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Turkish-German Innovation Networks in the European Research Landscape

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Abstract: Research networks are regarded as channels for knowledge creation and diffusion and are thus essential for the development and integration of economies. In this paper we have a look at the long Turkish-German-migration history which should offer opportunities for both countries to benefit from brain circulation, transnational entrepreneurs and research networks. The present paper examines the structure of research networks of the European Framework Programmes (FP) that are established by joint participation of organizations in research projects, in particular German research organizations with Turkish participants in FP5 to FP7 in the knowledge-intensive technology fields ICT, Biotechnology and Nanoscience. A better understanding of these networks allows for improving the design of research policies at national levels as well as at the EU level. The empirical examination of network properties reveals that the diverse networks show a range of similarities in the three technology fields in each FP such as the small-world properties. Moreover, our findings show that German actors play a specific role in most examined research networks with Turkish participation.

Keywords: Turkish-German-migration history, brain circulation, innovation networks, research networks, EU Framework Programmes, small-world characteristics, centrality measures.

1 Introduction

Innovation networks serve primarily as channels for knowledge creation and diffusion. Innovation networks offer access to scarce resources, create learning opportunities and are considered as means to share R&D costs as well as to cope with technological uncertainty. They are of particular importance for knowledge-intensive industries where the involved clients play a critical role in e.g. fast and new knowledge creation.[1] In addition, besides their role in creating learning opportunities and their impact on knowledge transfer, innovation networks are also important for the development and integration of economies. As Saxenian (2006) has shown, Silicon Valley has significantly benefited from 'transnational or commuting entrepreneurs' which transferred competences from the core to peripheral regions.[2] Thereby special innovation networks are created where knowledge is diffused that emerges due to local and international linkages of those transnational or commuting entrepreneurs.

Similar opportunities are offered in Europe by the Turkish-German-migration history where both economies may benefit from their long-lasting relation and brain circulation in innovation networks spanning actors from both countries.[3] That is, Turkish commuting entrepreneurs may help their home country to overcome typical disadvantages[4] of latecomer economies by their experience and ties to leading high-tech regions. As a side effect the Turkish-German innovation networks might support the European integration process. Simultaneously, like in the Silicon Valley case, the national frontiers bridging innovation networks transfer new knowledge into German innovation networks and diffuse market information of the highly dynamic Turkish economy.

An interesting case are European research networks created by the Framework Programmes (FPs) where since 1999 also Turkish actors are eligible to participate. A better understanding of these research networks in the European Research Area and in particular the specific relations between Turkish and German actors provides insights into the patterns of technology and knowledge transfer between Turkey and Germany. This in turn enables appropriate policy

[1] Cf. Buchmann, Pyka (2011, p. 468-469); Pyka (2011, p. 3).

[2] Transnational or commuting entrepreneurs are well educated people from Asia who left their home country due to poor economic or political conditions in order to study in the US. As soon as the home country's situation went better, those people moved back and founded knowledge-intensive companies benefiting from their experience and linkages with core, i.e. leading high-tech, regions [cf. Saxenian (2006); Sternberg et al. (2007, p. 1)].

[3] Cf. Hartmann et al. (2012, pp. 1, 4).

[4] Those are for instance linguistic and cultural skills, as well as weak (or missing) linkages with innovators who in turn have strong ties to global markets [cf. Saxenian (2006, p. 14); Sternberg et al. (2007, p. 1)].

designs in order to foster knowledge flows and thus enhance technological integration, development and mutual understanding.

In order to improve the understanding of these research networks, this paper deals with the following research questions and will thus contribute to the scarce information available on Turkish-German research networks of the EU FPs and their knowledge diffusion. In essence, it is of utmost interest to reveal whether there are specific patterns how Turkish actors find access to European research networks. Do German actors and the long-lasting Turkish-German relations play a specific role? Thereby it is assumed that Turkey connects with the most important actors in the EU (e.g. the German Fraunhofer Society)[5] according to the preferential attachment phenomenon. Furthermore, also the intensity of connections between Turkish and other actors (in particular German ones) is of interest.

In the present paper research networks of the EU FPs are examined that are established by joint participation of organizations in EU funded research projects in which at least one Turkish organization participated in FP5, FP6 and FP7. The empirical analysis is restricted to knowledge-intensive technology fields such as Information and Communication Technologies (ICT), Biotechnology and Nanoscience, which stimulate collaborative innovation (Pyka, Saviotti 2005).

The remaining part of this paper is structured as follows: Section 2 introduces the methodological approach and provides the empirical setting before the descriptive features of the networks are examined in more detail. Focus is placed on exploratory social network analysis in section 3 that allows revealing structural and dynamic features of research networks with Turkish participation as well as the role and position of network members, putting emphasis on key German cooperation partners. Finally, section 4 summarizes key results and draws conclusions providing suggestions for future research.

2 Methodological approach and empirical setting

Before introducing and analyzing the network data, we introduce the formal and theoretical concepts, as well as the empirical setting. For this purpose, section 2.1 begins with the theoretical concepts of social network analysis, section 2.2 moves on introducing the data source implemented in this work, and finally, Section 2.3 presents descriptive results of the examined network data.

[5] The Fraunhofer Society is the largest application-oriented research organization in Europe.

2.1 Theoretical concepts of social network analysis

Network formation

The networks are formed and expanded by joint participation of organizations in research projects funded within the FPs. Knowledge is diffused between organizations, and new knowledge can jointly be discovered. The single sub-networks are linked via participation of organizations in *different* projects forming a FP network. The bipartite graphs with the two sets of vertices, organizations and projects are drawn. These graphs are transformed to unipartite graphs where organizations are linked by undirected ties representing the joint participation of organizations in research projects.

The following paragraphs introduce important definitions of network metrics:

a) Size, density and degree of actors

Network size is determined by the number of vertices and ties which also determine the degree of connectivity of the network. Network size is important for the composition of social relations as it determines actor's resources for building connections within the network.[6]

The ratio of all present ties expressed as a proportion of all possible ties describes the *density* of a network. It may serve as an estimation about the intensity of knowledge flows among actors.[7]

The *degree of a node* represents the total number of ties linked to a vertex (total number of adjacent vertices) and measures the degree of interconnectedness of an actor.[8]

The above introduced properties deal primarily with actor's immediate connections, but social neighbors of an actor may be as well of interest, as they can be useful in certain environments.

b) Social distance and related concepts

Pairs of vertices are reachable via *paths*, i.e. a sequence of links connecting two vertices. Paths are used to determine the distance between nodes.[9] The *geodesic distance* captures the shortest path between two vertices in the network. The average geodesic distance in a connected graph is defined as the *average* (or *characteristic) path length*. The characteristic path length indicates a network's interconnectedness, i.e. its efficiency in knowledge diffusion. Thus low values of path length imply that information or knowledge is diffused efficiently as only a few intermediaries

[6] Cf. Izquierdo et al. (2006, p. 8).
[7] Cf. Jansen (2003, p. 108).
[8] Cf. Jansen (2003, pp. 94-96, p. 104); Izquierdo et al. (2006, p. 8).
[9] Cf. Jansen (2003, p. 96), Izquierdo et al. (2006, p. 13).

have to be surpassed.[10] The graph *diameter* is defined as the largest geodesic distance between any two vertices in a connected network.[11]

c) Local structures in networks

The *clustering coefficient* assesses the degree to which vertices in a graph tend to group together (i.e. the extent to which the friends of my friends are also my friends). Formally, the clustering coefficient of a vertex is determined by the ratio of present links that connect the neighbors of a vertex to each other, to all possible links among these vertices. The clustering coefficient of the network is determined by the mean clustering coefficient of all vertices. It is a measure of local density of a network denoting how close organizations are through direct and indirect ties (Watts and Strogatz 1998).[12]

d) Centrality and power

One important property of a vertex is its position in the network. Vertex centrality allows identification and the ranking of vertices according to their importance. Central actors possess extensive relations to other actors; they are assumed to have greater access and control over resources and are thus associated with greater innovative activity.[13] In the following three different centrality measures are presented which can be normalized to guarantee comparability across networks of different sizes.

(i) *Degree centrality* is a measure of prominence and power. It considers direct links of a vertex. Vertices with a high number of links are integrated stronger within a network and are therefore assumed to have many advantages: they are highly visible by others, can easily receive or diffuse information, or they may have better access to more resources.[14]

(ii) *Closeness centrality* takes into account the indirect ties of an actor, i.e. its reachability. It is defined as the inverse of the mean geodesic distance from one vertex to every other vertex, e.g. vertices having short distances from any other can obtain or spread new information more efficiently than more distant vertices. Higher closeness centrality scores indicate short distances. In the case of an only weak connected network, closeness centrality cannot be calculated since the distance between two disconnected vertices is infinite.[15]

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[10] Cf. Barabási et al. (2002, p. 594), Wasserman, Faust (1994, p. 107, p. 134).
[11] In case of a disconnected network the largest distance equals infinity [cf. Jansen (2003, p. 97)].
[12] Cf. Bornhold et al. (2003, p. 36); Heller-Schuh (2011, p. 28).
[13] Cf. Wasserman, Faust (1994, p. 174); Jansen (2003, p. 131); Izquierdo et al. (2006, p. 25).
[14] In undirected data vertices only differ from each other in the amount of connections they have.
[15] Cf. Jansen (2003, p. 132); Wasserman, Faust (1994, pp. 184-186); Krogmann et al. (2011, p. 10).

(iii) *Betweenness centrality* examines the role of actors according to their importance as an intermediary within the network. Hence it may be interpreted as a measure of control of information flow, as actors lying on many shortest paths between actors, i.e. having high betweenness centrality, may act as gatekeepers without the necessity to maintain many direct ties. Hence actors with high betweenness centrality are important to diffuse information. As a consequence, information flows in networks with high scores of betweenness centrality are more likely to be disrupted through strategic behavior of one of the gatekeepers.[16]

Network centralization

Degree centralization of a network measures the variation in the degree of vertices as a proportion of the maximal possible degree variation of a network of the same size. Hence, it reflects the relative dominance of single actors in the network.[17]

Besides the discussed structural properties, real-world networks show certain common characteristics that also hold for networks of knowledge-intensive technology fields.

e) Network characteristics

Small-world

Large real-world networks may show surprisingly short average geodesics, which can be attributed to the origin of the small-world phenomenon. A short average path length allows each vertex to reach another one in a few "steps" only. Networks that show small-world characteristics together with a high clustering coefficient are called *small-world networks* (Watts and Strogatz 1998). Small-worlds perform well in knowledge creation and diffusion, hence, contributing to the overall efficiency of a network.[18]

Scale-free networks

Classical random networks assume complete randomness with respect to the establishment of new links. That is, vertices are linked to each other independent of the number of ties they already have, whereby the degree distribution follows a Poisson law. However, many large real-world networks have a highly skewed degree distribution, i.e. they follow a power-law and are referred to as *scale-free* networks. A high skewness indicates that the majority of vertices have only a small number of direct connections and only a few vertices possess many

[16] Cf. Jansen (2003, p. 135f); Izquierdo et al. (2006, pp. 15-18); Wasserman, Faust (1994, pp. 189-191).
[17] Cf. Jansen (2003, pp. 138-142); de Nooy et al. (2005, pp. 125-131).
[18] Cf. Bornholdt et al. (2003, pp. 5-6); Roediger-Schulga et al. (2006, pp. 8-9).

ties. This leads to the assumption that actors act according to different preferences for vertices, suggesting that the probability is higher that a new vertex will link to another vertex which already has a high number of links. Thus, vertices with a high number of links get new connections at a higher rate which is also known as the *preferential attachment* phenomenon. Preferential attachment can explain the existence of a few actors having a high degree (hubs) and a large number of actors having a low degree.[19] The power-law degree distribution is a property that has been identified in a wide range of different networks (e.g. the Internet, world wide web (WWW), and research collaborations based on co-authorship of papers) and holds as well for knowledge-intensive industry networks as shown by Barabási and Albert (1999).

After the discussion of the theoretical background of the social network analysis, the next section is devoted to introduce the data analyzed in this work.

2.2 Data source and terminology

Our analysis focusses on joint research projects with the European FPs in different technology fields that were executed during three different time periods (FP5: 1992-2002), (FP6: 2002-2006), (first half of FP7: 2007-2010.03). The analysis is restricted to knowledge-intensive technology fields: Information and communication technologies (ICT), Biotechnology (Biotech) and Nanoscience (Nano).

The data source that has been implemented in this analysis is the latest version of the EUPRO database provided by the Austrian Institute of Technology (AIT). The EUPRO database contains comprehensive information on research projects funded by the EU FPs and its participating organizations.[20] EUPRO was developed by the AIT and is based on data of the CORDIS projects database. The EUPRO version 7.1.1 used in this analysis covers all projects from FP1 to FP7 until March 2010, which corresponds to the latest update of the database, hence, only the first half of the FP7 period is covered.[21] CORDIS is a Community Research and Development Information Service of the European Union to support cooperation in European research and innovation projects. It contains information on all EU funded FP projects and project participants.[22]

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[19] Cf. Barabási et al. (2002, pp. 599-600); Bornhold et al. (2003, pp. 6-7); Protogerou et al. (2007, p. 18).

[20] The information comprises, in particular, the project objectives, its achievements, project costs, total funding, start and end date, contract type, a standardized subject index, information on the call etc. Moreover information on participating organizations, their department, and contact person with contact details, organization type, and geographical location (NUTS2) are provided. More information is provided in Heller-Schuh et al. (2011, p. 21).

[21] AIT retrieved the project data from CORDIS, cleaned, standardized and consolidated it into the EUPRO database [cf. Heller-Schuh et al. (2011, pp. 21-23)].

[22] http://cordis.europa.eu/projects/home_en.html

For the present purpose of analysis, data from the EUPRO database was extracted that consists of joint research projects in which at least one Turkish organization participates. Data of the specific technology fields is thereby filtered as follows.

ICT: All projects are selected of the programs IST (in FP5 and FP6) and ICT (in FP7).

Biotech: All projects in FP5 to FP7 are selected containing 'biotech' in their subject index.

Nano: In FP6 and FP7 all projects are selected of the programs 'NMP' (in FP6) and 'Nanoscience and Nanotechnology' (in FP7).[23] In FP5 data was filtered containing 'nano' in the field 'other indexes'. Thereby three projects were found in FP5, but with no Turkish participation.

Terminology

The terminologies about different networks in the analyzed time frames are defined as follows: The *total* network in a specific Framework Program *x* and the technology field *y* is specified as FPx-y. If it is referred to a network *with Turkish participation* (TUR) the respective terminology is then FPx-y TUR. The technology field (sector) ICT is consequently expressed as:

FPx-ICT Total network of the ICT sector in FPx, with x = 5, 6, 7.

FPx-ICT TUR ICT network with Turkish participation in FP5, with x = 5, 6, 7.

Further, total networks of the technology fields Biotech and Nano are expressed as FPx-Biotech and FPx-Nano, respectively. Their counterparts with Turkish participation are defined as FPx-Biotech TUR and FPx-Nano TUR. Projects implemented in the respective technology field (ICT, Biotech or Nano) are referred to as 'ICT projects', 'Biotech projects' or 'Nano projects'. Projects containing Turkish participants are referred to as 'ICT projects with Turkish participants', and respectively for the other two technology fields.

2.3 Descriptive features of the examined networks

A first overview of projects and organizations in the different technology fields and FPs is presented in Table 1 including the share of Turkish participation. This will provide insights on the frequency of Turkish participation in FP projects.

[23] The subject index 'Nanoscience and Nanotechnology' was only introduced in FP7.

Table 1: Overview of projects (with and without Turkish participation) and organizations in the technology fields ICT, Biotech and Nano in FP5-FP7

Technology-field	FPx	Projects			Organizations		
		Total	TUR	Share	Total	TUR	Share
IST	FP5	2,520	18	0.7%	7,154	14	0.2%
IST	FP6	1,224	56	4.6%	4,741	35	0.7%
ICT	FP7	686	22	3.2%	2,557	12	0.5%
Sum ICT		4,430	96	2.2%	11,254*	44*	0.4%
Biotech	FP5	638	1	0.2%	1,263	1	0.1%
Biotech	FP6	717	38	5.3%	2,954	33	1.1%
Biotech	FP7	535	10	1.9%	1,355	11	0.8%
Sum Biotech		1,890	49	2.6%	5,572*	45*	0.8%
Nano	FP5	3	-	-	n.s.	-	-
Nano	FP6	414	26	6.3%	2,589	24	0.9%
Nano	FP7	239	18	7.5%	1,739	16	0.9%
Sum Nano		653	44	6.7%	4,328*	40*	0.9%

Note: FP = Framework Program; TUR = 'with Turkish participation' (regarding projects) or Turkish (organizations). N.s. = not specified.
*Total number of organizations over all FPs equals not to the sum of organizations over the single FPs as some organizations may participate in projects that go over several FPs.
Data for FP7 available until 03.2010

Source: Own illustration according to data of EUPRO/AIT.

According to the data in Table 1, ICT is the largest technology field with 4,430 projects (implemented from FP5 to FP7) followed by Biotech and Nano comprising 1,890 and 653 projects, respectively. It has to be noted that the number of projects in FP7 is lower compared to FP6 in all technology fields, which is due to the not fully covered time period of FP7 in the present data source as mentioned above. Moreover, FP6 experienced a significant increase in the average project size which has to be attributed to new policy instruments – Integrated Projects (IP) and Networks of Excellence (NoE) – implemented in FP6 intending to cope with fragmentation of research capabilities and establish the critical mass of expertise and resources. In addition, average funding per project increased in FP6.[24]

It is obvious that Turkey accounts for a relatively small share in EU funded FP projects (FP5-FP7) in all examined technology fields. Turkey's relatively small participation in European research projects in FP5 may find one reason in the funding and participation regulations of the EU FPs. Turkey was allowed to participate in EU FPs only in the last two years of FP5, i.e. since it has been officially recognized as a candidate country of the EU in 1999. In addition, it has had to finance research projects by its own. This is confirmed considering the significant increase of its participation share in FP6 where Turkey could finally benefit from the funding mechanism of the EU FPs. Finally, Turkey's exceptional high participation share in Nano projects (6.7%) requires further investigations.

[24] Cf. Heller-Schuh et al. (2011, p. 44f).

Following the clarification of the theoretical background, rationales and the scope of this work, it is now possible to examine research networks within FP5, FP6 and FP7 due to collaborations in EU funded research projects in which at least one Turkish organization participated, focusing on the technology fields ICT, Biotechnology and Nanoscience.

3 Empirical evidence

The main purpose of this section is to provide insights into research networks that are established by joint participation of organizations in EU funded research projects in which at least one Turkish organization also participated. The analysis is based on methods used in social network analysis, applying the network analysis and visualization programme Pajek (de Nooy et al. 2005).

3.1 Structural properties of the FP*x*-*y* TUR networks

This section examines structural properties of ICT[25], Biotech and Nano networks (i.e. FP*x*-*y* TUR networks) in FP5, FP6 and FP7 that were generated due to collaborations in EU funded research projects in which at least one Turkish organization participated. The structural properties of FP*x*-*y* TUR networks are summarized in Table 2.

Table 2: Structural properties of FPx-y TUR networks

Structural properties	ICT			Biotech			Nano		
	FP5	FP6	FP7	FP5	FP6	FP7	FP5	FP6	FP7
No. of vertices N	274	679	267	6	587	128		340	252
No. of edges M	7,941	15,172	3,718	15	16,977	1,043		4,601	2,572
M with line value >1	11	1664	51	-	374	37		125	53
No. of components	4	2	2	1	3	2		1	5
N for largest component	254	678	182	6	582	96		340	173
Share of total N (%)	92.7	99.9	68.2	100.0	99.1	75		100	68.7
Diameter of largest component	5	4	4	1	5	4		5	5
Average path length of largest comp.	1.0	2.4	2.1	1.0	2.5	2.2		2.5	2.7
Density	0.21	0.07	0.10	1.00	0.10	0.13		0.08	0.08
Mean degree	58.0	44.7	27.9	5	57.8	16.3		27.1	20.4
Mean clustering coefficient	0.98	0.87	0.94	1.0	0.93	0.95		0.92	0.94
Degree Centralization	0.39	0.38	0.29	0	0.29	0.17		0.28	0.16

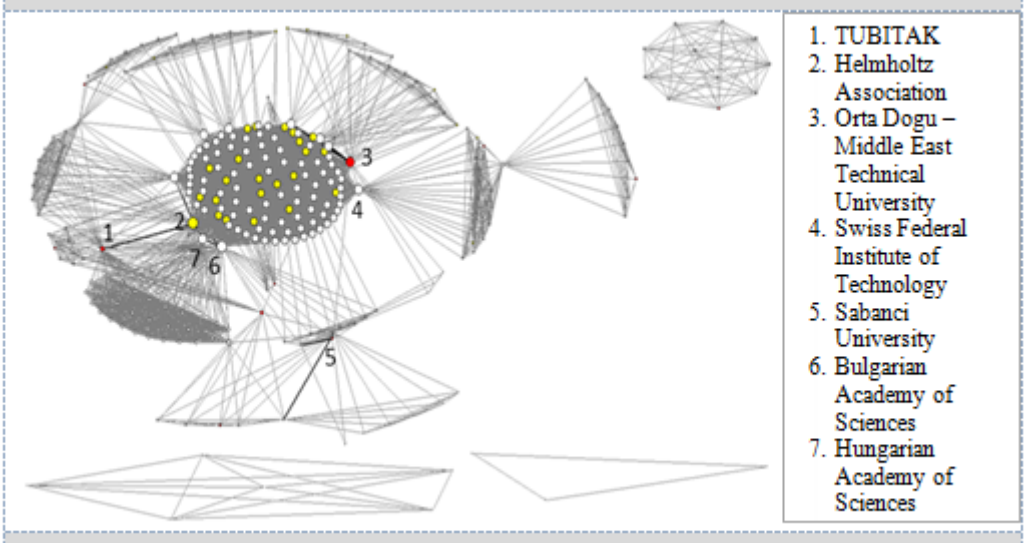
Source: Own illustration according to data of EUPRO/AIT.

[25] The IST element of FP6 has been succeeded by the ICT element in FP7. For a short writing IST in FP5 and FP6 are referred to as ICT.

Information and communication technologies (ICT)

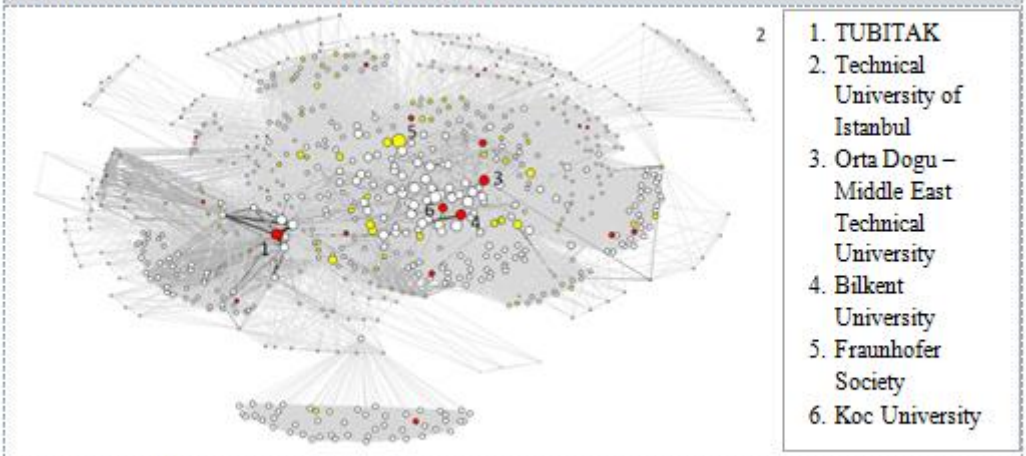
ICT networks with Turkish participation in FP5-FP7 are illustrated graphically in figures 1.1-3 where Turkish and German organizations are colored in red and yellow, respectively. All other countries are represented as white nodes. The node size reflects the degree centrality of actors.

Figure 1-1: ICT network with Turkish participation in FP5



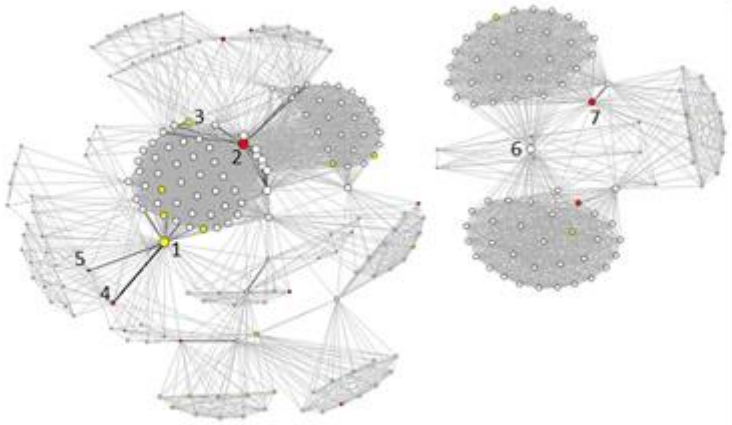
Source: EUPRO/AIT.

Figure 1-2: ICT network with Turkish participation in FP6



Source: EUPRO/AIT.

Figure 4-3: ICT network with Turkish participation in FP7



Source: EUPRO/AIT.

The FP5-ICT TUR network consists of one giant component containing 93% of all vertices. A majority of actors (43%) is interconnected by participation in one large project EURON[26] (in the center) which is crucial for the determination of FP5-ICT TUR network characteristics; all other projects are relatively smaller.

FP6-ICT TUR can be described by many projects that are of smaller size compared to FP5-ICT TUR. Additionally, FP6-ICT TUR shows significantly many *repetitive* partners (11%) that participate in FP6 in more than one project together compared to the other two networks (i.e. edges with line value >1).

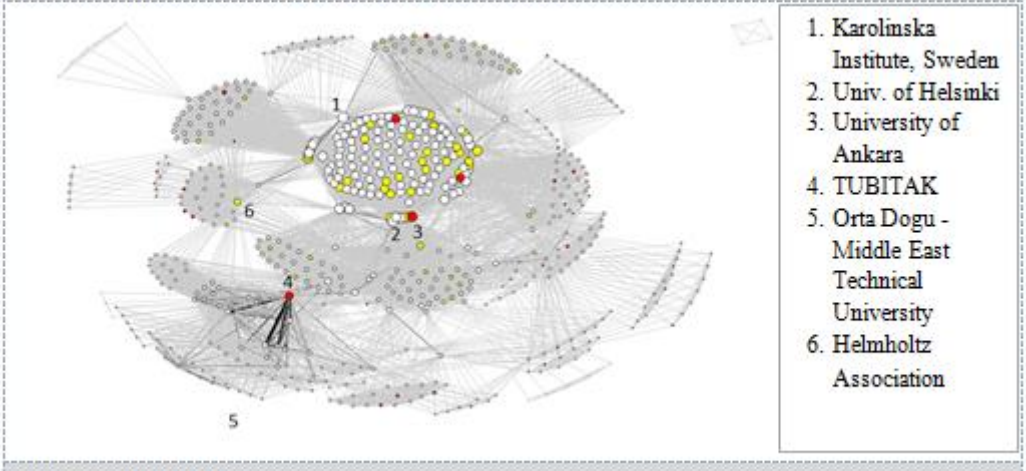
FP7-ICT TUR seems to be similar to FP5-ICT TUR showing several larger, rather separated projects instead of one very large one. Nevertheless, as the period of FP7 is not represented completely (only until March 2010) it is possible that it develops similar to FP6-ICT TUR by the end of FP7 when single organizations take part in projects of both components.

[26] The objective of EURON is to set up a network of excellence in robotics that is aimed at coordination and promotion of robotics research in Europe. Project Acronym: EURON, RCN: 53683 [cf. EURON (2000)].

Biotechnology

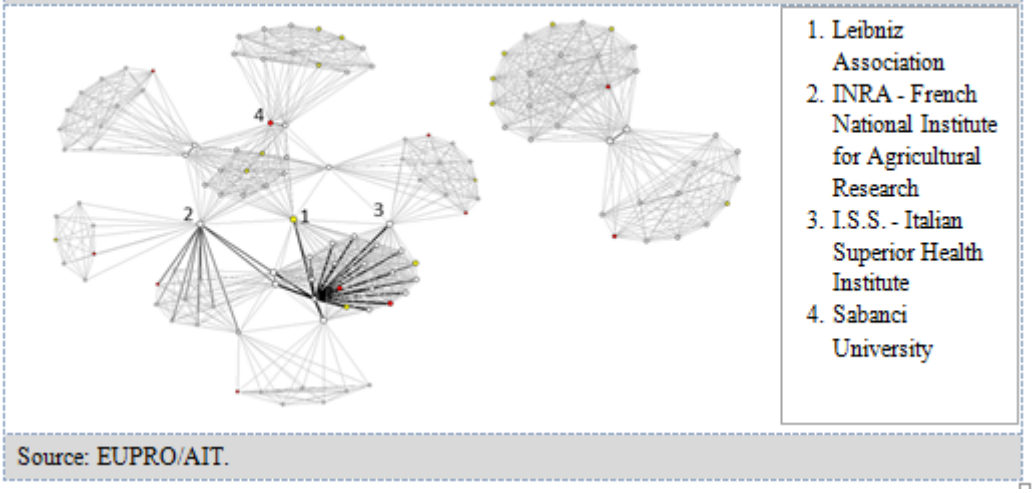
FP6-FP7 Biotech TUR networks are illustrated graphically in figures 2.1-2.

Figure 2-1: Biotech network with Turkish participation in FP6



Source: EUPRO/AIT.

Figure 2-2: Biotech network with Turkish participation in FP7



Source: EUPRO/AIT.

FP6-Biotech TUR consists of one giant component containing 99% of all vertices. FP6-Biotech TUR can be described by one large project (European Leukemianet)[27] that comprises 25% of all organizations and some relatively smaller ones. Moreover, not all central actors are located in the center of the network. For example, TUBITAK, the Scientific and Technical Research Council of Turkey in the lower left part of the network is an important actor with respect to a high betweenness centrality.

FP7-Biotech TUR is described by several relatively small, rather separated projects compared to FP6-Biotech TUR.[28]

[27] Project Acronym: European Leukemianet, RCN: 75278.

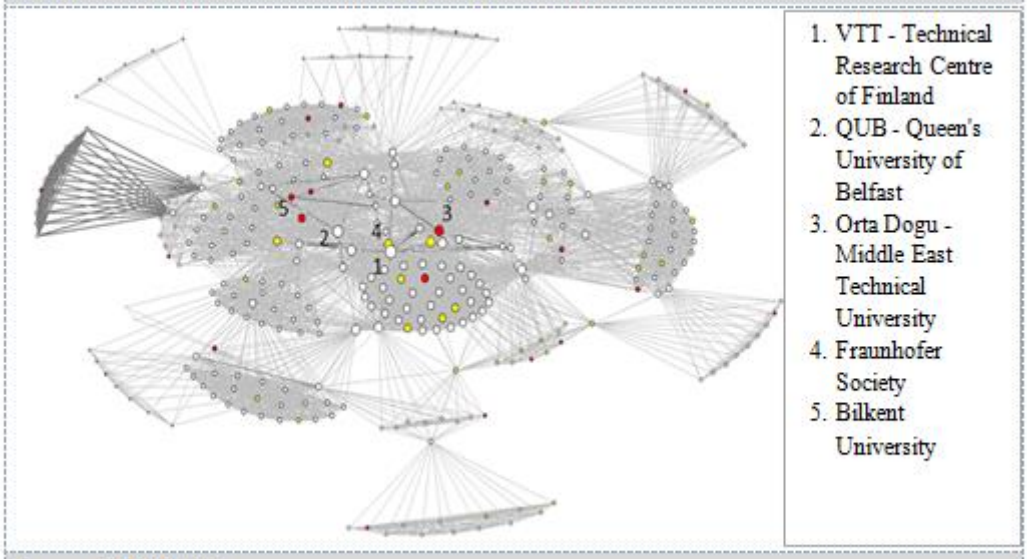
[28] With 'separated' projects it is meant that if an organization participates in project A and B and another organization participates in projects B and C. Then the organizations participating in the projects A and C are also indirectly interconnected due to participation in project B.

Organizations in FPx Biotech TUR networks participate with the same partners in fewer projects, hence there are only few edges with line value >1. Finally, it is possible that FP7-Biotech TUR develops similar to FP6-Biotech TUR by the end of FP7 if single organizations take part in projects of both components connecting them to a single one.

Nanoscience

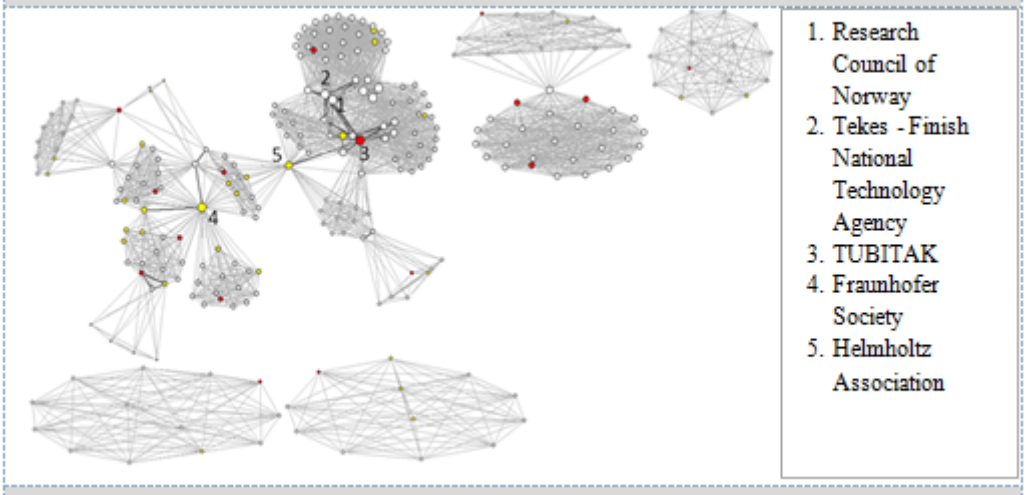
FP6- and FP7 Nano TUR networks are illustrated graphically in figures 3.1-2.

Figure 3-1: Nano network with Turkish participation in FP6



Source: EUPRO/AIT.

Figure.3-2: Nano network with Turkish participation in FP7



Source: EUPRO/AIT.

First of all it is important to mention that Turkey did not participate in Nanoscience projects in FP5. Further, network FP6-Nano TUR can be described by several relatively small projects with one project (Virtual Intelligent Forging - CA) which is slightly larger. Network FP7-Nano TUR is highly fragmented as it comprises five components implying a rather poor

interconnectedness of organizations. Moreover, this network consists of several relatively small, rather separated projects.[29] Additionally, FP7-Nano TUR shows some very central actors in terms of high betweenness centrality that connect organizations of different separated projects.

In fact, most structural properties in FP6- and FP7-Nano TUR networks are very similar. According to Table 2 organizations collaborate with same partners in few projects. That is, edges with line value >1 are marginal in both networks. Finally as already stated above, the separated components of FP7-Nano TUR may still get connected by the end of FP7 when organizations participate in projects of different components connecting them to one or more larger components.

Summarizing, as all examined networks exhibit specific properties such as high clustering coefficients and short average path lengths, they can be characterized as small-world networks according to the definition of Watts and Strogatz (1998). This implies that knowledge can diffuse rapidly and widely in the network and thus enhance local knowledge creation. Furthermore, scale-free properties in FP*x-y* TUR networks cannot be recognized as none of the networks shows a power-law degree distribution.[30] This may find one reason in the relative small size of the examined networks or the fact that only networks of projects with Turkish participants are examined whereby organizations may as well participate in other projects or cooperate with other partners.

3.2 Centrality and power of actors in FP*x-y* TUR networks

This section is devoted to identify central players in FP*x-y* TUR networks considering measures of centrality (degree, closeness and betweenness) in FP5-FP7. Degree centrality is calculated for both kinds of networks: networks *with Turkish* participation FP*x-y* TUR (**Fehler! Verweisquelle konnte nicht gefunden werden.**) and for the *total* FP*x-y* networks (**Fehler! Verweisquelle konnte nicht gefunden werden.**).

Information and communication technologies (ICT)

It is noticeable that most cooperation partners of Turkey in FPx-ICT TUR networks are central as well as important actors (in terms of high degree centrality) in the total ICT networks (FPx-ICT) implying that they may provide Turkish organizations with many other

[29] With 'separated' projects it is meant that if an organization participates in project A and B and another organization participates in projects B and C. Then the organizations participating in the projects A and C are also indirectly interconnected due to participation in project B.

[30] Charts of the degree distributions in FP*x-y* TUR networks are provided in appendix A.

(indirect) contacts.[31] The most important organizations (with respect to a high degree centrality) in ICT TUR research networks are the BAS – Bulgarian Academy of Sciences (FP5-ICT TUR), the German Fraunhofer Society (FP6-ICT TUR) and the Turkish Bilkent University (FP7-ICT TUR) whereby the Fraunhofer Society is also central positioned (rank 1)[32] in the *total* FP6- and FP7-ICT networks. It is possible that BAS occurs more often as a partner of Turkish organizations due to its geographical proximity to Turkey and has therefore a higher degree centrality value.

Analyzing Turkish actors in ICT projects (FPx-ICT TUR), three central Turkish actors are identified in the top 10 FPx-ICT TUR networks. Those are the METU – Middle East Technical University (FP5-ICT TUR), TUBITAK – the Scientific & Technical Research Council of Turkey (FP6-ICT TUR) and the Bilkent University where the latter is most central positioned in FP7-ICT TUR. Moreover, TUBITAK took part in 25% (14 projects) of all ICT projects in FP6-ICT TUR achieving the largest participation share next to the Fraunhofer Society.[33] Moreover, it turns out that none of the Turkish actors is central positioned in the total ICT networks (FPx-ICT).

Biotechnology

In FP5-Biotech TUR all organizations have equal centrality values as they participate in one project and are all interconnected. Further, none of the project participants represents a central actor in the total Biotechnology network (FP5-Biotech). In comparison, FP6- and FP7-Biotech TUR show mainly central and important organizations that are as well of high importance with respect to a high degree centrality in the respective total Biotech networks (FP6- and FP7-Biotech).[34] Those are the Finnish University of Helsinki (rank 8)[35] and the German Leibniz Association (rank 14) in FP6- and FP7-Biotech TUR respectively. In general, the same organizations are identified as most central actors in the three different centrality measures (degree, closeness, betweenness) in FP5-, FP6- and FP7-Biotech TUR networks.

[31] In the total ICT networks (FPx-ICT) are considered the 50 most important actors (with respect to a high degree centrality) out of 7,154; 4,741 and 2,557 organizations taking part in FP5-, FP6- and FP7-ICT, respectively. Further, the ranking of the FPx-ICT TUR networks considers the first 10 organizations.

[32] The rank orders organizations according to their importance (degree centrality) in the total FP5- to FP7-ICT networks.

[33] Fraunhofer Society participated in 35% of all projects in FP6-ICT TUR as is examined in more detail in Section 4.1.3.

[34] In the total Biotech networks (FPx-Biotech) are considered the 50 most important actors (with respect to a high degree centrality) out of 1,263; 2,954 and 1,355 organizations taking part in FP5-, FP6- and FP7-Biotech, respectively. Further, the ranking of the FPx-Biotech TUR networks considers the first 10 organizations.

[35] The rank orders organizations according to their importance (degree centrality) in the total network (FPx-Biotech) in the considered time periods (FP5 to FP7).

The only (non-Turkish) outlier is the German Helmholtz Association (HHG) having a high betweenness centrality in FP6-Biotech TUR but is not central positioned with respect to the other two centrality measures.

Three central Turkish organizations are identified: MERKAT (FP5-Biotech TUR), the University of Ankara (FP6-Biotech TUR) and the Sabanci University (FP7-Biotech TUR). In addition, TUBITAK - the Scientific and Technical Research Council of Turkey is identified as a very central actor in terms of a high betweenness centrality in FP6-Biotech TUR.

Nanoscience

Most central positioned in FP6- and FP7-Nano TUR are the Technical Research Centre of Finland (VTT) (rank 7)[36] and the Research Council of Norway, respectively.[37] But, whereas most actors in FP6-Nano TUR (degree centrality) are as well central positioned in the total FP6-Nano network, in FP7-Nano TUR only one single actor (Fraunhofer Society) is identified that constitutes simultaneously a central organization in the total FP7-Nano network. Moreover, the German Helmholtz Association (HHG) and the Fraunhofer Society are identified as particular central actors with respect to a high betweenness centrality in FP7-Nano TUR denoting that they are relatively more important as intermediaries in this network.

Examining Turkish actors, the Turkish Middle East Technical University (METU) and the Scientific and Technical Research Council of Turkey (TUBITAK) are identified in FP6- and FP7-Nano TUR, respectively. However, both organizations are not recognized as important players (in terms of high degree centrality) in the total FPx-Nano networks. METU participated in 19% and 11%, TUBITAK took part in 8% and 22% of all Nanoscience projects with Turkish participation in FP6 and FP7, respectively.

Finally, all centrality measures show a broad variety of organizations of different countries where research organizations and universities dominate.

Following the identification of central actors in FP*x-y* TUR networks it is important to examine the connections to reliable partners in more detail as they may be used to exploit and deepen existing knowledge. Thereby emphasis is put on Turkey's key German cooperation partners.

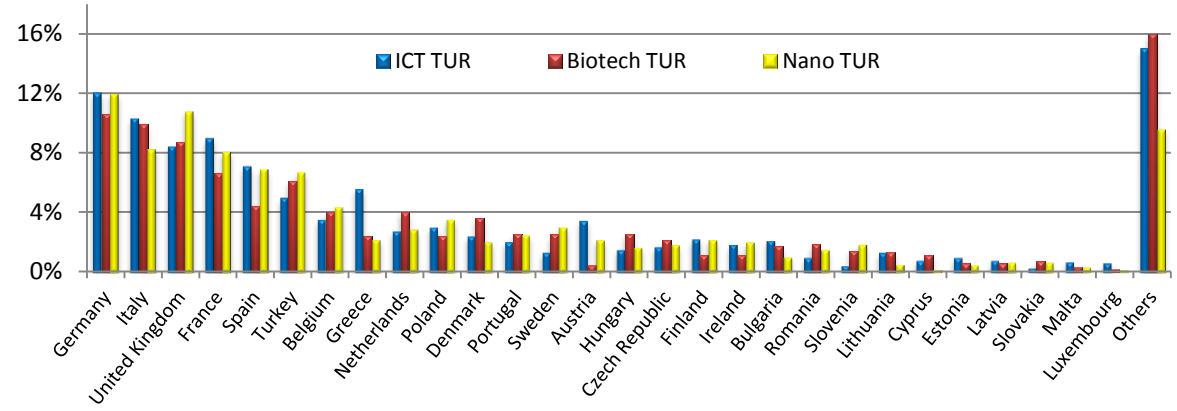
[36] The rank orders organizations according to their importance (degree centrality) in the total network (FPx-Nano) in the considered time periods (FP6 and FP7).

[37] In the total Nano networks (FPx-Nano) are considered the 50 most important actors (with respect to a high degree centrality) out of 2,589 and 1,739 organizations taking part in FP6- and FP7-Nano, respectively. Further, the ranking of the FPx-Nano TUR networks considers the first 10 organizations.

3.3 Key German actors in FP*x-y* networks with Turkish participation

The final section of FP*x-y* TUR network analysis intends to provide evidence whether Turkey's key German cooperation partners are as well of particular importance in FP*x-y* networks and may therefore support Turkey's integration in ICT, Biotechnology and Nanoscience networks on the European level. A first overview considers measures of participation to provide an impression of Europe's (EU27 and Turkey) performance in research projects with Turkish participation in FP*x-y* TUR networks (Figure).[38]

Figure 4: Share of Turkey's cooperation partners in ICT, Biotech and Nano TUR networks in FP5-FP7



Source: Own illustration according to data of EUPRO/AIT.

German organizations had the highest involvement in research projects with Turkish participation in the ICT, Biotech and Nano sector from FP5 to FP7. However, the results may also be referred to Germany's in general strong presence in European research projects. Unfortunately, the participation share of Germany in ICT-, Biotech- and Nano TUR projects compared to the overall participation share of Germany in the respective total networks cannot be validated, since for this study detailed data is only provided for projects with Turkish participants in ICT, Biotech and Nano. Nevertheless, as Germany is of particular interest in this network analysis it is examined in more detail.

It becomes particularly apparent that Germany participated in the majority of ICT, Biotech and Nano research projects in the examined FP*x-y* TUR networks (with an increasing trend) in the following.

Information and communication technologies (ICT)

Germany has the highest share (12%) in terms of participating organizations in FPx-ICT TUR networks, closely followed by Italy (10%) and France (9%) as seen in Figure . Thereby

[38] Countries that participate in EU FP projects but that are not member states of the EU are grouped to "others".

Germany participated in 50%, 89% and 95% of all ICT projects in the networks FP5-, FP6- and FP7-ICT TUR, respectively.[39] Appendix E.1 illustrates these figures graphically considering exclusively German and Turkish cooperation partners.

Analyzing the most important actors (in terms of a high degree centrality) in the FPx-ICT TUR networks (Appendix B.1) that are also centrally positioned in the total FPx-ICT networks (Appendix D.1) only three organizations could be identified in FPx-ICT TUR networks, the Helmholtz Association (in FP5- and FP6-ICT TUR), the Fraunhofer Society (in FP6- and FP7-ICT TUR) and the Berlin University of Technology (FP7-ICT TUR).[40] Most other central players in the FPx-ICT TUR networks are not central positioned (in terms of a high degree centrality) in the total FPx-ICT networks. This in turn implies that Turkey can strengthen its position in the ICT sector by increasing its collaborations with rather central German actors of the total FPx-ICT networks (e.g. Alcatel-Lucent in FP7-ICT).

In conclusion, the Helmholtz Association and the Fraunhofer Society are important with respect to their high degree centrality in FPx-ICT TUR and total FPx-ICT networks, but also in terms of their participation rate in ICT projects in FP5- to FP7-ICT TUR networks. Accordingly, Helmholtz and Fraunhofer participated in 8% (8 projects) and 30% (29 projects) of all ICT projects with Turkish participation, respectively, that were implemented in the FPs 5-7. Within these research organizations, Helmholtz German Aerospace Center (DLR) and the Fraunhofer Institute for Applied Solid State Physics (IAF) are partners in the majority of the examined ICT projects in FPx-ICT TUR networks.[41]

Biotechnology

Also in the Biotechnology sector Germany has the highest share (11%) of participating organizations in FP5- to FP7-Biotech TUR networks, closely followed by Italy (10%) and the United Kingdom (9%). Hereby, Germany took part in 50% and 70% of Biotechnology projects with Turkish participation in FP6 and FP7, respectively.[42] German organizations accounted thereby for 10% (61 organizations) and 12% (16 organizations) in FP6- and FP7-Biotech TUR. Appendix E.2 illustrates these figures graphically considering exclusively German and Turkish cooperation partners.

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[39] In total 40, 52 and 40 countries participated in the networks FP5-, FP6- and FP7-ICT TUR, respectively.

[40] Degree centrality is calculated for both kinds of networks: networks with Turkish participation (FPx-ICT TUR, Appendix B) and for total ICT networks (FPx-ICT, Appendix C). In FPx-ICT networks are considered the 50 most important actors out of 7,154; 4,741 and 2,557 organizations taking part in FP5-, FP6- and FP7-ICT, respectively.

[41] Further participating Fraunhofer institutes were the FIT, IFF, ISI and IGD that were involved only in a small number of projects.

[42] In total 5, 52 and 36 countries participated in the networks FP5- FP6- and FP7-Biotech TUR, respectively.

The most central German organizations in FPx-Biotech TUR (Appendix B.2) are also central positioned in the total FPx-Biotech networks (Appendix D.2), the Charite – University of Berlin and the Technical University of Munich in FP6-Biotech and the Leibniz Association with the Bonn University in FP7-Biotech. The results show that most central German cooperation partners of Turkey in FPx-Biotech TUR networks are rather less important (with respect to a high degree centrality) in the total FPx-Biotech networks. Most other central German actors of the total FPx-Biotech networks are less important in the FPx-Biotech TUR networks. This implies that Turkey can improve its position in the Biotechnology sector by strengthening its cooperation with those central German actors in the overall FPx-Biotech networks such as the Helmholtz Association. Moreover, Turkey can further enhance its position by cooperating with the Fraunhofer Society that is a central actor in the FPx-Biotech networks, with whom it did not yet collaborate.

In conclusion, Turkey seems to be strongly connected to the Leibniz Association which is a central actor in both, the FPx-Biotech TUR and the total FPx-Biotech networks. Another important German actor is the Helmholtz Association which accounted for the largest share of German organizations in Biotech projects in FPx-Biotech TUR networks although it is not central positioned there. Helmholtz and Leibniz participated in 12% (6 projects) and 6% (3 projects) of all Biotech projects with Turkish participation in FP6- and FP7-Biotech TUR networks.[43]

Nanoscience

As in the other two technology fields have German organizations the highest share (12%) in FPx-Nano TUR networks, closely followed by the United Kingdom (11%), Italy (8%) and France (8%). Germany participated in almost every Nano project (77% and 89%) in which Turkey took part in FP6 and FP7 as well.[44] Appendix E.3 illustrates these figures graphically considering exclusively German and Turkish cooperation partners.

Moreover, examining most central German actors (degree centrality) in FP6- and FP7-Nano TUR networks (Appendix B.3), that are also centrally positioned in the respective total FPx-Nano networks (Appendix D.3) shows that Turkey is already cooperating with more or less important German actors of the total Nano network in FP6, but not anymore in FP7). This implies that Turkey can improve its position in the Nanoscience sector by strengthening its cooperation with more central German actors of the FP7-Nanoscience network such as such

[43] In particular were following institutes involved in research projects in FP6- and FP7-Biotech TUR networks: AWI, UFZ, HZM, DLR, HZI of the Helmholtz Association and IPF, FZB, IPK of the Leibniz Association.

[44] In total 35 and 39 countries participated in FP6- and FP7-Nano TUR networks, respectively.

as for instance the Dresden University of Technology or the Karlsruhe Institute of Technology – KIT. Finally, potential German cooperation partners for Turkey in the future are for instance the BASF AG or the Bayer AG as they constitute central actors in FPx-Biotech networks with whom Turkey did not yet collaborate in Nanos projects.

As stated above Fraunhofer and Helmholtz are the most important partners of Turkey (in terms of degree centrality) in FPx-Nano TUR and in the total FPx-Nanoscience networks. Together they participated in 11% (5 projects) and 18% (8 projects) of all Nanoscience projects with Turkish participation in the FP6- and FP7-Nano TUR networks.[45]

4 Conclusions

The analysis of ICT, Biotech and Nano research networks with Turkish participation in FP5 to FP7 by social network analysis methods shows some interesting facts about the networks established under the EU FPs. As has been shown, Turkey accounts for a relatively small share in EU funded FP projects (FP5-FP7) in all examined technology fields. However, its participation share has been increasing over time since it was officially recognized as a candidate country of the EU in 1999 and could therefore gradually participate in European research programs.

The empirical examination of structural properties of the examined networks reveals that all networks show a range of similarities in the three technology fields in each FP. All networks show very high clustering coefficients and short average path lengths and can thus be characterized as small-world networks implying fast knowledge diffusion and enhanced knowledge creation. Further, there is no clear sign of scale-free properties of the networks as a power-law degree distribution could not be assessed in any network. The similarities in the outcomes indicate that the networks (and their structure) seem to be significantly affected (and formed) by their participating organizations and are not specific to a technology field.

The identified central actors in all networks are primarily research organizations and universities (with respect to their participation rate and high degree centrality). German organizations have the highest share in terms of participating organizations in almost all examined ICT, Biotech and Nano networks with Turkish participation in FP5 to FP7. Analyzing Turkey's key *German* collaboration partners (with respect to a high degree

[45] In particular were following institutes involved in research projects in FP6- and FP7-Nano TUR networks: UFZ, DLR and Forschungszentrum Jülich etc. of the Helmholtz Association and IPA, IAO and IPK etc. of the Fraunhofer Society.

centrality) it turns out that only a few are central positioned in total ICT, Biotech and Nano networks. This implies that Turkey can improve its position in all three examined technology fields by strengthening its cooperation with rather central German actors of those total networks, as well with those with whom it did not collaborate yet.

The results support the assumption that German actors play a specific role in most examined research networks with Turkish participation in FP5 to FP7. Established connections to key German actors might foster Turkey's integration in research networks of the examined technology fields on the European level, but there is also potential to enhance and expand the connections to German actors (with regards to central positioned German actors in the total networks).

The present results suggest that further research is required to gain in-depth knowledge about the emergence of the relationships between Turkish and German actors. In particular, case studies of the implemented research projects or interviews with its participants can be considered in order to examine whether the Turkish-German-migration history is of particular importance for the identified collaborations and whether it triggered network formation. Further, besides the analysis of project participation, also results of the identified projects, such as patents or co-publications can be examined with respect to their Turkish and German inventors or authors. This allows analyzing the roles of commuting entrepreneurs and researchers and their performance in the Turkish-German research networks and provides deeper insights into the patterns of technology and knowledge transfer between Turkey and Germany.

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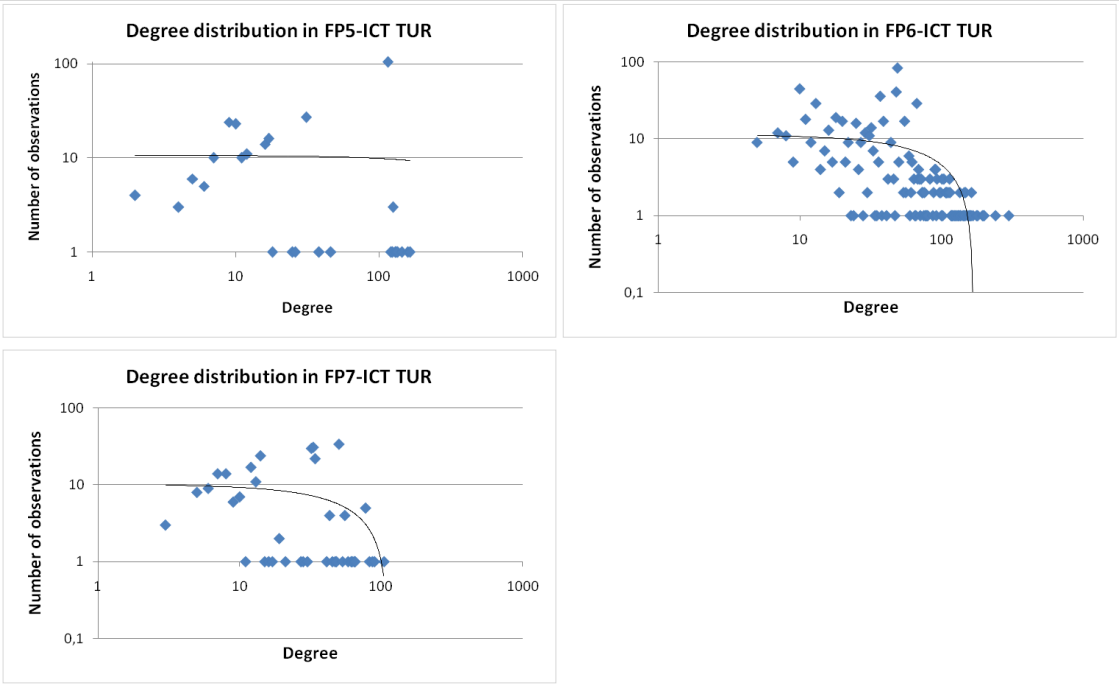
A Degree distribution of FP*x*-*y* TUR networks

All examined networks with Turkish participation (ICT, Biotech and Nano) don't show scale-free properties as none of the networks shows a power-law degree distribution. Figure A1 illustrates the degree distribution for the giant components of ICT TUR networks developed in FP5, FP6 and FP7.

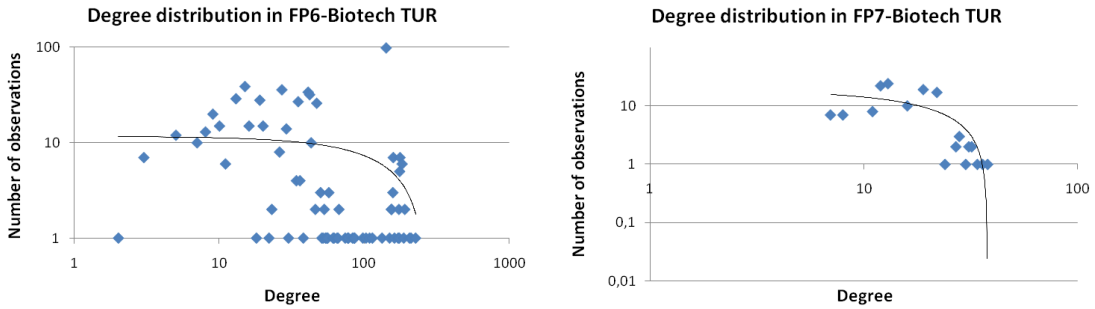
Figure A1: Degree distribution of FPx-ICT TUR networks in FP5 to FP7.



Source: Own illustration according to data of EUPRO/AIT.

Figure A2 shows the degree distribution for the giant components of Biotech TUR networks developed in FP6 and FP7.

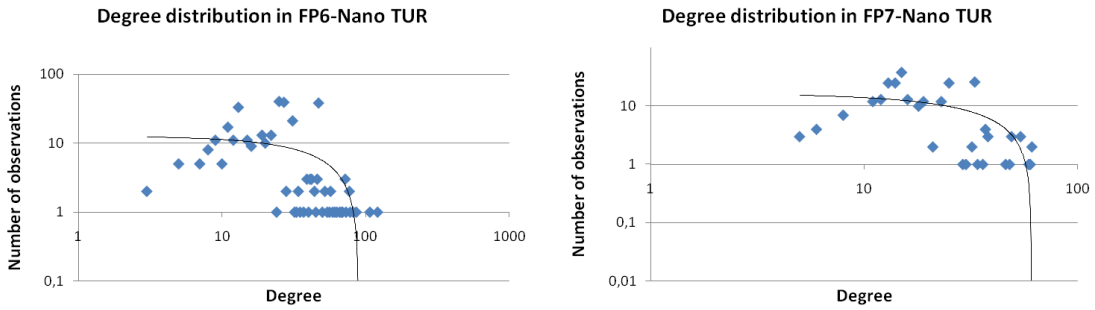
Figure A2: Degree distribution of FPx-Biotech TUR networks in FP6 and FP7.



Source: Own illustration according to data of EUPRO/AIT.

Figure A3 illustrates the degree distribution for the giant components of Nano TUR networks developed in FP6 and FP7.

Figure A3: Degree distribution of FPx-Nano TUR networks in FP6 and FP7.



Source: Own illustration according to data of EUPRO/AIT.

B Degree centrality of FP*x-y* TUR networks (with Turkish participation)

Tables B.1 to B.3 illustrate organizations with the ten highest degrees in FP*x-y* TUR networks in FP5 to FP7.[46] One has to note, that the precise position of individual organizations in the ranking should not be overemphasized as centrality scores may depend on the project type. That is, participation in one large project increases centrality scores disproportional (as seen in e.g. EURON in FP5-ICT TUR). Hence, single universities may appear in the higher ranks next to large research organizations (such as Fraunhofer Society or TUBITAK) although they did not participate in many projects but in single very large projects.[47]

Table B.1: Overview of centrality measures in FPx-ICT TUR networks in FP5-FP7

FP5-ICT TUR								
degree centrality	**T**	**value**	**closeness centrality**	**T**	**value**	**betweenness centrality**	**T**	**value**
Bulgarian Academy of Sciences (BAS)	R	0.60	Bulgarian Academy of Sciences (BAS)	R	0.71	Bulgarian Academy of Sciences (BAS)	R	0.18
Helmholtz Association (HHG), Germany (*)	R	0.58	Helmholtz Association (HHG)	R	0.70	Swiss Federal Institute of Technology	R	0.16
Magyar - Hungarian Academy of Sciences (MTA) (*)	R	0.53	Magyar - Hungarian Academy of Sciences (MTA)	R	0.67	Orta Dogu - Middle East Technical University (METU), Turkey	U	0.09
Orta Dogu - Middle East Technical University (METU), Turkey	U	0.49	Orta Dogu - Middle East Technical University (METU), Turkey	U	0.66	Helmholtz Association (HHG)	R	0.09
Swiss Federal Institute of Technology (*)	R	0.48	Swiss Federal Institute of Technology	R	0.66	National Technical University of Athens (NTUA), Greece	U	0.07
AIT Austrian Institute of	R	0.48	AIT Austrian Institute of	R	0.64	University of Sofia	U	0.06

[46] The empty fields indicate either that no organizations are listed further in the top 10 centrality measures (in Pajek), or that there are more than the listed 10 organizations having equal values

[47] Based on the data and the time frame of this paper, no further classification of the participating institutes was possible.

Technology GmbH			Technology GmbH			Kliment Ohridski, Bulgaria		
Polytechnic University of Milan, Italy (*)	R	0.46	Technical University Vienna (TU Wien), Austria	U	0.63	Magyar - Hungarian Academy of Sciences (MTA)	R	0.05
National Technical University of Athens (NTUA) (*)	R	0.46	Politecnico di Milano, Italy	U	0.63	University of Amsterdam, Netherlands	R	0.05
Technical University Vienna (TU Wien), Austria (*)	R	0.46	National Technical University of Athens (NTUA), Greece	U	0.63	Planet S.A., Greece	I	0.04
University of Amsterdam, Netherlands (*)	U	0.45	University of Amsterdam, Netherlands	U	0.63	AIT Austrian Institute of Technology GmbH	R	0.04

FP6-ICT TUR								
degree centrality	**T**	**value**	**closeness centrality**	**T**	**value**	**betweenness centrality**	**T**	**value**
Fraunhofer Society, Germany (*)	R	0.44	Fraunhofer Society, Germany	R	0.61	Fraunhofer Society, Germany	R	0.14
French National Centre for Scientific Research (CNRS), France (*)	R	0.36	French National Centre for Scientific Research (CNRS), France	R	0.58	Vilnius University, Lithuania	U	0.13
Turkiye Bilimsel - Scientific and Technical Research Council of Turkey (TUBITAK)	R	0.30	Turkiye Bilimsel - Scientific and Technical Research Council of Turkey (TUBITAK)	R	0.58	Turkiye Bilimsel - Scientific and Technical Research Council of Turkey (TUBITAK)	R	0.11
Polytechnic University of Catalonia (UPC), Spain (*)	U	0.29	Chalmers University of Technology, Sweden	U	0.57	Chalmers University of Technology, Sweden	U	0.06
VTT Technical Research Centre of Finland (*)	R	0.29	Budapest University of Technology and Economics (BME), Hungary	U	0.56	Orta Dogu - Middle East Technical University (METU), Turkey	U	0.06
Technical University Vienna (TU Wien), Austria (*)	U	0.27	Polytechnic University of Catalonia (UPC), Spain	U	0.55	Budapest University of Technology and Economics (BME), Hungary	U	0.05
Chalmers University of Technology, Sweden	U	0.26	VTT Technical Research Centre of Finland	R	0.55	VTT Technical Research Centre of Finland	R	0.03
Royal Institute of Technology (KTH), Sweden (*)	U	0.25	Technical University Vienna (TU Wien), Austria	U	0.54	Institute for Systems and Computer Engineering (INESC), Portugal	R	0.03
Bilkent University, Turkey	U	0.24	Orta Dogu - Middle East Technical University (METU), Turkey	U	0.54	Magyar - Hungarian Academy of Sciences (MTA)	R	0.03
Orta Dogu - Middle East Technical University (METU), Turkey	U	0.24						

FP7-ICT TUR								
degree centrality	**T**	**value**	**closeness centrality**	**T**	**value**	**betweenness centrality**	**T**	**value**
Bilkent University, Turkey	U	0.39	Polish Academy of Sciences (PAS/PAN)	R	0.82	Fraunhofer Society, Germany	R	0.13
Fraunhofer Society, Germany	R	0.33	Turkiye Bilimsel - Scientific and Technical Research Council of Turkey (TUBITAK)	R	0.73	Bilkent University, Turkey	U	0.08
National and Kapodistrian University of Athens (UOA), Greece (*)	U	0.32	Greek National Research and Technology Network Sa	R	0.69	Charles III University of Madrid (UC3M), Spain	U	0.04
Technical University Vienna, Austria (*)	U	0.31	Ministry of Education and Science, Montenegro	G	0.68	National Research Council (CNR), Italy	R	0.03
Ghent University (RUG), Belgium	U	0.29	Magyar - Hungarian Academy of Sciences (MTA)	R	0.66	T.X.T. E-Solutions Spa	I	0.03
Poznan University of Technology, Poland	U	0.29				National and Kapodistrian University of Athens (UOA), Greece (*)	U	0.03
Groupe des ecoles des Telecommunications, France (*)	U	0.29				Polish Academy of Sciences (PAS/PAN)	R	0.03

Polytechnic University of Catalonia (UPC), Spain (*)	U	0.29				French National Centre for Scientific Research (CNRS), France	R	0.03
Technological Centre of Telecomunicacions of Catalunya - CTTC, Spain	R	0.29				Open University UK (OpenU)	U	0.03
Polish Academy of Sciences (PAS/PAN)	R	0.24				University of Bologna, Italy	U	0.02

Note: (*) Organization is also under the top 50 organizations with the highest degree centrality in the total ICT network. T - Organization type: U - university; R - research organization; I - industry; C - consulting G - government; O - other. The empty fields imply either that no organizations are listed further in the top 10 (in Pajek), or that there are more than the listed 10 organizations having equal centrality values.

Source: Own illustration according to data of EUPRO/AIT.

Table B.2: Overview of centrality measures in FPx-Biotech TUR networks in FP5-FP7

FP5-Biotech TUR								
degree centrality	**T**	**value**	**closeness centrality**	**T**	**value**	**betweenness centrality**	**T**	**value**
Austrian Energy Agency	O	1	Austrian Energy Agency	O	1	Austrian Energy Agency	O	0
MERKAT, Turkey	C	1	MERKAT, Turkey	C	1	MERKAT, Turkey	C	0
EXERGIA, Greece	C	1	EXERGIA, Greece	C	1	EXERGIA, Greece	C	0
Green Land Reclamation Ltd, GBR	I	1	Green Land Reclamation Ltd, GBR	I	1	Green Land Reclamation Ltd, GBR	I	0
British Biogen Ltd	I	1	British Biogen Ltd	I	1	British Biogen Ltd	I	0
China Association of Rural Energy Industry	O	1	China Association of Rural Energy Industry	O	1	China Association of Rural Energy Industry	O	0

FP6-Biotech TUR								
degree centrality	**T**	**value**	**closeness centrality**	**T**	**value**	**betweenness centrality**	**T**	**value**
University of Helsinki, Finland (*)	U	0.39	University of Helsinki, Finland	U	0.61	Scientific and Technical Research Council of Turkey - TUBITAK	R	0.11
Karolinska Institute, Sweden (*)	U	0.36	Justus Liebig University Gießen, Germany	U	0.57	Helmholtz Association (HHG), Germany	R	0.10
University of London - UOL (*)	U	0.35	Heinrich Heine University, Germany	U	0.57	Queens University of Belfast (QUB), GBR	U	0.08
University of Bologna, Italy (*)	U	0.33	Christian-Albrechts-University Kiel, Germany	U	0.57	University of Milan, Italy	U	0.07
Queens University of Belfast (QUB), GBR	U	0.33	University of Bari, Italia	U	0.57	University of Bologna, Italy	U	0.05
University of Perugia, Italy	U	0.32	University of Ankara (ankaraU), Turkey	U	0.57	University of Helsinki, Finland	U	0.05
			University of Sheffield (SheffU), GBR	U	0.57	Academy of Sciences of the Czech Republic	R	0.04
			University of Bologna, Italy	U	0.57	University of London - UOL	U	0.04
			University of Newcastle upon Tyne (NCL), GBR	U	0.55	Wageningen University UR, Netherlands	U	0.04
			University of Aarhus (AU), Denmark	U	0.55	Karolinska Institute, Sweden	U	0.04

FP7-Biotech TUR								
degree centrality	T	value	closeness centrality	T	value	betweenness centrality	T	value
Leibniz Association, Germany (*)	R	0.30	Leibniz Association, Germany	R	0.63	Institut National de la Recherche Agronomique (INRA), France	R	0.15
Institut National de la Recherche Agronomique (INRA), France (*)	R	0.27	Institut National de la Recherche Agronomique (INRA), France	R	0.61	Leibniz Association, Germany	R	0.12
Superior Health Institute (I.S.S.), Italy (*)	R	0.27	University of Milan, Italy	U	0.56	University of Milan, Italy	U	0.07
French Agricultural Research Centre (CIRAD), France	R	0.25	Scottish Agricultural and Biological Research Institutes (SABRIs), GBR	R	0.56	Sabanci University (SabanciU), Turkey	U	0.06
National Institute for Agruculture and Food Research and Technology (INIA), Spain	R	0.25	Sabanci University (SabanciU), Turkey	U	0.56	Scottish Agricultural and Biological Research Institutes (SABRIs), GBR	R	0.06
Chalmers University of Technology, Sweden	U	0.24	University of Bologna, Italy	U	0.56	University of Bologna, Italy	U	0.06
ETH Zürich - Swiss Federal Institute of Technology (*)	R	0.24	Biotechnology and Biological Sciences Research Council (BBSRC), GBR	R	0.56	Biotechnology and Biological Sciences Research Council (BBSRC), GBR	R	0.06
New University of Lisbon (UNL), Portugal	U	0.24				Superior Health Institute (I.S.S.), Italy	R	0.05
						New University of Lisbon (UNL), Portugal	U	0.05

Note: (*) Organization is also under the top 50 organizations with the highest degree centrality the total Biotech network. T - Organization type: U - university; R - research organization; I - industry; C - consulting G - government; O - other. The empty fields imply either that no organizations are listed further in the top 10 (in Pajek), or that there are more than the listed 10 organizations having equal centrality values.

Source: Own illustration according to data of EUPRO/AIT.

Table B.3: Overview of centrality measures in FPx-Nano TUR networks in FP5-FP7

FP6-Nano TUR								
degree centrality	T	value	closeness centrality	T	value	betweenness centrality	T	value
VTT Technical Research Centre of Finland (*)	R	0.36	VTT Technical Research Centre of Finland	R	0.57	University of Ljubljana, Slovenia	U	0.11
Queen's University of Belfast (QUB), GBR (*)	U	0.32	Queen's University of Belfast (QUB), GBR	U	0.54	VTT Technical Research Centre of Finland	R	0.09
Orta Dogu - Middle East Technical University (METU), Turkey	U	0.25	University of Ljubljana, Slovenia	U	0.53	Queen's University of Belfast (QUB), GBR	U	0.08
University of Ljubljana, Slovenia	U	0.24	Orta Dogu - Middle East Technical University (METU), Turkey	U	0.52	Budapest University of Technology and Economics (BME), Hungary	U	0.07
Fraunhofer Society, Germany (*)	R	0.23	University of Birmingham (BirmU), GBR	U	0.52	National Physical Laboratory (NPL), GBR	U	0.07
University of Birmingham (BirmU), GBR (*)	U	0.23	Swerea IVF, Sweden	R	0.52	French National Centre for Scientific Research (CNRS), France	R	0.07
Swerea IVF, Sweden	R	0.23	University of Twente, Netherlands	U	0.52	Orta Dogu - Middle East Technical University (METU), Turkey	U	0.06
French National Centre for Scientific Research (CNRS), France (*)	R	0.22	Centre Technique des Industries Mecaniques - CETIM, France	R	0.51	Tekniker - Technological Centre of Spain	R	0.05
			Leibniz University of Hannover, Germany	U	0.51			
			Fraunhofer Society, Germany	R	0.51			

FP7-Nano TUR								
degree centrality	T	value	closeness centrality	T	value	betweenness centrality	T	value
Research Council of Norway	R	0.24	Helmholtz Association (HHG), Germany	R	0.55	Helmholtz Association (HHG), Germany	R	0.24
Tekes, National Technology Agency, Finland	G	0.24	Fraunhofer Society, Germany	R	0.50	Fraunhofer Society, Germany	R	0.18
Scientific and Technical Research Council of Turkey - TUBITAK	R	0.24	Scientific and Technical Research Council of Turkey - TUBITAK	R	0.47	French National Centre for Scientific Research (CNRS), France	R	0.06
Fraunhofer Society, Germany (*)	R	0.24	Research Council of Norway	R	0.46	Scientific and Technical Research Council of Turkey - TUBITAK	R	0.04
National Center of Management Programs, Romania	R	0.22	Tekes, National Technology Agency, Finland	G	0.46	National Interuniversity Consortium for the Technology Sciences of Matter - INSTM, Italy	R	0.04
Foundation for Science and Technology (FCT), Portugal	O	0.22	French National Centre for Scientific Research (CNRS), France	R	0.46	Research Council of Norway	R	0.04
SenterNovem - Netherland Agency for Energy and the Environment, Netherlands	O	0.22	Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning, Sweden	R	0.45	Tekes, National Technology Agency, Finland	G	0.04
Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning, Sweden	R	0.20	Latvian Academy of Sciences, Latvia	R	0.45	Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning, Sweden	R	0.03
Institute for the Promotion of Innovation, Belgium	G	0.20						
The Technology Strategy Board, GBR	O	0.20						

Note: (*) Organization is also under the top 50 organizations with the highest degree centrality in the total ICT network. T - Organization type: U - university; R - research organization; I - industry; C - consulting G - government; O - other. The empty fields imply either that no organizations are listed further in the top 10 (in Pajek), or that there are more than the listed 10 organizations having equal centrality values.

Source: Own illustration according to data of EUPRO/AIT.

C Degree centrality of FP*x-y* networks (total networks)

Following lists provide degree centrality scores of the top 50 organizations in the total networks of the examined technology fields. Names of organizations are as stated in the EUPRO database.[48]

C.1 FPx-ICT

FP5-ICT			
Rank	Vertex	Value	Organization
1	24	0.1733	Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung e.V.
2	309	0.0970	CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE - CNRS
3	77	0.0921	Siemens AG
4	21	0.0912	Consiglio Nazionale delle Ricerche (CNR)
5	17	0.0852	National Technical University of Athens (NTUA)
6	177	0.0829	Helmholtz-Gemeinschaft (HHG)
7	98	0.0785	Universitat Politecnica de Catalunya (UPC)
8	322	0.0756	Ecole Polytechnique Federale de Lausanne - EPFL - Swiss Federal Institute of Technology, Lausanne
9	25	0.0739	Institut National de Recherche en Informatique et en Automatique (INRIA)

[48] The degree centrality lists of total networks of all technology fields have been provided by the AIT.

10	380	0.0715	Magyar Tudomanyos Akademia - Hungarian Academy of Sciences (MTA)
11	134	0.0713	UPM Universidad Politecnica de Madrid/Madrid Polytechnical University
12	39	0.0708	Katholieke Universiteit Leuven
13	694	0.0700	CSIC - Consejo Superior de Investigaciones Cientificas/Higher Council for Scientific Research
14	830	0.0663	Universiteit van Amsterdam/University of Amsterdam
15	354	0.0636	Thales Group
16	339	0.0626	DaimlerChrysler AG
17	450	0.0609	Rheinisch-Westfälische Technische Hochschule (RWTH) Aachen/RWTH Aachen University
18	436	0.0600	ENEA - Ente per le Nuove tecnologie, Energia e Ambiente
19	796	0.0583	Politecnico di Milano
20	175	0.0576	University of Edinburgh (EdinburghU)
21	424	0.0573	Universiteit Twente
22	152	0.0571	Universita degli Studi di Genova/University of Genova
23	117	0.0570	Technische Universität Wien/ Technical University Vienna (TU Wien)
24	167	0.0570	University of London - UOL
25	81	0.0564	Philips NV
26	97	0.0563	Technical University of Denmark - Danmarks Tekniske Universitet (DTU)
27	168	0.0557	University of Southampton (SotonU)
28	404	0.0541	Universita degli Studi di Bologna, University of Bologna
29	835	0.0539	UTL - Universidade Tecnica de Lisboa, Technical University of Lisbon
30	100	0.0537	University of Manchester (ManU)
31	135	0.0534	UPV Universidad Politecnica de Valencia - Politechnical University of Valencia
32	784	0.0524	Helsinki University of Technology, Teknillinen Korkeakoulu
33	219	0.0521	Atos Origin
34	368	0.0513	VTT Technical Research Centre of Finland
35	652	0.0510	Universitá di Roma La Sapienza, University of Rome La Sapienza
36	779	0.0497	Cranfield University (CranfieldU)
37	206	0.0490	Royal Institute of Technology - Kungliga Tekniska Högskolan (KTH)
38	367	0.0490	Telecom Italia SPA
39	607	0.0490	Delft University of Technology
40	223	0.0486	University of Cyprus - UCY
41	113	0.0473	ETH Zürich - Eidgenössische Technische Hochschule - Swiss Federal Institute of Technology
42	644	0.0471	Kings College London - KCL - UOL
43	35	0.0471	British Telecom PLC (BT)
44	612	0.0468	TNO - Netherlands Organisation for Applied Scientific Research
45	270	0.0463	France Telecom
46	537	0.0463	Universität Stuttgart/University of Stuttgart
47	96	0.0461	Politecnico di Torino
48	23	0.0460	FORTH, Foundation for Research and Technology - Hellas
49	473	0.0454	Universität Wien/University of Vienna (UNIVIE)
50	196	0.0453	Czech Technical University / CESKE VYSOKE UCENI TECHNIKE V PRAZE
FP6-ICT			
Rank	Vertex	Value	Organization
1	20	0.3931	Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung e.V.
2	143	0.2473	CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE - CNRS
3	99	0.1906	Siemens AG
4	340	0.1834	Consiglio Nazionale delle Ricerche (CNR)
5	56	0.1832	Ecole Polytechnique Federale de Lausanne - EPFL - Swiss Federal Institute of Technology, Lausanne
6	107	0.1788	National Technical University of Athens (NTUA)
7	139	0.1729	Royal Institute of Technology - Kungliga Tekniska Högskolan (KTH)
8	54	0.1710	VTT Technical Research Centre of Finland
9	274	0.1699	Thales Group
10	30	0.1658	Telefonica de Espana SA
11	70	0.1647	UPM Universidad Politecnica de Madrid/Madrid Polytechnical University
12	59	0.1610	Institut National de Recherche en Informatique et en Automatique (INRIA)
13	93	0.1514	ETH Zürich - Eidgenössische Technische Hochschule - Swiss Federal Institute of Technology
14	126	0.1455	COMMISSARIAT A LENERGIE ATOMIQUE (CEA)
15	57	0.1453	France Telecom
16	419	0.1429	Universität Stuttgart/University of Stuttgart
17	213	0.1370	Universitat Politecnica de Catalunya (UPC)

18	359	0.1347	Helmholtz-Gemeinschaft (HHG)
19	136	0.1347	Katholieke Universiteit Leuven
20	27	0.1344	Politecnico di Milano
21	191	0.1344	FIAT Gruppo
22	305	0.1227	TNO - Netherlands Organisation for Applied Scientific Research
23	55	0.1218	Center for Research and Technology Hellas - CERTH
24	176	0.1205	Budapesti Mueszaki es Gazdasagtudomanyi Egyetem - Budapest University of Technology and Economics (BME)
25	8	0.1203	Philips NV
26	103	0.1199	University of Surrey (SurreyU)
27	146	0.1166	FORTH, Foundation for Research and Technology - Hellas
28	22	0.1153	IMEC (Interuniversity Micro Electronics Center)
29	460	0.1138	University of Southampton (SotonU)
30	13	0.1122	Alcatel-Lucent
31	209	0.1116	Technische Universität Wien/ Technical University Vienna (TU Wien)
32	60	0.1105	Karlsruher Institut für Technologie/Karlsruhe Institute of Technology - KIT
33	109	0.1027	Telecom Italia SPA
34	413	0.1025	Polish Academy of Sciences / Polska Akademia Nauk (PAS/PAN)
35	132	0.1009	Groupe des ecoles des Telecommunications
36	660	0.1003	Universiteit Twente
37	447	0.1001	Universitá di Roma La Sapienza, University of Rome La Sapienza
38	101	0.0992	University of Cambridge (CU)
39	410	0.0985	Lund University
40	108	0.0981	Technical University of Denmark - Danmarks Tekniske Universitet (DTU)
41	834	0.0981	University of Patras
42	133	0.0966	Helsinki University of Technology, Teknillinen Korkeakoulu
43	159	0.0961	INESC - Instituto de Engenharia de Sistemas e Computadores/Institute for Systems and Computer Engineering
44	114	0.0957	University of London - UOL
45	168	0.0944	Universite de Geneve/University of Geneva (UNIGE)
46	138	0.0933	Rheinisch-Westfälische Technische Hochschule (RWTH) Aachen/RWTH Aachen University
47	207	0.0929	Magyar Tudomanyos Akademia - Hungarian Academy of Sciences (MTA)
48	147	0.0925	Imperial College London (ImperialCL)
49	187	0.0911	DaimlerChrysler AG
50	166	0.0901	Universita degli Studi di Genova/University of Genova
FP7-ICT			
Rank	Vertex	Value	Organization
1	7	0.2735	Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung e.V.
2	113	0.1727	CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE - CNRS
3	53	0.1602	VTT Technical Research Centre of Finland
4	117	0.1578	Thales Group
5	2	0.1534	COMMISSARIAT A LENERGIE ATOMIQUE (CEA)
6	67	0.1470	Consiglio Nazionale delle Ricerche (CNR)
7	194	0.1321	Institut National de Recherche en Informatique et en Automatique (INRIA)
8	211	0.1305	Telefonica de Espana SA
9	93	0.1189	Ecole Polytechnique Federale de Lausanne - EPFL - Swiss Federal Institute of Technology, Lausanne
10	94	0.1185	ETH Zürich - Eidgenössische Technische Hochschule - Swiss Federal Institute of Technology
11	26	0.1165	Technische Universität Wien/ Technical University Vienna (TU Wien)
12	96	0.1145	Helmholtz-Gemeinschaft (HHG)
13	190	0.1092	UPM Universidad Politecnica de Madrid/Madrid Polytechnical University
14	64	0.1092	Royal Institute of Technology - Kungliga Tekniska Högskolan (KTH)
15	176	0.1052	Alcatel-Lucent
16	60	0.1048	Politecnico di Milano
17	253	0.1036	Philips NV
18	29	0.1036	IMEC (Interuniversity Micro Electronics Center)
19	233	0.1008	Siemens AG
20	199	0.0988	National Technical University of Athens (NTUA)
21	145	0.0988	University of London - UOL
22	30	0.0980	Katholieke Universiteit Leuven
23	84	0.0980	Rheinisch-Westfälische Technische Hochschule (RWTH) Aachen/RWTH Aachen University
24	170	0.0960	Center for Research and Technology Hellas - CERTH

25	205	0.0952	Eindhoven University of Technology
26	13	0.0932	Chalmers University of Technology
27	102	0.0928	Universität Stuttgart/University of Stuttgart
28	33	0.0920	STMicroelectronics NV
29	41	0.0843	FIAT Gruppo
30	122	0.0819	Karlsruher Institut für Technologie/Karlsruhe Institute of Technology - KIT
31	206	0.0819	France Telecom
32	151	0.0803	University of Cambridge (CU)
33	356	0.0791	Technische Universität Berlin/Berlin University of Technology
34	49	0.0779	TNO - Netherlands Organisation for Applied Scientific Research
35	351	0.0779	Universitat Politecnica de Catalunya (UPC)
36	316	0.0775	SAP AG
37	232	0.0747	National and Kapodistrian University of Athens (UOA)
38	456	0.0743	Universite de Paris VI (Universite Pierre et Marie Curie) (UPMC)
39	146	0.0707	University of Southampton (SotonU)
40	14	0.0703	Delft University of Technology
41	149	0.0703	Universita degli Studi di Bologna, University of Bologna
42	242	0.0691	Imperial College London (ImperialCL)
43	183	0.0687	Technische Universität München/Technical University of Munich
44	263	0.0687	Groupe des ecoles des Telecommunications
45	215	0.0683	UPV Universidad Politecnica de Valencia - Politechnical University of Valencia
46	381	0.0679	Alborg Universitet
47	1	0.0675	Budapest University of Technology and Economics (BME)
48	352	0.0667	FORTH, Foundation for Research and Technology - Hellas
49	210	0.0659	Politecnico di Torino
50	343	0.0655	IT - Instituto de Telecomunicacões/Telecommunications Institute

C.2 FPx-Biotech

FP5-Biotech			
Rank	Vertex	Value	Organization
1	16	0.2366	CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE - CNRS
2	33	0.1644	Helmholtz-Gemeinschaft (HHG)
3	51	0.1492	CSIC - Consejo Superior de Investigaciones Cientificas/Higher Council for Scientific Research
4	18	0.1323	Institut National de la Sante Et de la Recherche Medicale - INSERM
5	44	0.1283	Max-Planck-Gesellschaft zur Förderung der Wissenschaften eV (MPG)
6	89	0.1187	Institut National de la Recherche Agronomique (INRA)
7	30	0.1131	University of Copenhagen - Koebenhavns Universitet (KU)
8	41	0.1131	Consiglio Nazionale delle Ricerche (CNR)
9	48	0.1059	Universiteit Leiden /Leiden University
10	70	0.1002	Universiteit Utrecht/Utrecht University
11	87	0.0978	University of London - UOL
12	38	0.0962	Karolinska Institutet
13	201	0.0954	Biotechnology and Biological Sciences Research Council (BBSRC)
14	191	0.0954	Wageningen UR (EDU)
15	91	0.0930	Rijksuniversiteit Groningen
16	19	0.0922	Lund University
17	63	0.0890	University of Manchester (ManU)
18	17	0.0842	Imperial College London (ImperialCL)
19	85	0.0778	Universität Zürich - University of Zürich (UZ)
20	32	0.0762	Eberhard Karls Universität Tübingen/Eberhard Karls University of Tuebingen
21	248	0.0730	Georg-August-Universität Göttingen/Georg-August-University Göttingen
22	79	0.0714	Federation Nationale des Centres de Lutte Contre le Cancer (FNLCC)
23	14	0.0690	University of Umea/ Umea Universitet
24	340	0.0690	Katholieke Universiteit Leuven
25	9	0.0690	Technical University of Denmark - Danmarks Tekniske Universitet (DTU)
26	131	0.0690	University of Uppsala
27	15	0.0682	Weizmann Institute of Science (Weizmann)
28	210	0.0658	VIB (Flanders Interuniversity Institute for Biotechnology)
29	66	0.0650	European Molecular Biology Laboratory (EMBL)
30	241	0.0642	University of Helsinki, Helsingin Yliopisto
31	102	0.0642	Universitá di Roma La Sapienza, University of Rome La Sapienza

32	114	0.0609	Polish Academy of Sciences / Polska Akademia Nauk (PAS/PAN)
33	415	0.0609	Radboud Universiteit Nijmegen
34	617	0.0609	CIEMAT - Centro de Investigaciones Energeticas, Medioambientales y Tecnologicas/Centre for Energy, Environmental and Technological Research
35	36	0.0609	University of Newcastle upon Tyne (NCL)
36	141	0.0609	University of Cambridge (CU)
37	31	0.0601	University of Dublin - Trinity College (TCD)
38	97	0.0601	University of York (YorkU)
39	238	0.0593	Swedish University of Agricultural Sciences (SLU)
40	25	0.0593	University of Oxford (OU)
41	251	0.0585	Wageningen UR (ROR)
42	206	0.0585	Technische Universität Wien/ Technical University Vienna (TU Wien)
43	330	0.0585	Hebrew University of Jerusalem (HUJ)
44	74	0.0585	Universita degli Studi di Milano, University of Milan
45	52	0.0569	Institut Pasteur
46	133	0.0561	ETH Zürich - Eidgenössische Technische Hochschule - Swiss Federal Institute of Technology
47	34	0.0553	Medical Research Council (MRC), UK
48	198	0.0545	Wissenschaftsgemeinschaft Gottfried Wilhelm Leibniz e.V.
49	208	0.0537	Universite de Paris XI (Universite Paris-Sud)
50	791	0.0537	National Technical University of Athens (NTUA)
FP6-Biotech			
Rank	Vertex	Value	Organization
1	119	0.3109	Institut National de la Sante Et de la Recherche Medicale - INSERM
2	165	0.2739	Karolinska Institutet
3	159	0.2633	CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE - CNRS
4	157	0.2544	University of London - UOL
5	118	0.2437	Helmholtz-Gemeinschaft (HHG)
6	52	0.2314	Imperial College London (ImperialCL)
7	122	0.2036	Max-Planck-Gesellschaft zur Förderung der Wissenschaften eV (MPG)
8	465	0.2009	University of Helsinki, Helsingin Yliopisto
9	231	0.1933	CSIC - Consejo Superior de Investigaciones Cientificas/Higher Council for Scientific Research
10	287	0.1923	Universiteit Leiden /Leiden University
11	151	0.1916	Lund University
12	311	0.1796	Consiglio Nazionale delle Ricerche (CNR)
13	130	0.1762	University of Oxford (OU)
14	120	0.1759	Ludwig-Maximilians-Universität München
15	266	0.1748	Kings College London - KCL - UOL
16	187	0.1632	Katholieke Universiteit Leuven
17	209	0.1618	Universiteit van Amsterdam/University of Amsterdam
18	199	0.1615	Charite - Universitätsmedizin Berlin
19	197	0.1604	University of Uppsala
20	194	0.1591	Universiteit Utrecht/Utrecht University
21	908	0.1577	Universita degli Studi di Milano, University of Milan
22	117	0.1553	Technische Universität München/Technical University of Munich
23	566	0.1546	University of Copenhagen - Koebenhavns Universitet (KU)
24	163	0.1519	Institut Pasteur
25	133	0.1508	Erasmus Universiteit Rotterdam/Erasmus University Rotterdam
26	128	0.1495	University of Aarhus - Aarhus Universitet (AU)
27	123	0.1491	Medical Research Council (MRC), UK
28	314	0.1491	Institut National de la Recherche Agronomique (INRA)
29	259	0.1488	COMMISSARIAT A LENERGIE ATOMIQUE (CEA)
30	139	0.1484	Albert-Ludwigs-Universität Freiburg
31	210	0.1478	European Molecular Biology Laboratory (EMBL)
32	289	0.1454	Academy of Sciences of the Czech Republic / AKADEMIE VED CESKE REPUBLIKY
33	101	0.1423	University of Cambridge (CU)
34	466	0.1416	University of Newcastle upon Tyne (NCL)
35	205	0.1399	Istituto Superiore di Sanitá (I.S.S.)
36	89	0.1378	University of Birmingham (BirmU)
37	283	0.1358	Radboud Universiteit Nijmegen
38	13	0.1344	Hebrew University of Jerusalem (HUJ)
39	506	0.1334	University of Göteborg
40	115	0.1323	Polish Academy of Sciences / Polska Akademia Nauk (PAS/PAN)

41	71	0.1310	Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung e.V.
42	399	0.1296	Wageningen UR (EDU)
43	256	0.1286	Medizinische Universität Wien/Medical University of Vienna - MUW
44	206	0.1279	Ruprecht-Karls-Universität Heidelberg
45	386	0.1272	Technical University of Denmark - Danmarks Tekniske Universitet (DTU)
46	152	0.1262	Medizinische Hochschule Hannover/Hannover Medical School
47	328	0.1255	Universita degli Studi di Bologna, University of Bologna
48	126	0.1244	Universität Zürich - University of Zürich (UZ)
49	134	0.1200	Fondazione Centro San Raffaele del Monte Tabor
50	733	0.1179	Westfälische Wilhelms-Universität Münster
FP7-Biotech			
Rank	Vertex	Value	Organization
1	27	0.2109	CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE - CNRS
2	11	0.1900	Institut National de la Sante Et de la Recherche Medicale - INSERM
3	75	0.1714	CSIC - Consejo Superior de Investigaciones Cientificas/Higher Council for Scientific Research
4	28	0.1528	Consiglio Nazionale delle Ricerche (CNR)
5	41	0.1505	Max-Planck-Gesellschaft zur Förderung der Wissenschaften eV (MPG)
6	201	0.1461	University of Oxford (OU)
7	29	0.1379	Institut National de la Recherche Agronomique (INRA)
8	106	0.1349	Wageningen UR (ROR)
9	49	0.1304	University of London - UOL
10	175	0.1267	Helmholtz-Gemeinschaft (HHG)
11	22	0.1237	Lund University
12	55	0.1230	Katholieke Universiteit Leuven
13	92	0.1192	University of Cambridge (CU)
14	171	0.1170	Wissenschaftsgemeinschaft Gottfried Wilhelm Leibniz e.V.
15	15	0.1148	ETH Zürich - Eidgenössische Technische Hochschule - Swiss Federal Institute of Technology
16	12	0.1133	Karolinska Institutet
17	19	0.1095	Universität Zürich - University of Zürich (UZ)
18	253	0.1088	Universita degli Studi di Bologna, University of Bologna
19	211	0.1080	Institut Pasteur
20	24	0.1058	University of Newcastle upon Tyne (NCL)
21	278	0.1036	Wageningen UR (EDU)
22	3	0.1028	Ecole Polytechnique Federale de Lausanne - EPFL - Swiss Federal Institute of Technology, Lausanne
23	445	0.1021	Universiteit Leiden /Leiden University
24	209	0.0946	University of Edinburgh (EdinburghU)
25	154	0.0946	Rijksuniversiteit Groningen
26	63	0.0939	Universita degli Studi di Milano, University of Milan
27	179	0.0931	Universiteit Utrecht/Utrecht University
28	53	0.0924	Imperial College London (ImperialCL)
29	264	0.0909	Technical University of Denmark - Danmarks Tekniske Universitet (DTU)
30	71	0.0872	Istituto Superiore di Sanitá (I.S.S.)
31	248	0.0864	University of Aarhus - Aarhus Universitet (AU)
32	130	0.0864	Albert-Ludwigs-Universität Freiburg
33	126	0.0827	University of Uppsala
34	244	0.0805	Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung e.V.
35	259	0.0797	Department for Environment Food and Rural Affairs (DEFRA), UK
36	42	0.0790	Universita degli Studi di Padova/University of Padova
37	187	0.0782	Ruprecht-Karls-Universität Heidelberg
38	226	0.0768	Georg-August-Universität Göttingen/Georg-August-University Göttingen
39	128	0.0768	VTT Technical Research Centre of Finland
40	341	0.0760	Academy of Sciences of the Czech Republic / AKADEMIE VED CESKE REPUBLIKY
41	206	0.0738	Biotechnology and Biological Sciences Research Council (BBSRC)
42	440	0.0730	Kings College London - KCL - UOL
43	266	0.0730	USC Universidade de Santiago de Compostela - University of Santiago de Compostela
44	111	0.0723	Medical Research Council (MRC), UK
45	10	0.0715	Weizmann Institute of Science (Weizmann)
46	298	0.0715	Radboud Universiteit Nijmegen
47	44	0.0678	Johann Wolfgang Goethe-Universität Frankfurt am Main
48	155	0.0678	University of Helsinki, Helsingin Yliopisto

49	301	0.0671	COMMISSARIAT A LENERGIE ATOMIQUE (CEA)
50	34	0.0671	Hebrew University of Jerusalem (HUJ)

C.3 FPx-Nano

FP6-Nano			
Rank	Vertex	Value	Organization
1	114	0.3022	Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung e.V.
2	171	0.2658	CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE - CNRS
3	172	0.2195	Consiglio Nazionale delle Ricerche (CNR)
4	173	0.2175	CSIC - Consejo Superior de Investigaciones Cientificas/Higher Council for Scientific Research
5	402	0.2021	TNO - Netherlands Organisation for Applied Scientific Research
6	196	0.1990	COMMISSARIAT A LENERGIE ATOMIQUE (CEA)
7	66	0.1955	VTT Technical Research Centre of Finland
8	151	0.1681	FIAT Gruppo
9	209	0.1499	Universiteit Twente
10	186	0.1437	Katholieke Universiteit Leuven
11	270	0.1430	Ecole Polytechnique Federale de Lausanne - EPFL - Swiss Federal Institute of Technology, Lausanne
12	282	0.1383	Royal Institute of Technology - Kungliga Tekniska Högskolan (KTH)
13	299	0.1291	Technical University of Denmark - Danmarks Tekniske Universitet (DTU)
14	85	0.1244	Universität Stuttgart/University of Stuttgart
15	245	0.1236	Fundacion INASMET Asociacion de Investigacion Metalúrgica del Pais Vasco
16	190	0.1229	EADS European Aeronautic Defence and Space Company
17	477	0.1182	ARMINES - Structure de Recherche Contractuelle
18	43	0.1148	Helsinki University of Technology, Teknillinen Korkeakoulu
19	16	0.1136	Rheinisch-Westfälische Technische Hochschule (RWTH) Aachen/RWTH Aachen University
20	158	0.1132	Polish Academy of Sciences / Polska Akademia Nauk (PAS/PAN)
21	184	0.1117	Helmholtz-Gemeinschaft (HHG)
22	237	0.1094	Karlsruher Institut für Technologie/Karlsruhe Institute of Technology - KIT
23	9	0.1094	Russian Academy of Sciences
24	109	0.1070	Centro Tecnologico Tekniker
25	382	0.11	Siemens AG
26	112	0.1039	Eidgenössische Materialprüfungs- und Forschungsanstalt/Swiss Federal Laboratoires for Materials Testing and Research - EMPA
27	144	0.1039	University of Cambridge (CU)
28	167	0.1020	Max-Planck-Gesellschaft zur Förderung der Wissenschaften eV (MPG)
29	213	0.1005	Joint Research Centre (JRC) - Commission of the European Communities
30	94	0.0993	Universidade do Minho - University of Minho
31	350	0.0916	Politecnico di Milano
32	187	0.0896	Magyar Tudomanyos Akademia - Hungarian Academy of Sciences (MTA)
33	86	0.0866	University of Manchester (ManU)
34	1496	0.0842	DAppolonia SPA
35	179	0.0842	Technische Universität Darmstadt/Darmstadt University of Technology
36	131	0.0842	University College Cork, National University of Ireland, Cork (UCC)
37	92	0.0815	Queens University of Belfast (QUB)
38	327	0.0815	Linköping University (LIU)
39	258	0.0811	National Center for Scientific Research Demokritos (NCSR)
40	342	0.0796	Budapesti Mueszaki es Gazdasagtudomanyi Egyetem - Budapest University of Technology and Economics (BME)
41	67	0.0796	Academy of Sciences of the Czech Republic / AKADEMIE VED CESKE REPUBLIKY
42	160	0.0788	Technische Universität München/Technical University of Munich
43	219	0.0777	Lund University
44	133	0.0777	University of Patras
45	176	0.0773	Politecnico di Torino
46	312	0.0773	Technische Universität Wien/ Technical University Vienna (TU Wien)
47	95	0.0769	Imperial College London (ImperialCL)
48	383	0.0750	Slovak Academy of Sciences/Slovenska akademia vied
49	137	0.0750	Jozef Stefan Institute (JSI)
50	132	0.0750	University of Birmingham (BirmU)

FP7-Nano			
Rank	Vertex	Value	Organization
1	99	0.2681	Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung e.V.
2	2	0.1968	Consiglio Nazionale delle Ricerche (CNR)
3	1	0.1847	CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE - CNRS
4	48	0.1513	Technical University of Denmark - Danmarks Tekniske Universitet (DTU)
5	33	0.1461	COMMISSARIAT A LENERGIE ATOMIQUE (CEA)
6	538	0.1335	VTT Technical Research Centre of Finland
7	43	0.1243	Joint Research Centre (JRC) - Commission of the European Communities
8	215	0.1157	TNO - Netherlands Organisation for Applied Scientific Research
9	325	0.1122	Ecole Polytechnique Federale de Lausanne - EPFL - Swiss Federal Institute of Technology, Lausanne
10	55	0.1087	CSIC - Consejo Superior de Investigaciones Cientificas/Higher Council for Scientific Research
11	165	0.1076	Universität Stuttgart/University of Stuttgart
12	465	0.1053	SINTEF - Foundation for Scientific and Industrial Research at the Norwegian Institute of Technology/NTNU
13	262	0.1053	FIAT Gruppo
14	188	0.1024	DAppolonia SPA
15	314	0.0984	Swerea IVF
16	373	0.0955	Imperial College London (ImperialCL)
17	125	0.0915	Eindhoven University of Technology
18	104	0.09	BASF AG
19	132	0.0892	University of Cambridge (CU)
20	36	0.0875	Eidgenössische Materialprüfungs- und Forschungsanstalt/Swiss Federal Laboratoires for Materials Testing and Research - EMPA
21	129	0.0811	Academy of Sciences of the Czech Republic / AKADEMIE VED CESKE REPUBLIKY
22	61	0.0788	ETH Zürich - Eidgenössische Technische Hochschule - Swiss Federal Institute of Technology
23	183	0.0742	ACCIONA INFRAESTRUCTURAS SA
24	100	0.0736	Katholieke Universiteit Leuven
25	435	0.0725	Jozef Stefan Institute (JSI)
26	45	0.0725	National Center for Scientific Research Demokritos (NCSR)
27	87	0.0708	Helmholtz-Gemeinschaft (HHG)
28	366	0.0690	Technische Universität Dresden/Dresden University of Technology
29	12	0.0679	Karlsruher Institut für Technologie/Karlsruhe Institute of Technology - KIT
30	74	0.0679	Max-Planck-Gesellschaft zur Förderung der Wissenschaften eV (MPG)
31	24	0.0673	National Technical University of Athens (NTUA)
32	398	0.0673	Chalmers University of Technology
33	673	0.0667	electricite de France (EDF)
34	145	0.0662	Rheinisch-Westfälische Technische Hochschule (RWTH) Aachen/RWTH Aachen University
35	115	0.0639	Politecnico di Milano
36	112	0.06	Bayer AG
37	702	0.0621	ARMINES - Structure de Recherche Contractuelle
38	300	0.0621	Bundesanstalt für Materialforschung und Materialprüfung/Federal Institute for Material Research and Testing
39	118	0.0616	University of Manchester (ManU)
40	357	0.0610	Steinbeis-Stiftung für Wirtschaftsförderung
41	469	0.0604	Universita degli Studi di Pisa/University of Pisa
42	374	0.0604	Politecnico di Torino
43	231	0.0593	Centro Tecnologico Tekniker
44	46	0.0593	National Institute of Public Health and Environment (RIVM)
45	139	0.0593	Universita degli Studi di Bologna, University of Bologna
46	277	0.0593	EADS European Aeronautic Defence and Space Company
47	190	0.0581	Det Norske Veritas A/S
48	11	0.0575	Helsinki University of Technology, Teknillinen Korkeakoulu
49	354	0.0575	Czech Technical University / CESKE VYSOKE UCENI TECHNIKE V PRAZE
50	386	0.0564	Consorzio Interuniversitario Nazionale per la Scienza e Tecnologia dei Materiali (INSTM)

D Top 10 German organizations with the highest degree centrality values in total FPx-Nanoscience networks that collaborate with Turkey in FP6- and FP7

To identify whether Turkey's most central German collaboration partners (in terms of degree centrality, appendix B) in FPx-ICT TUR networks are as well central positioned in the total ICT networks (Appendix C), Table D.1 to D.3 display German organizations with the ten highest degrees in the total FP*x-y* networks, restricted to organizations appearing as well in networks with Turkish participation (FP*x-y* TUR) in FP5-FP7.

Table D.1: Overview of German organizations with the highest degrees in total FPx-ICT networks that collaborate with Turkey in FP5-FP7

Total ICT network - Degree centrality of German organizations											
FP5				FP6				FP7			
Rank	Organization	T	value	Rank	Organization	T	value	Rank	Organization	T	value
1	Fraunhofer Society	R	0.17	1	Fraunhofer Society (*)	R	0.39	1	Fraunhofer Society (*)	R	0.27
3	Siemens AG	I	0.09	3	Siemens AG	I	0.19	12	Helmholtz Association - HHG	R	0.11
6	Helmholtz Association - HHG (*)	R	0.08	16	University of Stuttgart	U	0.14	15	Alcatel-Lucent	I	0.11
16	DaimlerChrysler AG	I	0.06	18	Helmholtz Association - HHG (*)	R	0.13	23	RWTH Aachen University	U	0.10
17	RWTH Aachen University	U	0.06	32	Karlsruhe Institute of Technology - KIT	R	0.11	27	University of Stuttgart	U	0.09
67	University of Hamburg	U	0.04	46	RWTH Aachen University	U	0.09	30	Karlsruhe Institute of Technology - KIT	R	0.08
78	University of Bremen	U	0.04	49	DaimlerChrysler AG	I	0.09	33	Berlin University of Technology (*)	U	0.08
91	Rheinisch Friedrich-Wilhelms-University Bonn	U	0.04	64	Dresden University of Technology	U	0.08	43	Technical University of Munich	U	0.07
95	Albert-Ludwigs-University Freiburg	U	0.03	65	SAP AG	I	0.08	83	German Research Center for Artificial Intelligence - DFKI	R	0.05
				78	University Duisburg-Essen	U	0.08	86	University Duisburg-Essen	U	0.05

(*) Organization is as well central in the top 30 FPx-ICT TUR network. T - Organization type: U - university; R - research organization; I - industry; C - consulting.

Source: Own illustration according to data of EUPRO/AIT.

Table D.2: Overview of German organizations with the highest degrees in total FPx-Biotech networks that collaborate with Turkey in FP5-FP7

Total Biotech network - Degree centrality of German organizations							
FP5	FP6				FP7			
	Rank	Organization	T	value	Rank	Organization	T	value
No German participation in FP5-Biotech TUR	5	Helmholtz Association - HHG	R	0.24	10	Helmholtz Association - HHG	R	0.13
	7	Max Planck Society - MPG	R	0.20	14	Leibniz Association (*)	R	0.12
	14	Ludwig-Maximilians-University München	U	0.18	38	Georg-August-University Göttingen	U	0.08
	18	Charite - Berlin University of Medicine (*)	U	0.16	47	Johann Wolfgang Goethe-University Frankfurt am Main	U	0.07

	22	Technical University of Munich (*)	U	0.16	68	Rheinisch Friedrich-Wilhelms-University Bonn (*)	U	0.06
	30	Albert-Ludwigs-University Freiburg	U	0.15	77	Saarland University	U	0.05
	31	European Molecular Biology Laboratory (EMBL)	R	0.15				

(*) Organization is as well central in the top 30 FPx-Biotech TUR network. T - Organization type: U - university; R - research organization; I - industry; C - consulting.

Source: Own illustration according to data of EUPRO/AIT.

Table D.3: Overview of German organizations with the highest degrees in total FPx-Nanoscience networks that collaborate with Turkey in FP6- and FP7

Total Nano network - Degree centrality of German organizations							
FP6				FP7			
Rank	Organization	T	value	Rank	Organization	T	value
1	Fraunhofer Society (*)	R	0.30	1	Fraunhofer Society (*)	R	0.27
14	University of Stuttgart (*)	U	0.12	27	Helmholtz Association - HHG (*)	R	0.07
16	EADS European Aeronautic Defence and Space Company	I	0.12	28	Dresden University of Technology	U	0.07
19	RWTH Aachen University	U	0.11	29	Karlsruhe Institute of Technology - KIT	R	0.07
21	Helmholtz Association - HHG	R	0.11	30	Max Planck Society - MPG	R	0.07
22	Karlsruhe Institute of Technology - KIT	R	0.11	34	RWTH Aachen University	U	0.07
35	Darmstadt University of Technology (*)	U	0.08	46	EADS European Aeronautic Defence and Space Company	I	0.06
51	Leibniz Association	R	0.07	93	Siemens AG	I	0.04
75	Leibniz University of Hannover (*)	U	0.06				
98	DaimlerChrysler AG (*)	I	0.05				

(*) Organization is as well central in the top 30 FPx-Nano TUR network. T - Organization type: U - university; R - research organization; I - industry; C - consulting.

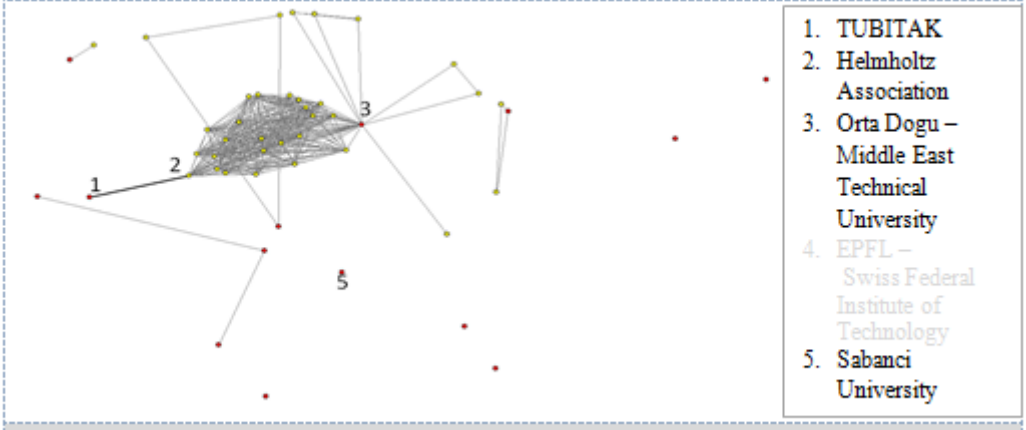
Source: Own illustration according to data of EUPRO/AIT.

E Graphical illustration of FPx-y TUR networks with exclusively German and Turkish cooperation partners

Figure E.1 to Figure E.3 display FP*x-y* TUR networks with exclusively German and Turkish cooperation partners. Turkish and German organizations are colored in red and yellow, respectively. It is noticeable that most Turkish organizations are linked to German partners.

E.1 FPx-ICT TUR

Figure E.1-1: Sub-network of FP5-ICT TUR with German-Turkish organizations



1. TUBITAK
2. Helmholtz Association
3. Orta Dogu – Middle East Technical University
4. EPFL – Swiss Federal Institute of Technology
5. Sabanci University

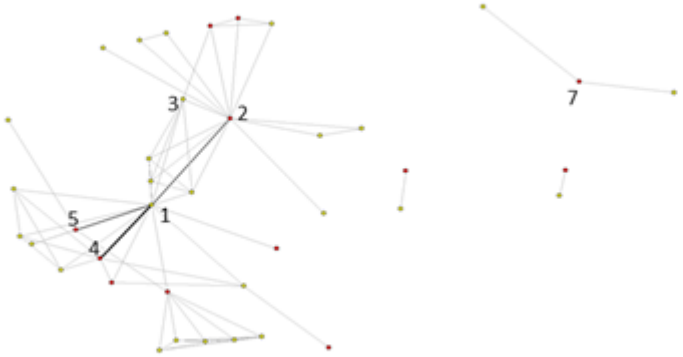
Source: EUPRO/AIT.

Figure E.1-2: Sub-network of FP6-ICT TUR with German-Turkish organizations

1. TUBITAK
2. Technical University of Istanbul
3. Orta Dogu – Middle East Technical University
4. Bilkent University
5. Fraunhofer Society

Source: EUPRO/AIT.

Figure E.1-3: Sub-network of FP7-ICT TUR with German-Turkish organization

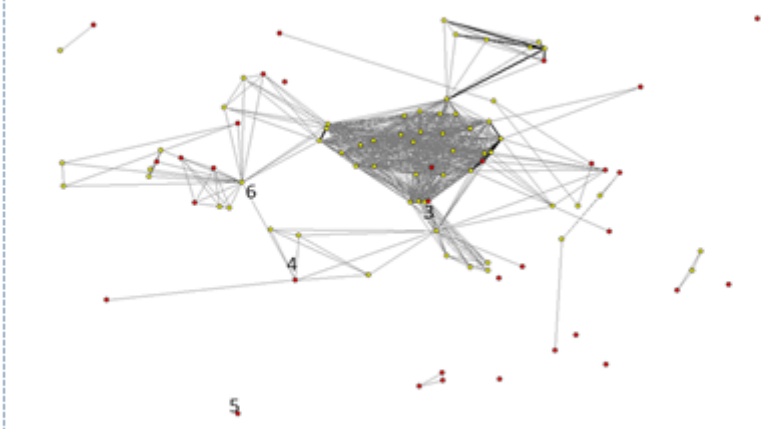


1. Fraunhofer Society
2. Bilkent University
3. Berlin Univ. of Technology
4. Koc Uiversity
5. Orta Dogu – Middle East Techn. Univ.
6. Polish Ac. of Sc.
7. TUBITAK

Source: EUPRO/AIT.

H.2 FPx-Biotech TUR

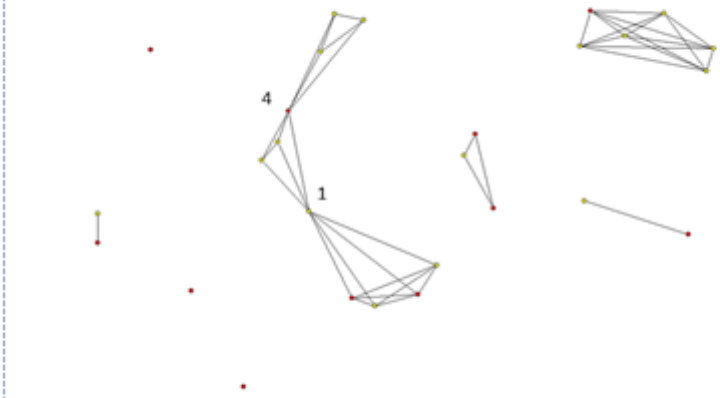
Figure E.2-1: Sub-network of FP6-Biotech TUR with German-Turkish organizations



1. Karolinska Institute, Sweden
2. Univ. of Helsinki
3. University of Ankara
4. TUBITAK
5. Orta Dogu - Middle East Technical University
6. Helmholtz Association

Source: EUPRO/AIT.

Figure E.2-2: Sub-network of FP7-Biotech TUR with German-Turkish organizations



1. Leibniz Association
2. INRA - French National Institute for Agricultural Research
3. I.S.S. - Italian Superior Health Institute
4. Sabanci University

Source: EUPO/AIT.

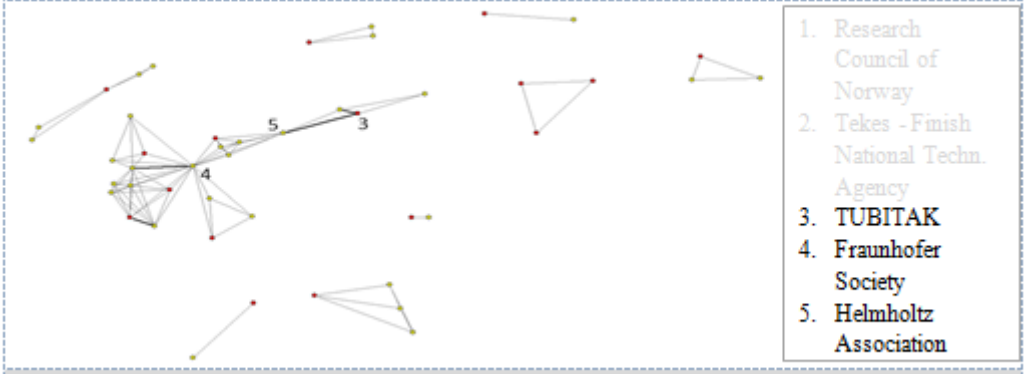
E.3 FPx-Nano TUR

Figure E.3-1: Sub-network of FP6-Nano TUR with German-Turkish organizations

1. VTT - Technical Research Centre of Finland
2. QUB - Queen's University of Belfast
3. Orta Dogu - Middle East Technical University
4. Fraunhofer Society
5. Bilkent University

Source: EUPRO/AIT.

Figure E.3- 2: Sub-network of FP7-Nano TUR with German-Turkish organizations



Source: EUPRO/AIT.

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