.0%). Except in Moscow itself, high-tech manufacturing did not add synergy to any other unit at any of the various levels of geographical granularity; instead it disturbed regional coordination. KIS (including laboratories) contributed to the synergy in all Federal Districts (except the North-Caucasian federal district), but only in 30 of the 83 Federal Subjects. The synergy in KIS was concentrated in centers of administration. The KIS (which were often state affiliated) provided backbone to an emerging knowledge-based economy at the level of Federal Districts, but the economy was otherwise not knowledge based (except for the Moscow region).

The Swedish system of innovation was studied by in 2013 (Leydesdorff & Strand, 2013). Therefore, based on the complete set of firm data for Sweden (1,187,421 firms), they analyzed three dimensional mutual information in terms of synergies at regional and national levels. They reported that aggregation at the regional level (NUTS-3) of the data organized at the municipal level (NUTS-5) showed that 48.5% of the regional synergy was provided by the

three metropolitan regions of Stockholm, Gothenburg, and MalmöLund. They concluded that Sweden could be considered as a centralized and hierarchically organized system. Interestingly, the authors stated that their results accord with other statistics, but the TH indicator measured synergy more specifically and quantitatively.

The knowledge-based economy of China in terms of synergy among technological, organizational, and geographic attributes of firms was reported in 2014 (Leydesdorff & Zhou, 2014). Using the possible synergy among three distributions of firms in the Orbis database, they found the greatest reduction of uncertainty at the level of the 31 provinces of China, and an additional 18.0% at the national level. Some of the coastal provinces showed up as expected, but the metropolitan areas of Beijing and Shanghai were most pronounced at the next-lower administrative level of (339) prefectures. Focusing on high- and medium-tech manufacturing, a shift toward Beijing and Shanghai was indicated, and the synergy was on average enhanced.

Apart from these applied researches based on TH model, it is worth mentioning that some criticisms of this model have also been reported in the literature (for example: Shinn (1999, 2002), Tuunainen (2005), Shinn (1999), Saad and Zawdie (2005, 2010), (Godin & Gingras, 2000). However, to the best of our knowledge such a similar study has not been addressed on the knowledge-based economy of Iran as an important and strategic country in the Middle East.

Methods and data

Based on Shannon informational entropy (1948), the uncertainty (H_x) in the relative frequency distribution of a random variable x is defined as:

$$H_x = -\sum_x p_x \log_2 p_x \quad (1)$$

This equation implies that the more entropy a system has, the more information can be potentially gained once one knows the outcome of the experiment. Shannon denotes this as probabilistic entropy which is dimensionless and therefore yet to be provided with meaning when a system of reference is specified. If one uses accordingly base two for the logarithm, then all values are expressed in bits of information. Likewise, the uncertainty in a two-dimensional probability distribution can be defined as:

$$H_{xy} = -\sum_x \sum_y p_{xy} \log_2 p_{xy} \quad (2)$$

In the case of interaction between the two dimensions, the uncertainty is reduced with the mutual information or transmission:

$$T_{XY} = (H_X + H_Y) - H_{XY} \quad (3)$$

If the distributions are fully independent then $T_{XY} = 0$ and therefore $H_{XY} = H_X + H_Y$. In the case of three interacting dimensions, the mutual information can be defined as follows:

$$T_{XYZ} = H_X + H_Y + H_Z - H_{XY} - H_{XZ} - H_{YZ} + H_{XYZ} \quad (4)$$

T_{XYZ} can no longer be considered as Shannon-type information, since transmission, by definition, is linear and positive. It should be noted that the bilateral relations between the variables reduce the uncertainty, but that the trilateral term feeds back on this reduction and adds another term to the uncertainty. A negative uncertainty or information can also be considered as a redundancy. The difference between redundancy generation and uncertainty generations can be positive or negative. The overall reduction of the uncertainty can be

considered as a result of the intensity and the productivity of an innovatedivision of labor in a broad sense.

Our calculations include three single-parameter uncertainties: a geographical H_G , a technological H_T , and an organizational H_O . The three two-parameter uncertainties are: H_{GT} , H_{GO} , and H_{TO} . The three-parameter uncertainty is denoted H_{GTO} . Similarly, the calculations contain three two-parameter transmissions (T_{GT} , T_{GO} , T_{TO}) and one three-parameter transmission T_{GTO} . The numerical results, however, are abstract and yet meaningless; they need to be appreciated using substantive theories. As noted, the values of the bilateral transmissions are appreciatedas indicators of the three knowledge functions specified above that may lead to synergy in one configuration more than in another.

One of the advantages of information theory is that the values are based on summations and can therefore be fully decomposed. Analogous to the decomposition of Shannon-type information (Theil,1972), the mutual information can be decomposed into groups as follows:

$$T = T_0 \sum_G \frac{n_G}{N} T_G \quad (5)$$

Since the decomposition is doneon the geographical dimension, T_0 will be in-between region uncertainty, T_G the uncertainty prevailing in each region G , n_G is the number of firms at this geographical scale, and N the total number of firms in the whole region. The T_0 can be considered as a measure of the dividedness among the regions. A negative value of T_0 indicates additional synergy at the higher level of national (or regional) agglomeration among the regions. Note that one cannot compare the quantitative values of T_0 across regions—because these values are sample-specific—but is allowed to compare the ‘dividedness’ in terms of the positive or negative signs of T_0 and as a percentage of the total synergy for each region. All values of the contribution of subsets to the knowledge-based economy are based on normalization on the total set (*i.e.* n_G/N). Microsoft Excel 2010 is employed to perform all the mathematical or statistical calculations.

Data

The data of 87934 active industrial firms were obtained through Iranian Ministry of industry, mine and trade updating to end of 2015. We came across with many limitations during acquiring these data due to the political restrictions and the whole non-industrial firms are absent in this list. Three variables consist of proxies for the dimensions of technology, organization, and geography at the systems levelwas extracted from the data. Technology will be indicated by the sector classification, organization by the company size in terms of numbers of employees, and the geographical position by the postal addresses. Sector classifications are based on the European NACE codes of the OECDas depicted in Table 1.

Table 1

NACE classifications (Rev. 2) of high- and medium tech manufacturing and knowledge-intensive services

High-tech Manufacturing	Knowledge-intensive Sectors (KIS)
21 Manufacture of basic Pharmaceutical products and pharmaceutical preparations	50 Water transport
26 Manufacture of computer, electronic and optical products	51 Air transport
30.3 Manufacture of air and spacecraft and related machinery	58 Publishing activities
33 Manufacture of medical precision and optical instruments, watches and clocks	59 Motion picture, video and television programmer production, sound recording and music publishing activities,
Medium-high-tech Manufacturing	60 Programming and broadcasting activities,
24 Manufacture of chemical and chemical products	64 Post and telecommunications
25.4 Manufacture of weapons and ammunition	65 Financial intermediation, except insurance and pension funding
27 Manufacture of electrical equipment,	66 Insurance and pension funding, except compulsory social security
28 Manufacture of machinery and equipment etc.,	67 Activities auxiliary to financial intermediation
	70 Real estate activities
	71 Renting of machinery and equipment without operator and of personal and household goods
	72 Computer and related activities
	73 Research and development
	74 Other business activities
	80 Education
	85 Health and social work
	92 Recreational, Cultural and sporting activities

The population of analysis was decreased to 46150 firms which could be classified using NACE into three sectors including 1186 high-tech (2.5%), 43546 medium-tech(94.3%) and 1418 knowledge intensive (3.0%).

The geographical dividedness of 31 Iran provinces into 5 regions is reported by Iranian Ministry of Interior in 2014. Such dividedness is possibly based on the proximity, geographical location and historical or cultural commonalities of provinces. These 5 regions are 1) Tehran, Qazvin, Mazandaran, Semnan, Golestan, Alborz and Qom; 2) Isfahan, Fars, Bushehr, Chaharmahal and Bakhtiari, Hormozgan and Kohkiluye-o-Boyer Ahmad; 3) East Azerbaijan, West Azerbaijan, Ardebil , Zanjan, Gilan and Kurdistan; 4) Kermanshah, Ilam, Lorestan, Hamedan, Markazi, Khuzestan;and 5) KhorasanRazavi; South Khorasan, North Khorasan, Kerman, Yazd as well asSistan and Baluchistan.These regions are very different in terms of number of firms and distribution of technology. Figure 1 exhibits the geographical distribution of Iranian firms.

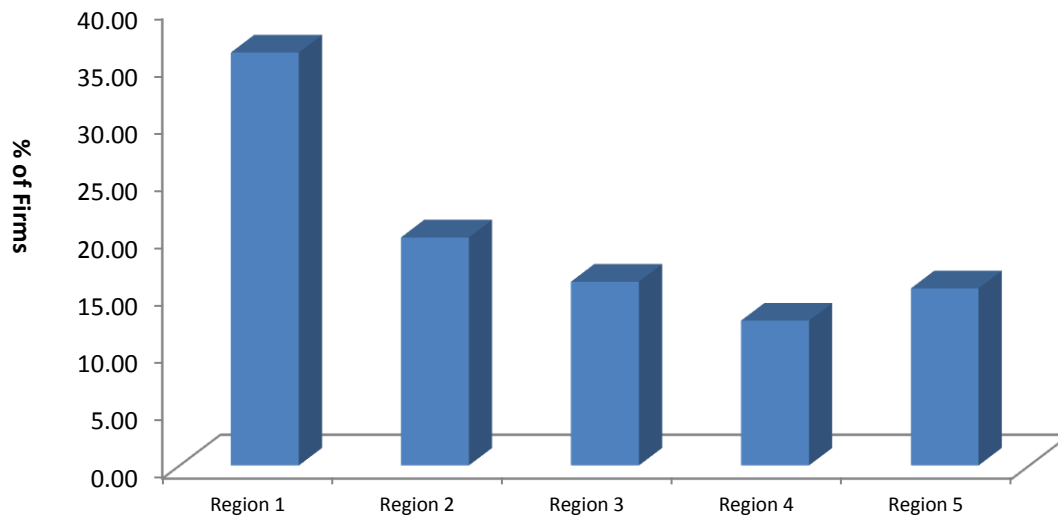


Figure 1. Distribution of firms by geographical regions.

While region 1 has attracted 36% of firms (16596), region 4 includes only 13%. Among the whole number of firms, only 3.0% are included in the knowledge intensive sector which is obviously less than the Netherlands (51.3%), Germany (32.2%) and Norway (43.5%). This low knowledge intensive sector contribution in Iranian firms is possibly due to the fact that, in contrast to other countries, our data cover only industrial firms as mentioned above. Accordingly, the most Iranian firms are classified as medium-tech (94.5%) and only 2.5% fall in the high-tech sector.

The distribution by firm size is provided in Table 2. The data contain 4 categories including micro, small, medium and large sizes. According to European Commission's (2011) classification of firms by number of employees, micro-entities have less than 10 employees; small-sized firms have less than 50 employees, medium-sized less than 250 employees, and large-sized more than 250 employees.

Table 2

Size classes of firms in terms of number of employees.

Size	No. of employees	No. of firms	Percentage
Micro	<10	20673	44.8
Small	10-50	21168	45.8
Medium	50-250	3550	7.7
Large	>250	759	1.6
Total			46150

The data show that more than 90% of Iranian industrial firms fall in the micro and small sized. In contrast to all the previous studies, herein we do not include firms without employees and all the firms are active.

Results and Discussions

Probabilistic entropies

We calculated the uncertainties for 5 regions of Iran (Table 3). Each uncertainty in the distribution was normalized as a percentage of the maximum entropy at the national level. A scaled uncertainty of 100% in the geographical distribution at the region level, for example, would indicate that firms are equally distributed among the municipalities in a region.

Table 3

Information contents (in bits) of the distributions in the three dimensions and their combinations.

	H_G	H_T	H_O	H_{GT}	H_{GO}	H_{TO}	H_{GTO}	N
Iran	4.417	0.371	1.416	4.77	5.8	1.786	6.146	46150
% H_{max}	89.1%	6%	39.5%	38.6%	57.4%	18.9%	38.5%	
Region 1	2.276	0.513	1.448	2.714	3.717	1.936	4.18	16596
Region 2	1.9552	0.26	1.368	2.24	3.31	0.98	3.65	9178
Region 3	2.358	0.327	1.351	2.42	3.7	1.69	5.274	7402
Region 4	2.376	0.226	1.394	2.618	3.777	1.61	4.182	5839
Region 5	2.063	0.281	1.405	2.357	3.48	1.458	3.905	7135

In Table 3, G = geography, T = technology/sector, and O =organization in H subscripts for Iran as a whole and the decomposition at the region level. The first value in the Table shows that the probabilistic entropy in the geography dimension is larger than 89% of the maximum entropy of this distribution at the level of the nation ($\log_2 31=5.04$), suggesting that the firm-density is not a major source of variance in relation to the population density. Among regions, the lowest value of H_G is encountered for region 2, while the other values appear close to each other. This finding denotes that economic activity is most centralized in region 2. This region contains both very advanced industrial provinces (e.g. Isfahan) along with the less-advanced industrial provinces (e.g. Chaharmahal and Bakhtiari or Kohkiluyeh o Boyer-Ahmad).

The corresponding percentage for the technology (sector) distribution H_T is only 6.0% which is clearly lower than all the corresponding values reported for other countries (e.g. Netherlands 69.2%) and appears different among regions. H_T is highest in region 1 and is low in regions 2, 4 and 5. This parameter is an indicative of specialization of industry structure, hence, the latter regions are found to have a relatively more specialized industry structure. The analogous percentage for the organization (or size) distribution is 39.5% which is again less than the corresponding values reported for other countries. The relatively low and narrow H_O uncertainties in all five regions are due to the skew in the distributions. The lower H_O values of regions 2, 3 and 4 indicate that a relatively small number of larger firms in these regions in contrast to region 1 where the numbers of firms of different sizes are more equally distributed.

The combined uncertainty in two dimensions of technology and organization (H_{TO}) does not add substantially to the redundancy. In other words, organization and technology have a relatively independent influence on the distribution different from that of geography. The combination of technological and organizational specialization exhibits a specific position of region 2 ($H_{TO} = 0.98$) versus region 1 ($H_{TO} = 1.93$) at the other end of the distribution. This finding suggests that firms of all sizes are distributed across municipalities of region 1. H_{GT} values are change in a narrow range, however, the highest H_{GT} value is found in region 1 (2.71), and the lowest in region 2 (2.24). A high value on this parameter suggests a weaker

linkage between geography and technology; therefore, firms in various industry sectors are more distributed.

The mutual information

Table 4 shows the values of the mutual information in two and three dimensions for Iran as a whole and for five regions. These values can be calculated straightforwardly from the values of the probabilistic entropies provided in Table 3 using equations 3 and 4 provided above.

Table 4

The mutual information contents (in bits) of the distributions in two and three dimensions disaggregated at the region level.

	T_{GT}	T_{GO}	T_{TO}	T_{TGO}
Iran	0.018	0.034	0.001	-0.005
Region 1	0.075	0.007	0.025	0.0505
Region 2	0	0	0.648	0.704
Region 3	0.265	0	0	1.494
Region 4	0	-0.007	0.010	0.175
Region 5	0.013	0	0.228	0.3588

The first line for Iran shows that there is less mutual information between the geographical distribution of firms and their technological specialization ($T_{GT} = 0.018$ bits) than between the geographical distribution and their size ($T_{GO} = 0.034$ bits). However, the mutual information between technology and organization ($T_{TO} = 0.001$ bits) is rather negligible. The regions exhibit a dissimilar pattern. In region 1, the highest mutual information is found for T_{GT} (0.075 bits) then for T_{TO} which is more than T_{GO} (0.025 vs 0.007 bits). In region 2, while T_{TO} is considerable (0.648 bits), the other two combinations are zero. In region 3, however, the only two-dimension T is found for T_{GT} (0.265 bits). In region 4 like region 2, the only two-dimension T found is T_{TO} (0.010 bits). Finally, in region 5 the largest two-dimension T is found for T_{TO} (0.228 bits) which clearly larger than T_{GT} (0.013 bits), while T_{GO} is again zero. In general, except for regions 1 and 4 all the regions have $T_{GO}=0$. A low value of mutual information—or covariation—between the distributions in the geography and industrial sectors indicating a diversified industry structure, as might be expected in the neighborhood of large cities (Lengyel & Leydesdorff, 2011). While the values for T_{GT} and T_{GO} can be considered as indicators of the geographical clustering of economic activities (in terms of technologies and organizational formats, respectively), the T_{TO} provides an indicator for the correlation between the maturity of the industry (Anderson & Tushman, 1991) and the specific size of the firms involved (Suárez & Utterback, 1995; Utterback & Suárez, 1993; Nelson, 1994). The relatively low value of this indicator for region 3 indicates that the techno-economic structure of this region is less mature than in other provinces. The high value of this indicator for region 2 indicates that the techno-economic structure in this region is perhaps relatively over-matured. In other words, this indicator can thus be considered as representing a strategic vector (Abernathy & Clark, 1985; Watts & Porter, 2003).

All values for the mutual information in three dimensions (T_{TGO}) are positive for regions in contrast to that of Iran which is small but negative in sign (-0.005 bits). However, these values cannot be compared and added up among geographical units without a further

normalization since the postal addresses are nominal variables. In the next section, we will focus on the relative effects of decompositions in terms of high- and medium-tech sectors on the geographical units of analysis.

The regional contributions to the knowledge base of the Iranian economy

In analogues to the decomposition of probabilistic entropy (Theil, 1972; Leydesdorff, Dolfsma & van der Panne, 2006), the mutual information in three dimensions could be decomposed into groups as equation 5. This decomposition algorithm enables us to study the next-order level of Iran as a composed system in terms of its lower-level units like the provinces and the regions. Note that in this case, the regions and provinces are not compared in terms of their knowledge intensity among themselves, but in terms of their weighted contributions to the knowledge base of the Iranian economy as a whole.

In Table 5, the calculated T_0 could be considered as a measure of the dividedness. A negative value of T_0 indicates an additional synergy at the higher level of national agglomeration among the lower level geographical units. Again, note that one cannot compare the quantitative values of T_0 across countries-because these values are sample-specific but is allowed to compare the dividedness in terms of the positive or negative signs of T_0 .

Table 5

The mutual information (in mbits) in three dimensions statistically decomposed at the region level.

	$\Delta T_{GTO}=(n_i*T_i/N)$ in mbits of information	n_i
Region 1	18.1	16596
Region 2	140	9178
Region 3	239.7	7402
Region 4	22.2	5839
Region 5	55.5	7135
sum($\sum_i P_i T_i$)	475.5	46150
T_0	-480.6	
Iran	-5.14	N=46150

Amazingly, data show that both the in-between regions interaction effect at the national level (T_0) and ΔT_{GTO} of Iran at the national level are negative ($\Delta T = -480.6$ and -5.14 mbits, respectively) however all the ΔT_{GTO} in each separate region is highly positive. $T_0 = -480.6$ mbits is an indicative that national agglomeration significantly adds to the synergy in the system (Fig. 2).

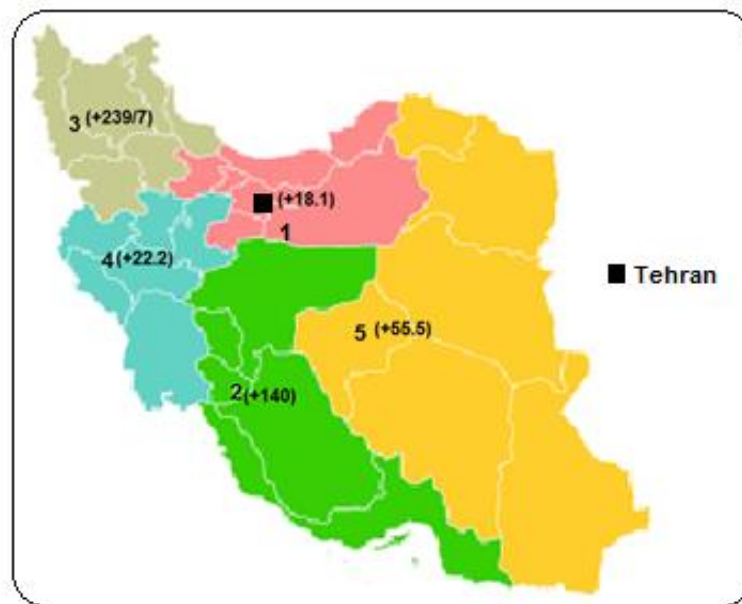


Figure. 2. Depicting the contribution to the knowledge base of Iranian economy at different regions 1-5 (the corresponding ΔT_{GTO} values in mbits are in the parenthesis).

This findings refer to a highly integrated national innovation system where the in between region term incredibly reduces the uncertainty at the national system level and hence has a high-synergistic function in the knowledge-based economy in comparison to other nations like the Netherlands, Norway, Sweden, Germany and Russia. In this unique situation, none of the regions contribute to the reduction of uncertainty in three dimensions. Moreover, the contribution of regions in disturbance of synergy function appears very dissimilar in a way that regions 1 and 4 ($\Delta T = +18.1$ and $+22.2$ mbits, respectively) cause less disturbance to the synergy compared with the other three regions. The highest synergy function inconvenience is appeared in region 3 with a contribution of $+239.7$ mbits of information to the knowledge base. This situation is similar to many nations (Netherlands, separate German states, China, Sweden and Norway), but clearly with a more pronounced impact, and dissimilar to Hungary and Germany which did not find national surplus value.

The sectorial decomposition

While the geographical comparison is compounded with traditional industrial structure like firm density, all effects of the decomposition in terms of the sectorial classification of high- and medium-tech sectors and KIS will be expressed as a relative effect, that is, as a percentage increase or decrease of the negative value of the mutual information in three dimensions when a specific selection is compared with the complete population. Hence, we use the categories provided by the NACE codes (Table 1) as selection criteria for subsets and compare the results with those of the full set provided in the previous section as a baseline. A more negative score for the probabilistic entropy as compared to the overall score indicates a reduction of the uncertainty, and is therefore considered as a more favorable condition for a knowledge-based economy.

Table 6

Effects of high-tech sectors on the mutual information in three dimensions.

T _{GTO}	All Sectors	High-Tech	% Change	N
IR	-0.005	-0.083	+1560	1186
Region 1	0.0505	-0.485	+1060	628
Region 2	0.704	-0.124	+118	157
Region 3	1.494	0.030	+98	142
Region 4	0.175	-0.555	+417	112
Region 5	0.3588	0.126	+65	147

Table 6 provides the results of comparing the subset of firms indicated as high-tech manufacturing (sectors 30, 32, and 33) with the full set. The column headed with 'All sectors' corresponds to values in Table 4. The third column provides the mutual information in three dimensions for the high-tech sectors. In the fourth column the percentage change is indicated in relative terms. The results confirm our hypothesis that the mutual information or entropy that emerges from the interaction between the three dimensions is more negative for high-tech sectors than for the economy as a whole. The dynamics created by these sectors deepen and tighten the knowledge base more than in the case of firms on the average.

However, the most effect is found for high-tech sectors in region 1 followed by region 4. On the other hand, the high-tech firms in regions 3 and 5 again have positive signs of T_{GTO} and disturb the synergy considerably by generating 0.030 and 0.126 mbits of uncertainty in these regions.

Table 7

Effects of medium-tech and knowledge intensive sectors on the mutual information in three dimensions.

T _{GTO}	All Sectors	Medium-Tech	% Change	N	KIS	% Change	N
IR	-0.005	-0.016	220	43546	-0.063	+1160	1418
Region 1	0.050	1.947	-3755	15146	-0.029	+157.4	822
Region 2	0.704	-0.243	+134.5	8848	-0.235	+133.4	173
Region 3	1.49	-0.489	+132.7	7041	-0.273	+118.3	219
Region 4	0.175	-0.191	+209.1	5660	-0.277	+258.3	67
Region 5	0.359	-0.007	+102.0	6851	-0.460	+228.2	137

Table 7 provides the same values and subsequent normalizations, again on the basis of selections according to the classifications provided in Table 1 for medium-tech manufacturing, and KIS, respectively. The results show again that the mutual information emerge from the interaction between the three dimensions for these two sectors are more negative than for the economy as a whole (+220% and +1160% change for medium-tech and KIS, respectively) confirming that the dynamics created by these sectors deepen and tighten the knowledge base more than is the case for firms on the average. In both sectors the synergy found at national level is considerably more than the regional levels. These results indicate a major effect on the indicator for the sectors of KIS. The synergy effect of medium-tech firms

is definitely the lowest in region 1 with 3755% decrease relative to the benchmark of all sectors combined. The other four regions are moderately effective in the regional synergy but clearly below the average effects of national level. Interestingly, region 4 is the first on this rank order with an increase of +209% and +258% in medium-tech and KIS, respectively. These results indicate that KIS favorably affects the synergy between technology, organization, and territory in the techno-economic system of the Iran and its regions or a relatively connection effect from the geographically defined knowledge bases of the economy. In contrast to many other countries, medium-tech manufacturing does not add to the knowledge-based of the Iranian economy that were studied using this methodology hitherto. In all advanced European countries, the investigations have been shown that KIS seem to be largely uncoupled from the knowledge flow within a regional or local economy and they contribute negatively to the knowledge-based configuration because of their inherent capacity to deliver these services outside the region. From this viewpoint, Iranian innovation system seems to be like Russian innovation system which proposed that KIS are provided in state-apparatuses and establishments related to these.

In general, Iranian innovation system could be best described as a specific historical situation which labeled as Triple Helix I (Etzkowitz & Leydesdorff, 2000). In this configuration, the nation state encompasses academia and industry and hence controls or directs the relations between them. The strong version of this model could be found in the former Soviet Union and in Eastern European countries under "existing socialism", while weaker versions were formulated in the policies of many Latin American countries and even in some European countries such as Norway.

Finally, our results based on TH synergies are relatively consistent to the previous reports on the Iranian economy using other indices. Dreger et al (2007) concluded Iran, like other countries with rich natural resources, has experienced low rates of economic growth due to the massive rent-seeking and corruption. Driving force for this problem is the nationalization of almost all big firms and the tendency for a more state-owned economy. They also found that Tehran could undermine the growth performance in the overall country but also regional convergence between other provinces due to the creation or transfer of substantial amount of rents. Moreover, our results are in line with those of Biranvandzadeh et al (2015) where they comparatively assessed the performance and efficiency of Iranian provinces in terms of development level using Taxonomy and Morris models. They also analyzed statuses of Iranian provinces in terms of inequality extent in enjoying development benefits using standard score method. Their results suggested that provinces in region 1 assumed the highest rank while provinces in region 5 assumed the lowest rank.

Conclusions

The scientometric indicator of triple-helix relations in an economic context are employed to delineate the Iranian innovation system. It should be cautioned that our data merely on active industrial firms is based on official government statistics which is remaining otherwise unrevealed to the user of this database. However, we are currently not aware of data of higher quality than this about the Iranian economy in the three relevant dimensions and at other levels of establishments. Nevertheless, our results allow us to present the following findings:

1. Mutual information in three dimensions is positive in all regions separately, while aggregation at the national level makes ΔT_{GTO} to be negative with a T_0 of -480.6 mbits.

2. The knowledge base of Iran regional economy is carried by high-tech manufacturing, but more importantly by KIS.

3. The Medium-tech manufacturing has a relatively unfavorable effect on the territorial knowledge base of Iran economy and one could say that these technologies tend to uncouple the knowledge base from its geographical dimension.

4. It transpires that the Iranian economy is not knowledge-based. Synergies in the regions among existing technological and economic structures are disturbed instead of reinforced by medium-tech manufacturing.

5. KIS are grounded and not, as many authors hypothesized, a mechanism that uncouples from the local economies.

6. Both KIS and high-tech manufacturing are heavily centralized in regions 1 and 4.

In terms of policy implications, these conclusions suggest that regions 2, 3 and 5 which are less developed may wish to strengthen their knowledge infrastructure by trying to attract medium-tech and high-tech manufacturing and services. The efforts of firms in medium-tech sectors can be considered as focused on maintaining absorptive capacity (Cohen & Levinthal, 1989) so that knowledge and technologies developed elsewhere can more easily be understood and adapted to particular circumstances. KIS can be important for generating employment and high-tech manufacturing may be more focused on the (internal) production and global markets than on the local diffusion parameters. Medium-tech manufacturing contributes to the integration at the levels of regions more than nationally, whereas high-tech and KIS contribute mainly nationally (especially in regions 1 and 4). Differently from Western Europe, KIS are embedded at all three levels, and function more or less comparably to the respective synergy for all sectors. Enhancing the circulation of these services and encouraging the diffusion of high-tech across the country—perhaps in the form of more competition—could be beneficial to the further development of a knowledge-based economy in Iran.

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Endnotes

1. Organization for economic co-operation and development.
2. At <http://Www.Oecd.Org>.
3. At www.Worldbank.Org/Kam.
4. Information and communications technologies.
5. Nomenclature of Units for Territorial Statistics.

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