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Innovation and knowledge spillovers in Turkey: The role of geographic and organizational proximity*

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Abstract. This study focuses on spatial dimensions of innovation and tests whether there is an overlap between geographical clusters and the location of knowledge creation in Turkey. We used patent documents as indicators of inventors' collaboration in innovation and examine diverse characteristics of inventors by social network analysis. Using the address and company affiliation of the inventors, this study suggests that the role of geographical and organizational proximities in knowledge creation and diffusion can be tested by using social network analysis. This study concludes that innovation processes in Turkey are highly concentrated geographically and rather than organizational proximity between the actors, being close to industrial clusters is more important for innovative knowledge production and flows.

JEL classification: O30, O31, L65

Key words: Innovation geography, patent, knowledge spillovers, industrial clusters, Turkey

1 Introduction

According to growth and trade theories increasing mobility of labor, commodities, and capital paves the way for knowledge flows between regions and countries across the world. However when it comes to specific forms of knowledge there can be place-specific characteristics that function as barriers to knowledge flows between different locations. Examples include the sectoral composition of regional economies, regional institutional structures, geographical distance, and cultural dissimilarities (Cooke and Morgan 1998; Audretsch and Aldridge 2009). Beside these barriers, distinguishing characteristics of knowledge itself may influence the speed or form of flows as well. For instance, while geographical and social proximity are necessary conditions

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for tacit knowledge diffusion, institutional proximity and the industrial composition of regions may positively impact codified knowledge flows (Capello 1999; Gertler 2003; Boschma 2005; Knoben and Oerlemans 2006; Boschma and Frenken 2010). Likewise, knowledge arising from pure research and development (R&D) processes and knowledge arising from using technology may occur at different speeds in terms of flows between locations and actors (Griliches 1979). Developed and developing countries also perform differently when it comes to knowledge creation and transfer (Malecki 1997).

It appears that the idiographic characteristics of regions, industries, and agents (individuals, companies, organizations etc.) has prevented the creation of a universally accepted broad and unique explanatory framework or theory that explicates the multiple dimensions of innovation and knowledge diffusion. In other words characteristics or attributes that are specific to industries, spaces (regions, localities, countries) and clusters has obstructed the development of an agreed upon general analytic framework for the explanation of innovation and its policy implications. For high tech clusters international networking becomes an important key to success, while for traditional production cost-based industrial districts internal interactions or local buzz are more influential (Becattini 1990; Brusco 1990). In some cases the coexistence of both local and global networks can be indispensible (Bathelt et al. 2004). Yet, economies or externalities of agglomeration and networking are common explanations in the innovation literature.

The role of geography in innovative knowledge production and spillovers has been frequently mentioned with the rejuvenation of Marshallian agglomeration economies by both new economic geography (Krugman 1991a, 1991b) and cluster theory (Porter 1990). It has been argued that knowledge creation and flows is consistent with geographical concentrations of industries and clusters. Locally oriented homogenous collaboration networks within clusters leads to innovation via intense labor mobility and spin-offs (Soetanto and Geenhuizen 2011; Renski 2012). As a condition of development and competition, regional knowledge accumulation has been seen as an outcome of local buzz in clusters and global pipelines that extend between distant regional clusters (Bathelt et al. 2004; Owen-Smith and Powell 2004; Giuliani and Bell 2005). Therefore the geographical concentration of economic activities has been considered as a significant factor associated with innovation and knowledge creation and flows. In this regard, many case studies find diverse and sometimes contradictory findings. Some identify regional specialization as being key while others emphasize the importance of regional industrial diversification in terms of knowledge production and innovation. While regional specialization incentivizes intra-sectoral knowledge flows, many studies confirm that regional diversification facilitates knowledge flows between diverse industries (for more detail see Van der Panne and Van-Beers 2006; Frenken et al. 2007).

Once space has been considered as a factor in innovative knowledge production and spillovers, defining and measuring the effect of geography becomes an issue. It is often not clear if innovative knowledge diffuses between agents because of the short geographical distance and co-location of them in the same cluster or because of other factors taking place in the same geographical area. Considering inventors and other actors as an 'epistemic community', spatial proximity, by itself, may not be a sufficient condition for interaction and innovation networking between them. Codes and meanings of technical changes generally require that people are familiar with those fields and their ongoing novelties. For that reason, networking for innovation necessitates to a certain extent mutual understanding and the sharing of a common set of values and norms between agents. Though, geography is conducive for these common set of values and norms (Boschma 2005), when it comes to production of innovative knowledge, some other kind of proximities may become more explicative. In this context, in the literature social, cultural, cognitive, institutional, and organizational proximities (Coenen et al. 2003; Boschma 2005) are mentioned as influencing the absorptive capacity of agents in terms of knowledge transfer and spillovers. Knowledge dissemination is more likely to occur between agents or actors who have similar institutional and organizational backgrounds (Boschma and Frenken 2010) or between regions which have diverse knowledge bases (Asheim et al. 2007).

However it is difficult to precisely define and delineate the boundaries of these diverse proximities because of the fact that they are strongly interconnected and interchangeable.

Therefore methodologically measuring and revealing the role of clusters or spatial proximity and these diverse proximities has been challenging. Since knowledge diffusion "*leaves no paper trail to be measured or tracked*" (Krugman 1991b, p. 53) it has been difficult to define the geography of knowledge flows in the past. However in the last two decades patent documents have become a very significant source for understanding knowledge flows, not only because of their quantity and availability but also because of the information they provide. This information allows the geographical boundaries of knowledge flows to be defined as well as potentially enhancing our understanding of innovation dynamics. Studies concentrating on the geography of knowledge dissemination by deploying patent data highlight certain and clear localization of knowledge spillovers at diverse spatial scales. Using citation information on patent documents, Jaffe et al. (1993) and Thompson and Fox-Kean (2005) revealed that localization of knowledge spillovers happens at both the metropolitan and regional levels in USA. Similarly looking at interregional knowledge spillovers in Europe, Maurseth and Verspagen (2002) concluded that patent citations are inclined to happen more frequently between regions in the same country. Despite being deployed as indicators of knowledge flows, patent documents suggest more than that. Nationality and company information on patents makes it possible to use them for defining diverse proximities between applicants or inventors. For instance, again using citation information, Agrawal et al. (2008) used nationality of inventors as a proxy of social proximity and measured its effect on localization of knowledge spillovers.

In this study we suggest that patent documents can be used to understand innovation dynamics and to test the role of organizational proximity as well. Using patent data for the Turkish chemistry industry this study aims to reveal whether geography of innovative knowledge production overlaps with geographical clusters or not. Rather than the detection of localization of knowledge spillovers, based on citation information in patent documents, we concentrate on Turkish inventors' social networks and try to understand if clusters and the diverse characteristics of inventors have an impact on innovative knowledge production processes. The second purpose of this study is to compare the role of geographical proximity and organizational proximity on innovative knowledge production in the chemistry industry via incorporating patent information. The remainder of this paper is structured as follows. The next section introduces data and methodology. Section 3 focuses on the innovation dynamics of the chemistry industry in Turkey by using some descriptive and explorative statistics to explore the social networks of inventors. The final section presents general evaluations and suggestions for innovation policy.

2 Methodology and data

As mentioned above patents are a "*valid but noisy measure of technology spillovers*" (Jaffe et al. 1998:183) and have been used as a "*paper trail*" to address the localization of innovative knowledge spillovers. Since patent documents include name and address information of applicants and inventors, they can be used to delineate knowledge flows between inventors of citing and cited-patent pairs. Based on citation and address information of inventors, this method is known as JTH (Jaffe-Trajtenberg-Henderson) or the matched-pairs approach in the literature. Jaffe et al. (1993) used geographical matches between patent groups as evidence of localization or geographical concentration of knowledge spillovers. A higher geographical match between original (cited) and citing patent pairs compared to original-control patent pairs is taken as an indicator of localization of knowledge flows (Jaffe et al. 1993; Almeida and Kogut 1997; Thompson and Fox-Kean 2005). Despite some shortcomings (see Breschi and Lissoni 2001, 2003; Thompson and Fox-Kean 2005) this method is applicable for large patent populations. In the case of Turkish chemistry patents, relatively small numbers of patents means that it is not possible to use the same procedure and run statistically significant analysis.

Therefore in this study instead of the JTH approach, knowledge flows between Turkish inventors and other inventors are examined by descriptive indicators. Since the main focus of this study is exploring the innovation dynamics of the Turkish chemistry industry and testing the role of geographical and organizational proximities, patent documents are deployed for specifying the inventors' network. Co-occurrence of inventors on the same patent document makes patents the best option for revealing the collaboration network of inventors. The inventors who participate in the same patent represent a common "*team*" and have direct linkages. Departing from this logic Breschi and Lissoni (2003) suggest that measures of connectedness among pairs of patents and therefore of inventors can be derived. Once the affiliation of inventors and patents are prepared in the form of a bipartite (two mode) matrix, the affiliation network of the inventor can be derived too. The affiliation network of inventors is a unipartite (one-mode) network (sociogram) in which co-inventors of a group of patents are linked with each other (see Breschi and Lissoni 2003 for more details and a graphic illustration).

Following Breschi and Lissoni (2003) we prepared affiliation networks of Turkish inventors and examined diverse dimensions of this network with social network analysis (SNA). Since the affiliation network of the inventors is one mode, diverse measures of connectivity of the inventors or some other general measures of the network structure can be analyzed using SNA software. Using UCINET and NetDraw software, for detection of temporal changes in the network structure and connectivity of the inventors, we did a temporal analysis of various measures of the network such as geodesic distances, centrality degrees, density and the network component structure. To identify sectoral differentiations the same analyses were repeated for subsectors of the chemistry industry as well. Some other information on the patent documents such as publication year, classes, nationality, applicants' names (which are mostly company name) are examined to understand distinguishing characteristics of innovation processes in Turkey.

To test the role of clusters and organizational proximity in innovation processes we used address and company information on the patent documents and prepared an attribute table of the inventors. On the attribute table, inventors are classified according to their membership of geographical clusters and organizations. At the province level, if an inventor resides in a geographical cluster he/she is designated as a member; otherwise a non-member. Similarly, in terms of company affiliation, inventors are classified as private sector workers or university researchers. However there are two different types of universities in Turkey – technical and non-technical. Technical universities are designed to be more research and development (R&D) oriented than non-technical universities. Additionally, having research institutions, techno parks, R&D Labs and science parks allows technical universities to take a central role in university-industry collaborations which are supported by a variety of incentives that are provided by certain central public institutions and governments. Therefore, to detect the impact of university-industry collaborations and university policy, inventors are classified in both dual (private-university) and triple (private, non-technical university, technical university) forms in terms of organizational affiliation. We then conducted some inferential statistics to test the role of clusters (a proxy for geographical proximity) and organizational proximity in innovative knowledge production for the pharmaceuticals subsector.

In the literature organizational proximity is defined as similarity and closeness of actors in terms of organizational forms. Thus we believe that company affiliation is a good proxy for organizational proximity. Boschma (2005, p. 63) defines it as "*…the extent to which actors share the same reference and knowledge space, taking on board the cognitive dimension of organizational forms*". From this point of view boundaries between cognitive and organizational proximity are relatively ambiguous and to some extent both concepts are interchangeable. On the other hand, in the case of inventors, being part of a university or private business clearly expresses different organizational forms. Inventors working in the same knowledge area, even if they are in different settings, may have cognitive similarities. At the same time working in different institutional settings may result in different routines and practices on a daily basis. While motivations and practices of university inventors are oriented mostly by values and norms emanating from scientific collaborations and networks shaped by distinctive institutional frameworks, business or private sector's inventors are expected to be oriented by mostly pragmatic routines imposed by market conditions and institutional structures within which their organizations are embedded. Depending on such differentiating institutional structures, inventors' cognitive base, knowledge absorptive capacity, learning and transfer skills are expected to differ between both types of organization.

The patent data deployed in this study was obtained from the Europe Patent Office (EPO) database and provided by the Center for Research in Innovation, Organization and Strategy (CRIOS). Since the Turkish Patent Institution's (TPI) database does not record the patent information electronically its database is not suitable for such a study. Furthermore the other patent authorities like the United States Patent and Trademark Office's (USPTO) have a limited number of applications from Turkey and the most of these applications are already registered at the EPO. Because of intense business networks, geographical proximity, and relatively institutional similarity between the European Union and Turkey in terms of patenting processes, Turkish companies are more likely to register with the EPO than the USPTO. Therefore the EPO's database represents a unique and appropriate source for this study. The patent dataset used in this study includes all patent applications by Turkish assignees from 1992 to 2014. It consists of the C section and its ten subsections at the two digit level according to International Patent Classification (IPC). Notwithstanding the relatively long time period, the numbers of patents are quite small. This reflects Turkey's low innovation rate as well as the fact that it does not include patent applications of foreign companies in the country.[1]

To detect geographical clusters in the chemistry industry we used 2009 employment and establishments' numbers for the industry which were obtained from the Social Security Institution (SGK). As an industrial census has not been conducted since 2002 this represents unique official data collected at the province level and assigned according to ISIC Rev.3 classification codes. Under this classification version, C Section (chemistry industry) of IPC corresponds to coded industries 20 and 21 which are Manufacturing of Chemistry Products and Pharmacy and Manufacturing of Pharmaceutical Apparatus, respectively. The provinces which have location quotients of 1.25 or higher and above 5 percent employment and establishment share in total manufacturing are delineated as geographical clusters of the chemistry industry. However pharmacy and pharmaceuticals industries are not disaggregated in the ISIC Rev.3 classification. For that reason, geographical clusters of pharmaceuticals subsector are defined according to the data obtained from the Association of Research-Based Pharmaceutical Companies (AIFD) in the Turkey. More information about the data is provided in the following section.

3 Analysis and results

3.1 Innovation indicators for chemistry industry in Turkey

It is known that innovation activities tend to be geographically concentrated and selective. In developing countries a scarcity of resources and human capital leads to a higher concentration

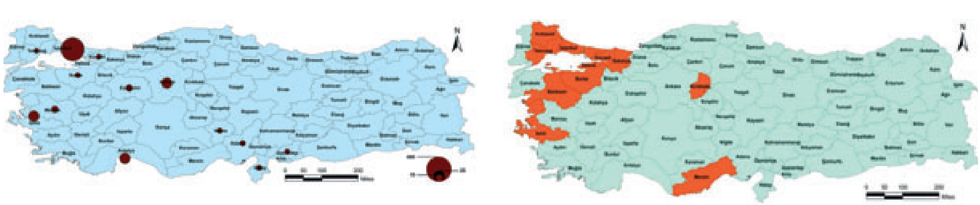
[1] As a matter of fact, since patent applications are classified according to nationality of assignees it is not possible to separate foreign companies' patents. Additionally a foreign company's patents are more likely to be produced by inventors in the home country or in other countries. Since the focus of this study is local production of innovative knowledge, and to exclude Turkish inventors in other countries, the patents are chosen according to applicants' nationality. Information relating to the address, name, company affiliation of applicants and inventors etc and all other misspellings are corrected where necessary and verified by internet searches.

of existing innovation around urbanized large-sized cities (Audretsch and Feldman 1996; Malecki 1997; Breschi and Malerba 2001). This is the case for Turkey as well. According to the TPI database, total patent applications between 1995 and 2014 in Turkey are highly concentrated around the largest metropolitan cities. İstanbul alone has a 43.3% share of total applications, followed by Ankara (12%), Bursa (6.9%), İzmir (6.2%) and Kocaeli (4.1%) respectively. The ten most industrialized provinces have over 80% of total patent applications in the country (Figure 1). Considering patent numbers, the most innovative provinces are the most industrialized and urbanized large-sized metropolitan areas.

When it comes to the chemistry industry the gap between İstanbul and other provinces becomes greater. According to the EPO database, from 1992 to 2014 there were 477 patent applications by Turkish assignees with 382 of them (80%) belonging to İstanbul (Figure 2a). It is not only because İstanbul has the largest share of manufacturing in the country but because of the fact that many companies with a presence in other provinces often have their headquarters or branches in Istanbul. Besides, for the patent application processes small and medium sized firms (SME) especially tend to use proxy companies (e.g., a law company) specialized in this process and these are generally located in İstanbul. Patent applications in the chemistry industry show higher concentrations than other industries in İstanbul. In terms of location quotients, the employment and establishment shares of 11 geographical clusters can be defined for the chemistry industry in Turkey (Figure 2b). Figures 2a and 2b show there is no strong match between the location of clusters and the geographical distribution of patents. Except for İstanbul and İzmir, the other geographical clusters either do not have or have a small number of patents in the chemistry industry.

Besides the uneven geographical distribution the sectoral distribution of patent applications is striking as well. Again, according to the TPI database, between 1998 and 2014 there were 61,380 patent applications and over 60% of these were concentrated in three sections of the patent classification in Turkey. According to the IPC classifications these were the

Fig. 1. Total patent applications at province level between 1995 and 2014 in Turkey (TPI)



(a) (b)

Fig. 2. a: Patent applications for the chemistry industry by provinces between 1992 and 2014 (EPO). b: Geographical clusters of the chemistry industry in Turkey

A (Human necessities), B (Performing operations and transporting) and C (Chemistry and metallurgy) sections. This is consistent with the industrial structure of the country. In the last two decades the industrial structure of Turkey has transformed from low technology industries into medium-low and medium-high technology industries (Celebioglu and Dall'erba 2010). Since the chemistry industry has multiple backward and forward linkages with other industries, as the industrial composition of the country changes it stimulates a robust chemistry industry. Indeed by 2014 it became one of the most competitive industries accounting for with 10.5% Turkish exports and 8.3% of total manufacturing employment share.

This robustness seems to be reflected in its innovation capacity. Chemistry and metallurgy (C section) patent applications generate the second largest patent group in Turkey, accounting for 22.5% of total patent applications with 13,778 patent applications between 1998 and 2014. Since the TPI does not distinguish between chemistry and metallurgy patents we do not know the exact number of chemistry patent applications alone. However the TPI database shows the numbers of both patent and utility models together which consist of the second largest group according to the NACE classification. This suggests that the largest volume of C section patents consists of chemistry, rather than metallurgy, patents. Another striking point is about the origin of the patent applications. These 13,778 patents mostly belong to foreign, rather than Turkish applicants. The share of Turkish applicants in these patent applications is about 3.4% (462 patents). This is confirmed by the number of applicants at the EPO as well. As seen in Figure 3, the growth of patent numbers at the TPI and the EPO show similar tendencies with total numbers being 462 and 477 respectively. These data show that the innovative knowledge production and patents applications are mostly done by foreign companies in Turkey. The share of local companies in patent applications is very low. This is true for all other industries as well. It should be noted that the main growth in patent applications happened after 2005 both at the TPI and EPO (Figure 3). Since some government institutions (TPI, TÜBİTAK, KOSGEB) started to incentive firms and provide counseling services for patent applications the numbers increased sharply after 2005.

The indicators mentioned above show that the chemistry industry is significant to the Turkish economy and compared to other industries its innovative capacity is more promising. However these numbers and indicators are not enough to understand the dynamics of innovative knowledge production for the industry. Furthermore, in the patent classification system the chemistry industry is highly aggregated and includes many diverse subsectors and classes.

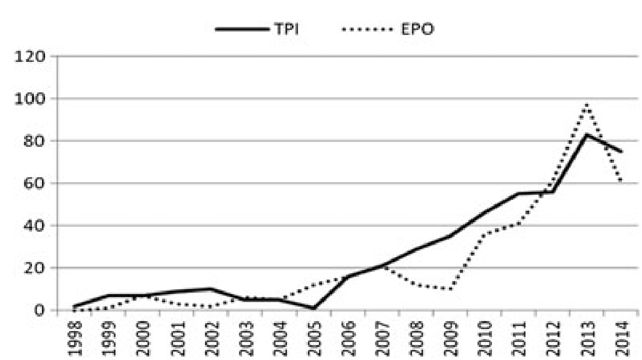


Fig. 3. Growth of patent numbers in chemistry industry between 1998 and 2014 (TPI and EPO)

Therefore to understand differentiations between those subsectors and the knowledge diffusion between them we turn to an analysis of the industry's inventors' network.

3.2 The structure of inventors' collaboration network

Before analyzing the inventors' network structure, it might be meaningful to evaluate citation data and some characteristics of Turkish inventors in the chemistry industry in terms of knowledge diffusion. The total number of patents in the chemistry industry between 1992 and 2014 was 477. These patents were produced by 443 inventors. Thirty-five of these inventors (7.9%) are not Turkish. Most of them reside in Germany (19) France (6), Denmark (4) and other European countries. Therefore collaboration between Turkish inventors and foreign inventors favors European countries. However this is not the case for citation data. The inventors of Turkish patents cited 1,087 foreign patents which were generated by 3,243 inventors. When we look at the addresses of these foreign inventors 20.9% of them are from Germany, 19.7% from the USA and 12% are from Japan. This array is the same for applicants' addresses as well. So rather than being an indicator of localization of knowledge spillovers, citations happen to a large extent to depend upon the geography of related knowledge production outside of Turkey. Since these countries are also prominent in both patent production and the chemistry industry, naturally Turkish inventors cite them more.

As patent examiners ask the applicants to add previous scientific work, patents, inventions etc. to the citation list (Breschi and Lissoni 2003) these numbers do not show knowledge diffusion between Turkish inventors and foreign patent inventors. On the other hand those 443 chemistry patents in Turkey cite only 30 other Turkish patents, with 26 of them being self-citations. This suggests that in the creation of innovative knowledge Turkish inventors are highly dependent upon external knowledge sources. Rather than learning from each other, external connections and accessibility to outside knowledge is vital for innovative knowledge production. Since citations between Turkish inventors or patents is very low, in order to detect localization of knowledge spillovers, a matched-pairs approach or JTH method is not applicable in this case. Thus the collaboration network of Turkish inventors is a unique way to understand innovation dynamics in the country.

As mentioned above, in the methodology section, to understand the inventors' collaboration networks in innovative knowledge production we used their patent affiliation and mapped the networks. Then using SNA software we measured various attributes of the network. Some descriptive statistics from our analysis are presented in Table 1. To detect longitudinal changes in innovation processes the same analysis was done for different time periods (Table 2). As seen in Table 1 according to the IPC-35 classification system there are ten subsectors in the chemistry industry. This demonstrates the diversity in terms of the technological base which ranges from biotechnology to environmental technology.

The results show that, except for the pharmaceuticals subsector, all subsectors have a limited number of inventors. With 16 inventors biotechnology has the smallest number while pharmaceuticals have the largest number with 270 inventors. Except for pharmaceuticals and biotechnology, the numbers of ties are less than the number of inventors which points to very much low connectivity between inventors. This is verified by the number of components of the network as well as by the size of the largest component. In a well-connected network, numbers of components are supposed to be low while the size of the largest component is supposed to be high (Wasserman and Faust 1994). This is not the case, however, for each subsector or for the total chemistry sector inventors' network. The component structure of the network highlights weak inter-connectedness between inventors. Both the low numbers of ties and the component structure show the inventors to be very isolated and collaboration to be limited between the populations.

Table 1. Analysis results according to subsectors

Subsections	Number of inventors	Number of ties	Number of Components of Size = 2	Size of largest component	Geodesic distance	Network density	Mean Centrality (Network centrality %)
Organic fine chemistry	21	8	2	3	1.000 (0.000)[1]	0.024 (0.181)[1]	0.476 (0.957)[1] 6.625%
Biotechnology	16	38	5	6	1.000 (0.000)	0.158 (0.365)	2.375 (2.058) 18.667%
Pharmaceuticals	270	378	39	46	2.301 (0.800)	0.006 (0.091)	1.622 (3.570) 2.939%
Macromolecular chemistry, polymers	34	28	6	4	1.067 (0.200)	0.027 (0.172)	0.882 (1.105) 3.306%
Food chemistry	25	6	3	2	1.000 (0.000)	0.010 (0.099)	0.240 (0.427) 3.299%
Basic materials chemistry	30	10	3	3	1.000 (0.000)	0.011 (0.107)	0.333 (0.650) 5.945%
Surface technology, coating	32	14	4	3	1.125 (0.300)	0.014 (0.118)	0.438 (0.704) 5.203%
Micro-structural and nano-technology	42	44	7	5	1.000 (0.000)	0.026 (0.158)	1.048 (1.344) 7.377%
Chemistry engineering	37	36	5	5	1.000 (0.000)	0.029 (0.175)	1.027 (1.423) 4.244%
Environmental technology	18	6	1	3	1.000 (0.000)	0.020 (0.139)	0.333 (0.745) 10.381%
Total network	443	752	72	49	2.044 (0.700)	0.005 (0.086)	2.032 (4.121) 2.002%

Note: [1]Number in bracket are standard deviation.

Table 2. One-mode network structure of Turkish inventors by years

Years	Number of inventors	Number of ties	Number of Components of Size = 2	Size of largest component	Geodesic distance	Network density	Mean Centrality (Network centrality %)
1992–1999	16	10	3	3	1.000 (0.000)	0.042 (0.200)	0.625 (0.781) 9.778%
2000–2002	14	26	2	7	1.458 (0.500)	0.154 (0.390)	2.000 (1.964) 20.710%
2003–2005	26	8	4	2	1.000 (0.000)	0.012 (0.110)	0.308 (0.462) 2.880%
2006–2008	79	202	16	12	1.000 (0.000)	0.033 (0.181)	2.582 (3.797) 5.465%
2009–2011	129	224	19	15	1.674 (0.700)	0.015 (0.130)	1.876 (2.506) 3.182%
2012–2014	200	318	27	61	3.637 (2.000)	0.010 (0.139)	2.040 (4.160) 2.811%
1992–2014	443	752	72	49	2.044 (0.700)	0.005 (0.086)	2.032 (4.121) 2.002%

This evaluation is verified by average geodesic distance, network density, mean centrality and network centrality. In social network analysis these measures are the basic indicators of actor connectivity (Wasserman and Faust 1994; Hanneman and Riddle 2015). The network density of all subsectors and the total network (chemistry) is very low. This explains why average geodesic distance is low. Besides it shouldn't be forgotten that the average geodesic distance here is the distance among reachable pairs in the network, not all other isolated inventors. Considering another measure of connectivity the network centralization of biotechnology and environmental technology is relatively high (19% and 10% respectively) compared to the rest. However this happens because of the limited numbers of inventors in those two subsectors. Even though they have small numbers of ties the low numbers of inventors results in relatively higher network centralization. However considering the much lower network centralization of the total chemistry industry we arrive at the conclusion that there is no substantial amount of concentration or centralization in the whole network.

Therefore the structure of inventors' network shows collaboration between inventors to be low with inventors to a large extent being isolated from each other. In other words there is limited collaboration between inventors with regard to innovative knowledge production. This also means that knowledge diffusion or spillovers between inventors in the chemistry industry is limited. The existing connectivity or connectedness between inventors of the network springs to a great extent from the pharmaceuticals subsector. In Table 1 the size of the largest component of the total network and pharmaceutical network is the same. Not only in terms of the overwhelming numbers of inventors but also in terms of connectivity as well the pharmaceutical industry dominates and strongly influences the total network structure.

Since, after 2005, the number of patent applications increased at considerable speed, we were curious as to whether this increase was reflected in the interrelationships and connectivity of the inventors. To answer this question we repeated the same analysis longitudinally. The patents before 2000 were placed in a single cohort and the remainders were separated and placed in three-year cohorts (Table 2). The results show that, before 2005, numbers of components and the size of the largest component again point to inventors in the network being very isolated. With a small number of inventors, even a small number of ties cause relatively higher network centralization. Again because of highly isolated structure, the average geodesic distance between reachable pairs becomes short. However the component structure and mean centrality of the networks before 2005 signify a weak connection between the inventors in the network.

As the number of inventors increased after 2005 the component structure of the network changed as well. Similarly, the increasing number of inventors is the main reason for low network density and network centrality. It looks like between 2006 and 2014 the size of the largest component increased considerably. That means connectivity and interrelations between inventors increased. In fact this is reflected in the average geodesic distance and mean centrality as well. Since connectedness increased after 2006 the average geodesic distance differs from the previous period and becomes larger than 1.0 which signifies isolation. This is also valid for mean centrality.

To sum up, like the sectoral network structure above, the general network structure over time is still weak and not dense. The low density of the network and the highly isolated position of the inventors in the network suggest that knowledge sharing and spillovers between inventors is relatively weak. Collaboration in knowledge production and innovation is lower than other cases in the literature (Kyung-Nam and Park 2012; Ter-Wal 2014). Inventors in the chemistry industry are not very well interconnected and interdependent in the innovation process. This is verified by the low numbers of mobile inventors between the applicant companies. It appears that in Turkey firms tend to create innovative knowledge more independently from their counterparts. However in the last few years, especially after 2008, the inventors have become more connected and their collaboration network becomes denser. As a matter of fact the numbers of inventors after 2008 comprises 75% of total inventors. Our subsector analysis showed that the pharmaceuticals subsector dominates the general structure of chemistry sector inventors' network. Therefore rather than focusing on the total network, it would be more meaningful to test the role of geographical proximity and organizational proximity via the pharmaceuticals network after 2008.

3.3 Geographical proximity versus organizational proximity

Information and knowledge exchange between actors in a region play a key role in successful innovation systems. Intensive interaction and mutual understanding between actors facilitates knowledge diffusion and exchange and leads to a dense collaborative network between agents of innovation systems. Such networks take on more importance as technology and industries become more complex as learning takes place in networks of firms or actors and interaction become more important than ever for innovation (Powell et al. 1996; Graf 2006). In this regard trust-based reciprocal relationships of actors necessitate at certain degree closeness between actors. Accordingly geographically and organizationally-close inventors should engage in more collaboration and have more connections than others in the network.

As we have already produced an affiliation network of the inventors, various SNA measures can be used to test this hypothesis. Geodesic distance and different centrality measures of the inventors in the network allow us to detect which inventors have more ties and occupy a more critical network position with respect to knowledge diffusion and transfer. We suggest that the closeness centrality measure of inventors can be used as an indicator of this position. Closeness centrality is a measure that emphasizes the distance of an actor to all other actors in the networks and can be calculated in various ways (Gürsakal 2009; Hanneman and Riddle 2015). In the inventors' affiliation or collaboration networks it expresses capability to access knowledge. Higher closeness centrality for an inventor means he/she is more reachable and closer to all other inventors and therefore can perform a bridge function in terms of knowledge diffusion between inventors. Thus if geographical proximity is important for knowledge diffusion geographically-close inventors should have higher values than others. Similarly, organizationally-close inventors should display meaningful differentiation in terms of their values. Once inventors are categorized according to their organizational structure and geographical location, differences in their closeness centrality shows which type of proximity is more significant for knowledge flows.

With respect to the influence of closeness we tested the role of geographical and organizational proximities for pharmaceutical networks after 2008. According to the records of AIFD there were 110 pharmaceutical companies in Turkey in 2014, 64 of which are manufacturers.

With respect to geographical distribution, most of these companies are located in İstanbul. However when taking into account employment share, establishment numbers, and location quotients İstanbul, Kocaeli, Düzce and Kırklareli are defined as geographical clusters for the pharmaceuticals industry. These provinces are neighbors and all located in the Marmara Region. That is why membership of clusters can be taken as proxy for geographical proximity. As mentioned above working in the private sector or universities is taken as proxy of organizational proximity. Then we conducted independent sample T-tests to reveal differentiation between the groups.

The result of the T-test statistic shows meaningful differentiation between the two groups. As seen in the first panel of Table 3, the number of inventors who are part of a cluster (196) overwhelms the number of non-cluster members (37). Likewise, means of closeness centrality – respectively 0.1748 and 0.2898 – differs by 0.115 in favor of cluster members. The second panel of the table contains the main test statistics. In the first part of the panel Levene's test (0.170) is not significant at $p \leq .05$ level. Therefore the assumption of homogeneity of variances has not been violated (Field 2009). Since the two-tailed value of p is .007 it can be concluded that statistically there is a highly significant difference between the means of these two groups of inventors in terms of closeness centrality. The difference is significant $t(231) = -2.730$, $p > .05$ and it represents a medium-sized effect with $r = .32$ effect size. The t-statistics highlight that inventors who reside in geographical clusters or are geographically closer to each other have greater connectivity with other inventors in the network than non-cluster inventors. And geographically being closer supports collaboration and knowledge diffusion between inventors.

With respect to organizational proximity, closeness centrality differs at a negligible level (0.0046). Despite the assumption of homogeneity of variances not being violated the difference is not significant $t(231) = 1.672$, $p > .05$ (Table 4). In other words, there is no meaningful differentiation between private company inventors and university researchers in terms of closeness centrality. Besides, the numbers of university researchers is small (23). It should also be noted

Table 3. Differentiation in closeness centrality for organizational proximity

Group Statistics

	Cluster	N	Mean	Std. Deviation	Std. Error Mean
nCloseness	not cluster	37	,1748	,21461	,03528
		196	,2868	,23136	,01653

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
nCloseness	Equal variances assumed	1,891	,170	−2,730	231	,007	−,11198	,04102	−,19280	−,03117
	Equal variances not assumed			−2,874	53,058	,006	−,11198	,03896	−,19012	−,03384

Table 4. Differentiation in closeness centrality for organizational proximity

Group Statistics

	Organ_two	N	Mean	Std. Deviation	Std. Error Mean
nCloseness	private	210	,2685	,23323	,01609
	university	23	,2731	,22529	,04698

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
nCloseness	Equal variances assumed	1,672	,197	−,089	231	,929	−,00452	,05106	−,10513	−,09609
	Equal variances not assumed			−,091	27,428	,928	−,00452	,04966	−,10634	−,09729

Table 5. Differentiation in diverse centrality measures of inventors

	Degree	nCloseness	Betweenness
Private	1.6857	0.2685	6.3452
Non-technical University	3.0000	0.3325	0.0333
Technical University	0.3750	0.1616	0.0000
Significance ($p \leq .05$)	0.267	0.243	0.820

that many university researchers are isolated nodes. To reveal differentiations between technical universities and non-technical universities we also conducted an ANOVA test for three types of organizational proximity, analyzing degree centrality, closeness centrality and betweenness centrality of the three groups. Notwithstanding that the results of ANOVA test are statistically not significant, the test verifies that private sector inventors have more centrality degrees and occupy critical positions in the network. Furthermore inventors who are members of technical universities have the lowest scores with respect to those measures (Table 5). In fact, values of the first two groups (private sector and non-technical universities) are three times higher than technical university members. The results show that in the innovation network of pharmaceuticals private sector inventors are more dominant and play a more critical role in collaboration, and therefore knowledge diffusion, than university researchers.

4 Conclusion

The results suggest that Turkey has many of the typical characteristics of a developing country in terms of innovation. Limited local patent production shows that technological change and transfer has been done mostly by foreign companies while local companies perform relatively weakly in this respect. This is also confirmed by the very small numbers of citations for local patents. Citation information for local patents verifies that basic knowledge input for innovation comes to large extent from outside. Rather than a robust and dense innovation network, inventors in the chemistry industry are very isolated. Collaboration between the inventors of different subsectors is very uncommon. Likewise, with the exception of the pharmaceuticals subsector, labor mobility is rare and is not an important mechanism for knowledge exchange and transfer between firms. From 1992 to 2014 only 5% of inventors changed their company and all of them worked in the pharmaceutical industry. While citation information signifies an openness to external knowledge, other indicators show the internally density of innovation network is weak.

Geographically, the general pattern of innovation or innovative knowledge production based on patent numbers is highly concentrated and it is located mostly around the largest cities. With respect to the chemistry sector there is no overlap between geographical clusters and innovative knowledge production. Small provinces which appear as geographical clusters have no significant role in innovative knowledge production. They have a low number of patents and their inventors do not have tight linkages with others in their cluster – the exception to this is the pharmaceuticals sector. Despite the existence of a strong geographical concentration around İstanbul, the inventors of pharmaceuticals clusters are more connected.

Differentiation between cluster member inventors and non-member inventors in pharmaceuticals show that the externalities that spring from regional or industrial concentrations may be more significant for knowledge production. Geographical proximity is important for knowledge diffusion in the case of pharmaceuticals. In terms of organizational proximity private companies play a more important role than universities in innovative knowledge production. Large-sized companies are more innovative than their small-medium sized counterparts in the pharmaceutical industry. Despite relatively high numbers of companies in the pharmaceuticals sector, only a few of them participate in knowledge creation. Similarly universities and other research institutions do not contribute as much to the inventive capacity of the industry.

Despite the fact that the share of higher education in research and development expenditures is higher than the private sector (Varol et al. 2011), less interaction and non-open knowledge channels between the two sides hinder companies from getting benefits. Enhanced university-industry collaboration may help SMEs to improve their innovative capacity and exploit the knowledge externalities that can spring from sectoral concentrations. However considering the non-significant role of research institutions and technical universities that this study highlights universities are not effective enough in innovative knowledge production or spillovers within their current structures. Therefore in terms of innovation polices in the country building horizontal linkages between industry and universities should be a major priority. For that reason higher education policy should be revised with increased emphasis on innovation.

Pecuniary incentives by central government on the other hand look like they have a positive effect on innovation. The growth trend in the number of patents coincides with an increase in the provision of consulting assistance and other pecuniary incentives provided by some government agencies. However, these policies are not enough to bring together actors from diverse organizations and create cooperative interactions for innovation. Not only does university-industry collaboration appear as a bottleneck for interactive joint actions underpinning the generation of innovative knowledge but so does collaboration between industries. Instead of a one-glove fits-all approach innovation should be thought of in a systemic way and all agents or components of regions must be involved this process. Therefore defining regional industrial structure and their knowledge dependencies will help in the pursuit of regional specific policies that may be far more appropriate and useful for developing innovation capacity in the country. In other words hierarchically structured institutional infrastructure and innovation policies that ignore space should be abandoned and new policies that facilitate enhancement of horizontal linkages between diverse agents of innovation should be pursued.

Methodologically this study suggests that in the case of a developing country the smaller number of patents hinders efforts to understand the localization of knowledge spillovers by using patent citation information. Thus the networks of inventors itself is a unique approach to understand the innovation dynamics using patents as indicators. Rather than an external network of innovation this approach is better suited for revealing internal networks of inventors and possible knowledge flows. Yet information about inventors and companies on the patent documents can help define diverse proximities and incorporate them into analysis. So far in the literature patents are used to define social and geographical proximity. However, we believe this study demonstrates that companies' information on the patent documents is an appropriate way to define organizational proximity of inventors as well. Indeed social network analysis represents a meso level examination. However assigning inventors' characteristics based on patent information allows understanding of the role of individual actors and their differing characteristics in innovation and therefore represents micro level analysis.

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Resumen. Este estudio se centra en las dimensiones espaciales de la innovación y prueba si hay una superposición entre conglomerados geográficos y la localización de la creación de conocimiento en Turquía. Se utilizaron documentos de patentes como indicadores de la colaboración de los inventores en la innovación y se examinaron las diversas características de los inventores mediante un análisis de redes sociales. Haciendo uso de la dirección y la empresa a la que estaban afiliados los inventores, este estudio sugiere que se puede probar el papel de las proximidades geográficas y de organización en la creación y difusión del conocimiento mediante el uso de análisis de redes sociales. Este estudio concluye que los procesos de innovación en Turquía están altamente concentrados geográficamente y que, en vez de la proximidad de organización entre los actores, el estar cerca de los conglomerados industriales es más importante para la producción y flujos de conocimiento innovador.

要約: 本論文では、イノベーションの空間的次元に注目し、トルコにおける地理的クラスターと知識創造のロケーションのオーバーラップがあるか否かを検証する。特許申請をイノベーションにおける発明家のコラボレーションの指標として使い、ソーシャルネットワークを分析して発明家の様々な特徴を分析する。発明家の居住地と所属企業を使用して、知識の創造と拡散における地理的近接性と組織的近接性の役割を、社会的ネットワーク分析により検証できる事を示す。結論として、トルコのイノベーション・プロセスは、アクター間の組織的近接性よりも、地理的に高度に集中しており、産業クラスターに近いことの方がイノベーティブな知識の生産とフローにとって重要であることがわかる。