Qual Quant
DOI 10.1007/s11135-016-0344-z

Decomposing the Triple-Helix synergy into the regional innovation systems of Norway: firm data and patent networks

Øivind Strand[1] · Inga Ivanova[2,3] · Loet Leydesdorff[4]

Abstract The Triple Helix model of university-industry-government relations allows us to use mutual information among geographical, sectorial, and size distribution of firms to measure synergy at various geographical scales in a nation. In this paper we decompose the synergy in Triple Helix relations and analyze the decomposition at the county level. We use micro-level data for all Norwegian firms from 2002 to 2014. This provides new and more detailed insight into the factors explaining the previously reported variation in synergy at county level in Norway. Furthermore, we analyze the county and city level distributions of all national as well as USPTO granted patents with at least one Norwegian inventor. Co-inventor networks for Norwegian USPTO patents are visualized using Google maps. The counties with technology-dominated synergies and strong knowledge institutions have a higher level of international co-inventor networks. Sectorial and geographical networks characterize the oil and gas dominated county, Rogaland. In contrast the knowledge institution dominated county of Sør-Trøndelag has broader networks both with regard to sectors and geography. In the small industry dominated county of Møre og Romsdal with high synergy, the lack of international co-inventor network is striking. This might be interpreted as a sign of industrial lock-in. The use of both firm level and patent data together give a broader and more precise picture of the innovation systems under study. The use of both national and international patent data also broadens the picture of the innovation activity of the nation.

✉ Øivind Strand
ost@hials.no

1 Department of International Business, Norwegian University of Science and Technology (NTNU) Ålesund, PO Box 1517, 6025 Ålesund, Norway

2 Institute for Statistical Studies and Economics of Knowledge, National Research University Higher School of Economics (NRU HSE), 20 Myasnitskaya St., Moscow, Russian Federation 101000

3 School of Business and Public Administration, Far Eastern Federal University, 8, Sukhanova St., Vladivostok, Russian Federation 690990

4 Amsterdam School of Communication Research (ASCoR), University of Amsterdam, PO Box 15793, 1001 NG Amsterdam, The Netherlands

Published online: 30 April 2016

Keywords Triple Helix · USPTO patents · Regional innovation system · Probabilistic entropy

1 Introduction

For almost two decades, the Triple-Helix theory of university-industry-government relations has been a framework for analyzing innovation and innovation policy (Etzkowitz and Leydesdorff 1995, 2000). Within this theoretical framework, one can distinguish the dynamics of knowledge production, markets and governance as three interacting, but analytically different mechanisms that may interact synergetically in the development of a knowledge-based economy. A range of various research methods have been used, such as webometrics, scientometrics, and informetrics (Khan and Park 2012). A considerable volume of research has focused on the quantification of Triple-Helix indicators (Leydesdorff and Meyer 2006; Meyer et al. 2014) and Triple-Helix relation synergy (Leydesdorff and Park 2014; Choi et al. 2015). These calculations have been based mainly on academic co-author networks, firm level register data, patents networks, but also hyperlinks (Kim 2012). The analyses of interactions among social, knowledge, innovation and Triple-Helix networks have been the focus of the previous DISC conferences (Jung and Park 2014; Park 2014). Alongside these empirical lines of research, considerable progress has been made in the mathematic formulation of the Triple-Helix theory (Ivanova and Leydesdorff 2014; Leydesdorff and Ivanova 2014).

Triple-Helix relations can be analyzed in terms of mutual information among geographical, sectorial, and size distribution of firms using probabilistic entropy measures. The reduction of uncertainty in the distributions can be interpreted as an indicator for a higher level of coordination, resulting in a higher efficiency in the innovation system. This allows us to identify geographical areas, or innovation hot spots, where this synergy is higher compared to other areas. This paper examines how the Triple-Helix synergy can be decomposed in order to study the underlying mechanisms. We further elaborate the county-level results of these mechanisms and how these results develop over time. For this purpose, we use Norwegian data at firm level.

Analyses of patents have previously been used as indicators for output of R&D and input in the knowledge-based economy (Leydesdorff and Bornmann 2012; Stek and van Geenhuizen 2015). Benner and Sandstrøm (2000) found that the institutionalization of a Triple Helix model is critically dependent on the form of research funding. Shelton and Leydesdorff (2012) found that a high level of private R&D funding promotes cooperation between academia and industry, resulting in a larger number of patents, compared to publicly funded R&D. The relationships between academic research and knowledge-transfer activities, such as patenting, have been investigated by Kwon (2011) and Kwon and Martin (2012). They model the relationship with either synergy or separation between academic research and industrial collaboration. In a survey among Norwegian university professors, Gulbrandsen and Smeby (2005) found that professors with research funding from industry reported more interactions with researchers both in academia and industry, more scientific publications, and a more applied research focus compared to purely publicly funded researchers.

For the patent analysis, this paper uses Norwegian USPTO patent data. Based on these patent-data the paper investigates the location of the city where the inventor has his or her home address and the cities where the co-inventors are located. The results are compared to previous data on the Norwegian innovation system (Strand and Leydesdorff 2013) and the geographical distribution of national patents (Strand 2014). The aim of the paper is to combine the streams of research on firm level data and patent data. Following Leydesdorff and Bornmann (2012) and Leydesdorff and Persson (2010), we analyze the geographical dimensions of patent co-inventor networks using overlays to Google Maps and network analysis.

This research is relevant to the discussion on the roles of knowledge institutions in regional development (Rodríguez-Pose 2013), the role of the cooperation between knowledge institutions and firms (Robin and Schubert 2013), and the role of firms and global networks (Fitjar and Rodríguez-Pose 2013). It is also relevant to the more analytical literature on Triple Helix systems (Ranga and Etzkowitz 2013) and the literature on the Norwegian innovation system in particular. This paper is explorative in nature and aims to develop and demonstrate a novel use of methods and data, more than a statistical testing of hypotheses.

We address the following research questions:

1. Can the county-level decomposition of synergy along the dimensions of geography, technology and firm size provide insight into the regional innovation system of Norway?
2. What are the relationships between patenting patterns and synergy patterns in Norwegian counties?

This paper is organized as follows: Sect. 2 elaborates on the theoretical aspects of patent data and the characteristics of the Norwegian innovation system. Section 3 provides details on the methods for decomposing the Triple Helix synergy and for retrieving patent data. The results are given in Sect. 4, which is followed by a section comprising the discussion and conclusions. Details on the high-level integration of industry (NACE)[1] codes used in the firm level analysis are provided in the "Appendix".

2 Theoretical aspects

In order to develop indicators for Triple Helix relations in a national economy, Leydesdorff et al. (2006) combined the perspectives from a regional economy (Storper 1997) with Triple Helix theory. Three dimensions are distinguished: technology, geography, and organizations. By using firm level register data, technology is related to industry code, geography to municipality code, and organization to firm size. Lengyel and Leydesdorff (2011) specified the synergetic functions as "knowledge exploration" (between technology and geography), "knowledge exploitation" (between technology and organization), and "organization control" (between organization and geography). The mutual information among the three dimensions of technology, geography, and organization can be negative and then be interpreted as an indicator of the reduction of uncertainty, or synergy. This method has been applied for analyzing characteristics of the innovation system in various countries such as the Netherlands (Leydesdorff et al. 2006), Hungary (Lengyel and Leydesdorff 2011), Sweden (Leydesdorff and Strand 2013) and Norway (Strand and Leydesdorff 2013), which is the backdrop for this study. However, these studies analyzed

[1] Nomenclature générale des activités économiques dans les Communautés Européennes (General Industrial Classification of Economic Activities within the European Communities).

register data statically at one moment in time, whereas one of the main characteristics of the TH theory is the dynamic interactions over time.

Adding the time dimension to the analysis of the register data is expected to give a more realistic picture of the development in the synergy of the innovation system. Due to changes in the industry code standards, we have introduced a high-level integration of industry codes as described in the "Appendix". Since the synergy calculations are based on the three dimensions of technology, geography, and organizations, we decompose the synergy into the contributions from each of the elements. The objective is to find out if the synergy is dominated by one of the underlying dimensions.

Furman et al. (2002) used international patent data as input for measuring national innovation capacity. They found that R&D productivity varied, among other factors, in the share of R&D performed by the academic sector and funded by the private sector. This study underlines the dependent relationship between national innovation capacity and the quality of the links between the knowledge institutions and the microeconomic environment present in a nation's industrial clusters. Likewise, Shelton and Leydesdorff (2012) found that a high level of industry funded R&D resulted in a higher number of patents, compared to publicly funded R&D projects. Bettencourt et al. (2007) found a super-linear scaling relationship between population size in metropolitan areas of the U.S and the number of USPTO patents. The analyses of the geographical characteristics of the co-inventor networks suggested that the range of informal interaction effects were more dominating than the effect of geographical co-location. They also pointed out that larger firms, especially those with R&D labs, tended to be located in larger cities. Carlino et al. (2007) reported that patent intensity was about 20 percent higher in a metropolitan area with employment density that was twice that of another metropolitan area. This indicates that more populated areas may be associated with a relatively higher number of patents. Networks of inventors have been investigated by Balconi et al. (2004). They found that academic inventors exchanged information with more people and across more organizations compared to non-academic inventors. The role of spatial proximity in co-inventor networks has been investigated by Breschi and Lissioni (2009). They found that inventors' activities across firms, such as consulting, contract research and mobility explained a large part of the localized knowledge flow; the market based social ties were more important than informal (non-market) social ties. This paper confirms the findings from Almeida and Kogut (1999) that knowledge is transferred by individuals who move from one organization to the other, but do not necessarily relocate geographically.

Based on the findings above we would expect a higher concentration of patents in the university cities and regions. We would also expect a higher degree of local knowledge flow in these regions, resulting in a higher level of startups. This confirms the findings of Simmie (2003), who reported that innovation activities are highly concentrated in urban geographical regions in Europe and the US. This is due to a concentration of R&D activities as indicated by regional R&D expenditure and regional patent rates. However, Grillitsch and Nilsson (2015), basing their findings on data from Sweden, have found that knowledge spillover from local academic institutions is most important for small firms. They report that firms located in peripheral regions compensate for lack of local knowledge spillover by collaboration with international partners. Regarding the size of firms, the authors found that in order to benefit from this collaboration the firms have to be medium sized.

Synergy studies from Sweden (Leydesdorff and Strand 2013) identify three hotspots for innovation in the regions centered on Stockholm, Gothenburg and Malmo where most R&D resources in Sweden are concentrated. This is in strong contrast to Norway, where the highest synergy is identified in Rogaland and Møre og Romsdal, whereas most R&D resources are directed towards the university cities of Oslo, Trondheim, and Tromsø.

2.1 The Norwegian innovation system

The Norwegian innovation system has been studied by several authors (Asheim and Isaksen 1997; Reve and Sasson 2012; Strand and Leydesdorff 2013). Some researchers have focused on industry clusters (Asheim and Coenen 2005; Isaksen 2009) and some on regions (Isaksen and Onsager 2010; Isaksen and Karlsen 2012). Several authors use the typology from Jensen et al. (2007) that firms can be characterized by a 'Doing, Using, and Interacting' (DUI) mode of firm learning or a 'Science, Technology, and Innovation' (STI) mode. Firm level cooperation in Norway has been investigated by Fitjar and Rodríguez-Pose (2013), while systemic R&D lock-in in Norway has been discussed by Narula (2002).

The Norwegian economy is a combination of free-market activities and governmental interventions. Norway is among the few European countries that is not a member of the EU, albeit closely aligned with it. Norway is richly endowed with natural resources such as petroleum, fish, and hydropower. The country is highly dependent on the petroleum sector.

There are three administration levels. The central government is located in the capital Oslo; the country level (NUTS 3)[2] comprises 19 counties, indicated in Fig. 1, and these are subdivided into 428 municipalities (NUTS 5).

Most government institutions are located in the capital Oslo (3), in the southeastern part of Norway. The distribution of inhabitants in each county can be seen in Table 1. Most of the population is located in the agglomeration around Oslo and along the coastline on the western coast. Rogaland (11) with its main city Stavanger is the center of the Norwegian oil and gas industry. The maritime industry cluster (Reve and Sasson 2012) is located on the west coast with a focal point in Møre og Romsdal (15). Some of the inland counties, such as Hedmark (4) and Oppland (5) are dominated by agriculture and forest industries, others such as Buskerud (6) and Telemark (8) are more dominated by heavy industries. The electronic industry dominates most in Vestfold (7), close to Oslo. The four northernmost counties and Sogn og Fjordane (14) on the west coast, are sparsely populated and dominated by agriculture and marine (fishing) industries.

The population, the industries' share of R&D expenditures and the locations of the major knowledge institutions in Norwegian counties are also given in Table 1. The number of researchers per 1000 inhabitants for each of the counties is given in column two. As can be seen from this table, Sør-Trøndelag (16) with the main technical university and Oslo (3) with the largest university have more than 40 researchers per 1000 inhabitants. The locations of the universities in Tromsø, located in Troms (19), and Bergen, located in Hordaland (12), and the research institutes in Akershus (2) contribute to the high numbers of researchers in these counties. The newly established universities in Agder and Rogaland (Stavanger) have minor effects on the number of researchers in these counties.

The main university counties, together with the northernmost counties, are characterized by a low fraction of industrially funded R&D. The industrial counties, such as Buskerud, Vestfold, Telemark, and Møre og Romsdal are characterized by a high fraction of industrially funded R&D.

The location of research centers, universities and technology transfer offices (TTO) are also given in Table 1. As can be seen from this table the knowledge infrastructure is highly concentrated in the major university cities. Trondheim in Sør-Trøndelag is the only city

[2] Nomenclature des unités territoriales statistiques.

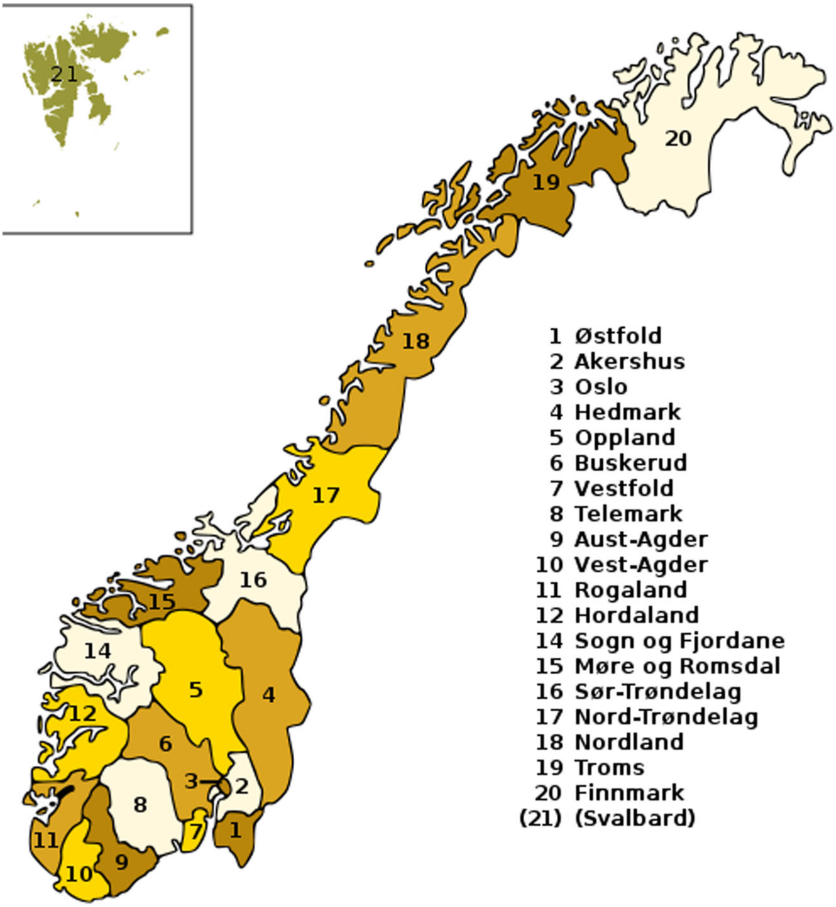

Fig. 1 Norwegian counties (Reis and Tereso 2005)

with two TTO's, one for the technical university (NTNU) and one for the largest independent research institute in Scandinavia; SINTEF.

The level of funding for research and development in Norway is relatively low compared to the other north European countries. Norway uses only 1.66 % of GDP for R&D (Eurostat 2012); this is lower than the EU28 with an average of 2.06 % and far below its neighboring countries of Sweden with 3.41 % and Finland with 3.55 %. Norway is ranged as a moderate innovator in the Innovation Union Scoreboard 2014 (EU 2014).

3 Methods and data

This section gives a detailed mathematical description of the decomposition of synergy and we explain how register data are retrieved. This is followed by sections presenting the patent data methods for USPTO and national patents.

Table 1 Inhabitants and knowledge infrastructure in Norwegian counties (NRC 2014)

	County	Inhabitants 2014	Researchers per 1000	Research centers	Universities	TTO offices	Industry share of R&D (%)
1	Østfold	284,962	6	0			53
2	Akershus	575,757	17	5	1	1	59
3	Oslo	634,463	43	18	1	1	42
4	Hedmark	194,433	5	0			34
5	Oppland	187,820	7	0			64
6	Buskerud	272,228	9	0			93
7	Vestfold	250,860	10	0			81
8	Telemark	171,469	11	0			76
9	Vest-Agder	178,478	5	0	1		54
10	Aust-Agder	113,747	10	0	1		60
11	Rogaland	459,625	9	1	1	1	61
12	Hordaland	505,246	22	10	1	1	25
14	Sogn og Fjordane	108,965	7	0			71
15	Møre og Romsdal	261,530	7	0			67
16	Sør-Trøndelag	306,197	46	15	1	2	28
17	Nord-Trøndelag	135,142	7	0			41
18	Nordland	240,877	7	0	1		39
19	Troms	162,050	28	5	1	1	9
20	Finmark	75,207	6	0			3

3.1 Decomposition of Triple Helix relation synergy

We use a vector space representation of the Triple Helix model of University-Industry-Government relations. We use G as an abbreviation for the geographical dimension, T for the technological dimension, and O for the organizational dimension. Having three relevant inputs (G, T, O) Triple Helix can be presented as a vector in three dimensions (Fig. 2).

$$T_{GTO} = T(G) + T(T) + T(O)$$

Three-lateral mutual information, interpreted as synergy, is calculated as (Abramson 1963:131 ff.):

$$T_{GTO} = H_G + H_T + H_O - H_{GT} - H_{GO} - H_{TO} + H_{GTO}. \tag{1}$$

Here index G refers to the geographical dimension; T refers to technologies; and O refers to organizational structure. Because mutual information is an additive measure, T_{GTO} can be decomposed in either of three ways: by 19 counties, 11 technologies, and 8 organizational levels:

$$T_{GTO} = \sum_{i=1}^{19} T_i^G = \sum_{j=1}^{11} T_j^T = \sum_{k=1}^{8} T_k^O. \tag{2}$$

Each of the decompositions can be used to estimate distributions in geographical, technological, and organizational dimensions at the country level. In a similar manner, one can calculate the input of technological and organizational synergies at county level

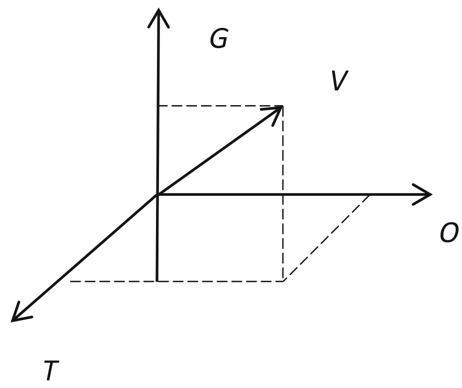

Fig. 2 Triple Helix as a vector in three dimensions

$$\begin{cases} T_1^T = \frac{n_1^1}{N_1} T_1^T + \ldots + \frac{n_{11}^1}{N_{11}} T_{11}^T \\ \vdots \\ T_{19}^T = \frac{n_1^{19}}{N_1} T_1^T + \ldots + \frac{n_{11}^{19}}{N_{11}} T_{11}^T \end{cases}. \tag{3}$$

$$\begin{cases} T_1^0 = \frac{m_1^1}{M_1} T_1^0 + \ldots + \frac{m_8^1}{M_8} T_8^0 \\ \vdots \\ T_{19}^0 = \frac{m_1^{19}}{M_1} T_1^0 + \ldots + \frac{m_8^{19}}{M_8} T_8^0 \end{cases}. \tag{4}$$

Here n_j^i—the number of firms with j-th technology in i-th county; m_k^i—the number of firms with k-th organizational structure in i-th county. N_j—the number firms with j-th technology over the country and M_k—the number of firms with k-th organization structure over the country.

Thus, one obtains for i-th county three synergies: geographical (T_i^G), technological (T_i^T), and organizational (T_i^O). The relative values of the three synergies can be considered as relative input of the corresponding institutional actors in the total county synergy.

Norwegian firm data from 2002 to 2014 are downloaded from Statistics Norway and include all firms registered in the nation. Each firm is represented by a geographical indicator (county), an industrial sector indicator (technology) and a firm size indicator. There are 19 counties, 11 high-level industry codes, and 8 firm size levels. The Norwegian industry code data from 2002 to 2008 follow the SIC2002 standard and from 2008 onwards, the SIC2007 standard is used. In order to bridge the two systems we introduce a high-level industry code aggregation. The details of the new high-level aggregations are given in Appendix of Table 3 and in Ivanova, Strand and Leydesdorff (in preparation). It should be noted that the industry code systems are not equal and that the time traces should be evaluated with great care, especially in the year where data changes from one system to another (2008). Unfortunately, this shift in the industry code system occurred at the same time as the worldwide economic crisis.

3.2 Patent data method for USPTO patents

Patent data can be considered as indicators of inventions or, in other words, as 'windows' on the knowledge economy (Jaffe and Tratjienberg 2002). These data are available from a range of online databases, in various formats, some open such as the American USPTO and some fee-based such as the Patent Statistical Database (PATSTAT) developed by the European Patent Organization (EPO). More and more of the data is becoming open and available for inventors, educators, and researchers. The distribution of patents among cities and regions is of interest to researchers in fields such as economic geography, innovation studies as well as technology policy and forecasting. The reasons for focusing on USPTO data are threefold. First, the U.S. market for patents is considered to be the most competitive. Second, the USPTO database is transparent and considered to be the most relevant for innovation policies. Third, the software routines for automatic download and analysis of these data have been made freely available by one of the authors.

This paper utilizes a set of dedicated routines developed by one of the co-authors (Leydesdorff and Bornmann 2012). The routines can be downloaded by the user at http://www.leydesdorff.net/software/patentmaps/index.htm. Data are retrieved from the USPTO database of granted patents found at http://patf.uspto.gov.netahtml/PTO/search-adv.htm.

The routines allow the user to analyze both the inventors and assignees. This paper uses the address information for the inventors as a geographical indicator. The quality of the patents is indicated through citation analysis where the number of citations is used. The address information is geo-coded with information regarding longitudes and latitudes. We follow Leydesdorff and Bornmann (2012) and use the GPS Visualizer at http://www.gpsvisualizer.com/geocoder for coding of the addresses.

3.3 Patent data method for Norwegian national patents

Data on National patents granted in Norway were downloaded from the Norwegian patent authorities at https://search.patentstyret.no/Search.aspx?Category=Patent on October 27, 2014. The number of inventors from each county is downloaded, analyzed and compared to previous data from Strand (2014).

4 Results

4.1 Synergy decomposition

The county and regional levels of Triple Helix synergy in Norway have previously been reported by Strand and Leydesdorff (2013). These calculations were based on municipality level data and are from 2008. Synergy cycles at county level for the timespan between 2002 and 2014 are reported in Ivanova, Strand, and Leydesdorff (in preparation). In the following, we report on the decomposition of county-level synergy.

We follow the procedure outlined in section three—using county level data and decomposing the Triple Helix synergy into its three components: geography, technology and organization.

The county of Rogaland, which is the center for oil and gas activity on the west coast, has previously been shown to have the highest level of synergy. As shown in Figure three, the decomposition of synergy shows that the synergy is technology dominated and stable over time (Fig. 3).

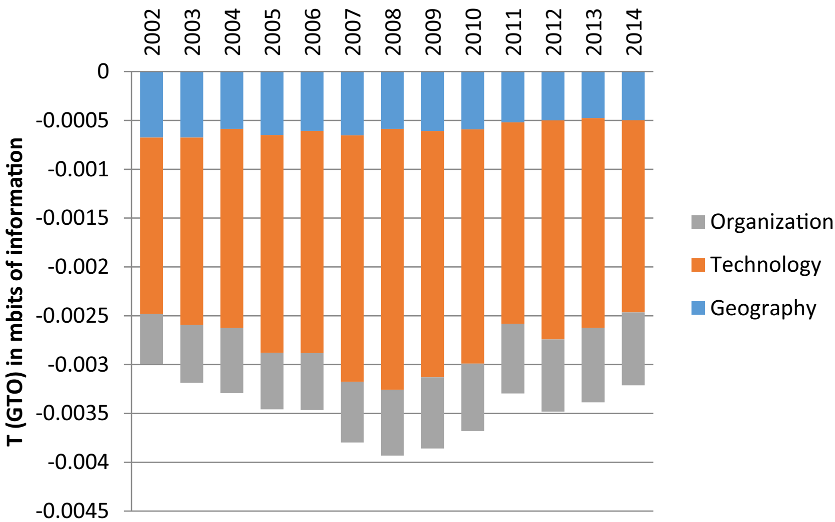

Fig. 3 Development of decomposition of Triple Helix synergy for the county of Rogaland

The calculations for the county of Finmark (far north) are given in Fig. 4. We can see that the results are highly fluctuating over time and that the synergy is dominated by the geographical component. However, an increased importance of technology can be detected; this may indicate that we observe an effect of increased oil and gas activity in the arctic areas. The number of inhabitants and firms in this county is low compared to the other counties in Norway. The county is larger than Denmark, but has a population of only 75,000.

The results of the decomposition for the county of Østfold, close to Oslo, are given in Fig. 5. The synergy in this county is dominated by the organizational dimension. This county was previously dominated by large companies in the pulp- and mechanical industries, but a considerable part of the population is now commuting to Oslo and Akershus. The old industries are being substituted by smaller and more technologically oriented companies, especially in the energy sector.

The center for technological education and research in Norway is located in Sør-Trøndelag, where the main technological university, NTNU in Trondheim, is located. The industry in this county is dominated by small technological companies, but there is only a small number of larger industrial companies. The results shown in Fig. 6 indicate that the synergy is dominated by the technological component.

From previous studies, it is known that the synergy is high in the small industrial county of Møre og Romsdal. The results from this county are given in Fig. 7. It is dominated by the technology component, but the geographical component is also of significance. The county has 36 municipalities, but no towns with a population above 45,000 inhabitants.

4.2 Norwegian USPTO patents

A search in the USPTO database using the search term “icn/no” on September 8, 2014 recalled 1056 patents issued with a Norwegian address among the inventors. The results when using a lower limit of five patents are given in Fig. 8. It should be noted that some of

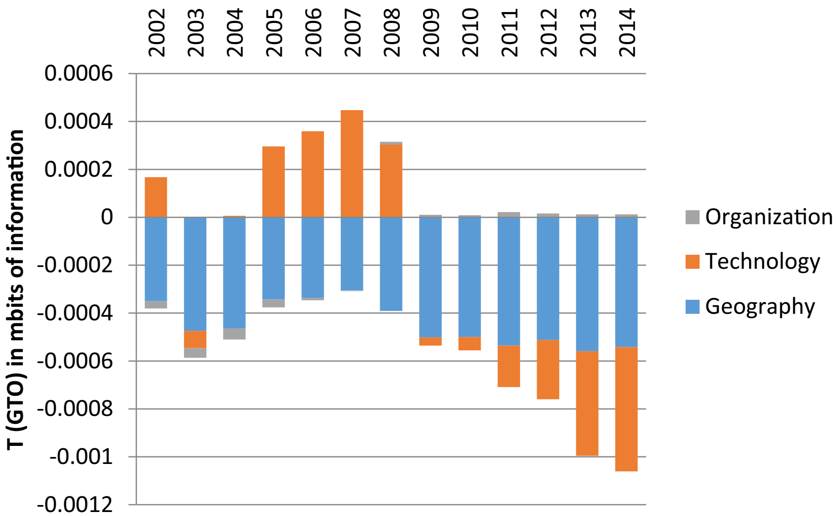

Fig. 4 Development of decomposition of Triple Helix synergy for Finmark

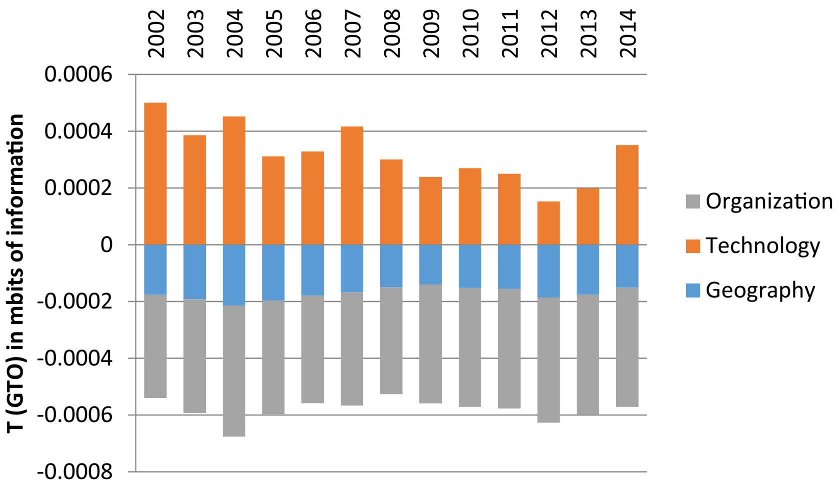

Fig. 5 Development of decomposition of Triple Helix synergy for Østfold

the addresses containing the Norwegian letters Æ, Ø and Å have an inaccurate spelling in English.

The 5 % top cities in Norway are Oslo (331 patents), Trondheim (124 patents) and Stavanger (75 patents.). The top 10 % cities included also Sandnes (52), Asker (32), and Porsgrunn (21). Sandnes is located in Rogaland, close to Stavanger and has a considerable oil and gas industry. Asker is located in the "engineering valley" in Akershus close to Oslo, where a number of engineering companies have their main offices. Porsgrunn is an old industrial town in Telemark where Norsk Hydro and Yara, have their main R&D facilities.

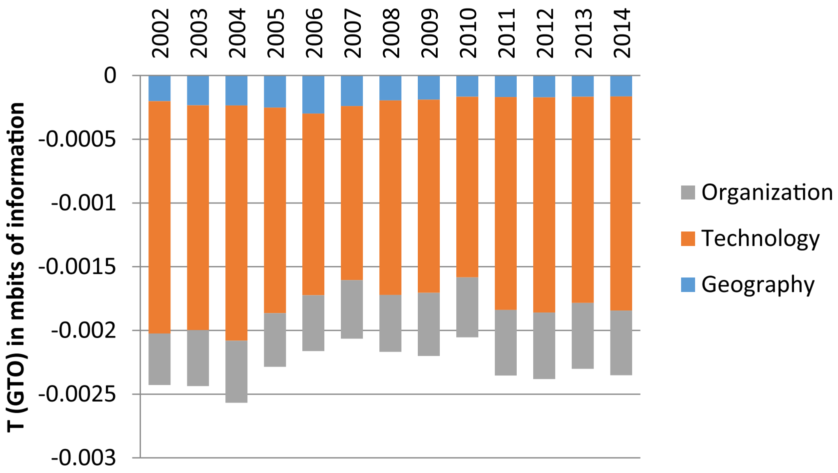

Fig. 6 Development of decomposition of Triple Helix synergy for Sør-Trøndelag

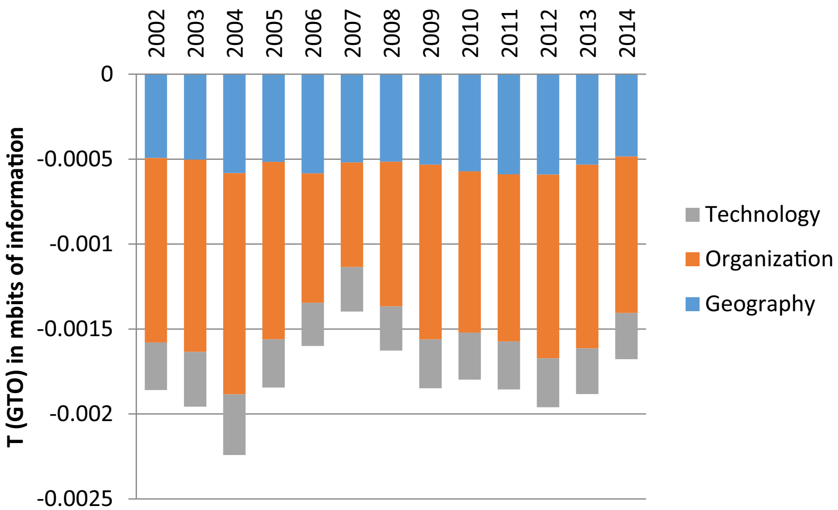

Fig. 7 Development of decomposition of Triple Helix synergy for Møre og Romsdal

The quality of a patent can be indicated using the number of citations of the actual patent. Where are the inventors with high quality patents located? In order to answer this, we used data building on the fractional counting of the inventors. The result is given in Fig. 9. We used the top-quartile (the 25 % most cited patents) and tested whether the city had more than its expected 25 % of patents in the top-quartile (z-test). These top locations are colored dark green in the figure; they are found in Oslo, Trondheim, Stavanger and Sandnes. The significance level is $p < 0.001$.

Fig. 8 Cities in Norway with more than five USPTO patents. The node sizes are proportionate to the logarithm of the number of patents

4.3 Norwegian national patents

The geographical distribution of granted industrial rights in Norway can be found in Strand (2014). A comparison between the national granted patents and the USPTO patents is given in Table 2. We compare the fraction of national and USPTO patents in each county in order to indicate differences between the two patterns. The counties with a higher fraction of international patents are Oslo, Vestfold, Telemark, Rogaland and Sør-Trøndelag.

The county-level distributions of national and international patent intensity (patents per 1000 inhabitants) are given in Fig. 10. The national patent intensity is highest in Rogaland, Sør-Trøndelag, Akershus, and Oslo. The results do not comply with the scaling relation between population size and patent numbers given by Bettencourt et al. (2007). The international patent intensity is closer, but still far from following the scaling law.

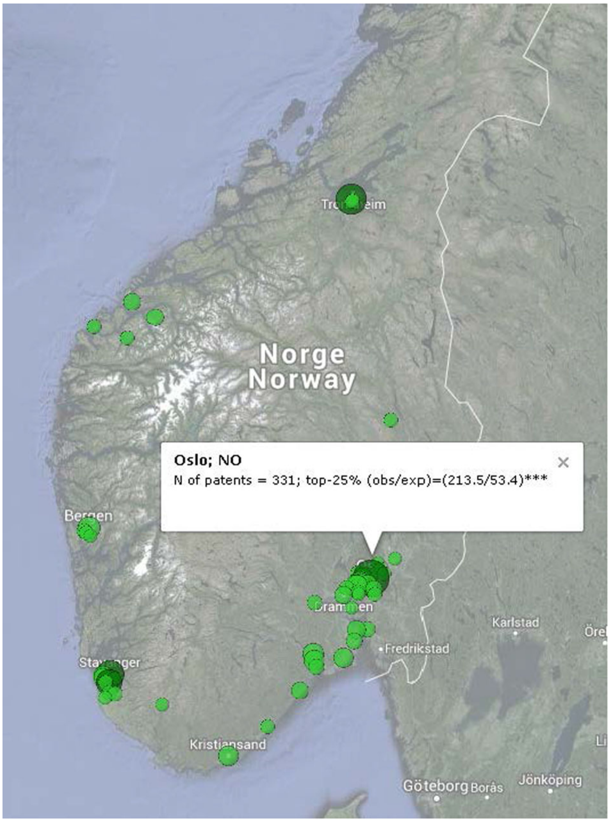

Fig. 9 Location of highly cited USPTO patents in Norway

4.4 Norwegian co-inventor networks, based on USPTO patents

The co-inventor networks, based on USPTO patents and overlaid on Google Maps are given in Fig. 11. Working interactively with this map allows us to analyze the geographical distribution of the co-inventor networks.

A closer inspection of the networks in Norway is found in Fig. 12. Rogaland with Stavanger and Sandnes show a high number of co-inventors located in the Houston area in the U.S. This shows the strong link between the Norwegian and U.S. oil and gas industries.

The co-inventor networks from Trondheim are very broad, ranging from the U.S., Europe, and Asia, but also to a large number of Norwegian cities. This indicates that the Trondheim region functions as a knowledge hub in Norway.

Strong links between the industries located in Vestfold and Finland can also be identified. From the county of Møre og Romsdal the picture is very different; almost all connections are national, mainly to Oslo and Trondheim.

The use of Google Maps allows us to interactively explore the characteristics of the co-inventor network. A further analysis of the data was performed in Pajek (de Nooy et al. 2011). Networks from the three cities, Stavanger, Trondheim and Ålesund are given in Fig. 13.

Table 2 Geographical distribution of national and USPTO patents in Norway

	County	USPTO patents	National patents	
1	Østfold	8	170	N
2	Akershus	127	806	N
3	Oslo	331	808	I
4	Hedmark	6	42	N
5	Oppland	5	73	N
6	Buskerud	26	294	N
7	Vestfold	46	190	I
8	Telemark	62	165	I
9	Vest-Agder	24	227	N
10	Aust-Agder	6	108	N
11	Rogaland	193	857	I
12	Hordaland	46	465	N
14	Sogn og Fjordane	0	65	N
15	Møre og Romsdal	32	291	N
16	Sør-Trøndelag	135	515	I
17	Nord-Trøndelag	0	64	N
18	Nordland	0	69	N
19	Troms	9	45	N/I
20	Finmark	0	20	N

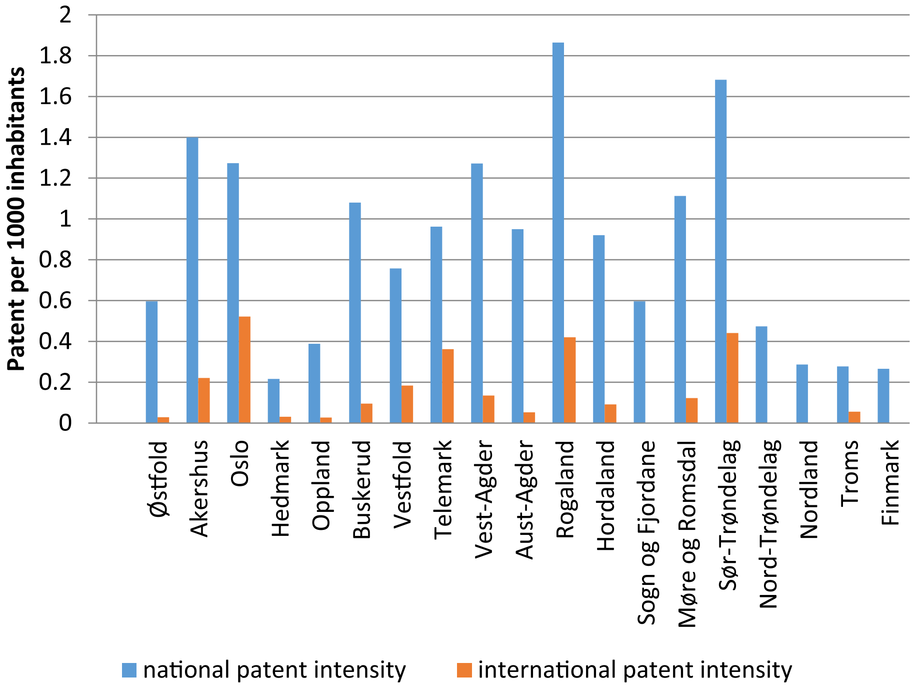

Fig. 10 County-level distribution of national and international patent intensity

Fig. 11 Google map of worldwide co-inventor network for all Norwegian USPTO patents

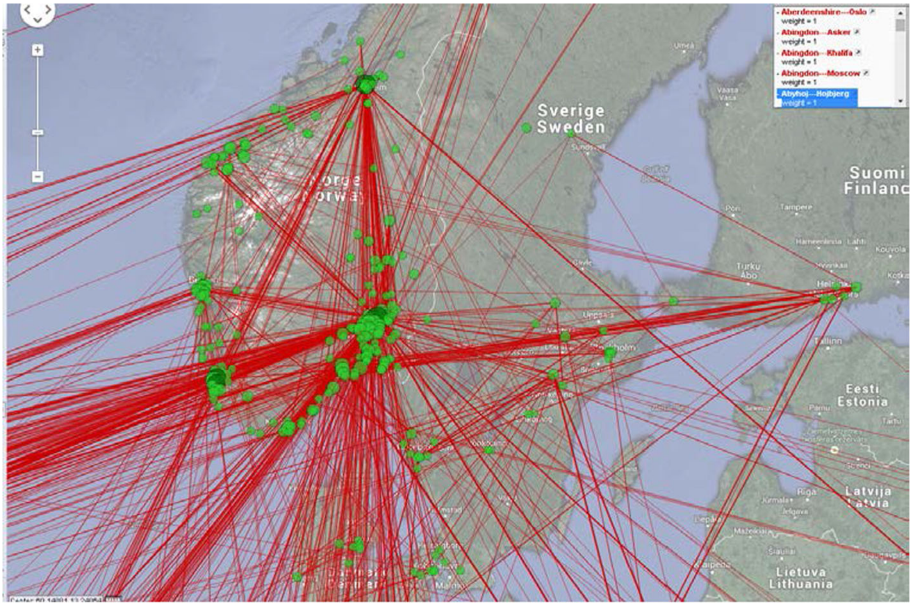

Fig. 12 Google map of co-inventor networks for Norwegian USPTO patents

The small industrial county Møre og Romsdal with Ålesund as the main town has a relatively high level of national patents, but a low level of international co-inventors in the case of the USPTO patents. This can be interpreted along two lines. First, that most patents in this county originate from industry rather than research institutes (as in Trondheim).

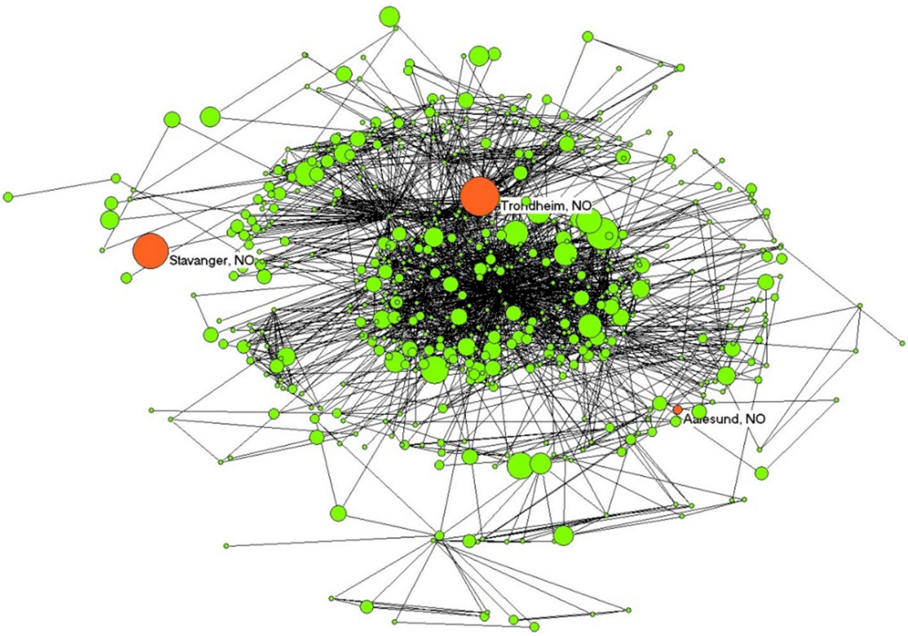

Fig. 13 Network for Norwegian co-inventors based on all Norwegian USPTO patents; three selected cities (Pajek)

Second, since the county has a high level of synergy, this might be interpreted as a sign of industrial lock-in (Leydesdorfff and Park 2014).

The networks originating from Trondheim are very broad with many connections to all parts of the world. This indicates that there are strong, worldwide connections to research groups and a high level of knowledge input from international partners. The networks from Stavanger are strong, but seem more limited with regards to the industry sector (oil and gas) and geography (Houston, Texas).

5 Discussion and conclusions

The first research question was related to the usability of decomposing the Triple Helix synergy. It is shown that this method gives new and valuable information on the factors that lead to Triple Helix synergy. An example is the stronger role of geography in Møre og Romsdal compared to Rogaland and Sør-Trøndelag where the contribution from technology dominates the synergy. These findings confirm the characteristics of these counties previously reported (Reve and Sasson 2012; Strand and Leydesdorff 2013).

The inclusion of time adds another extra dimension to the data, which allowed the researchers to explore emerging trends, typically a slight decline in synergy in Rogaland and high fluctuations in Finmark. It should however be underlined that longitudinal data are difficult to interpret, such as the findings from Østfold and Finmark. External changes, such as the economic crisis in 2008 may influence the results in several ways: first by an expected drop in start-up rates and second by an increase in start-up rates as a result of political and regional-political countermeasures in order to fight the crisis. Changes in trade restrictions with Russia and oil explorations in the Artic may affect results from Finmark. The dramatic drop in oil prices in the fall during 2014 may affect the data from Rogaland.

The second research question concerns the relation between patenting, and synergy pattern in Norwegian counties. Regions with high levels of TH synergy, such as Rogaland and Møre og Romsdal, are very different when it comes to international co-inventor networks. Rogaland seems to have a strong international network within the oil and gas sector, mainly to Houston in the U.S. This is very different for Møre og Romsdal with almost no international connections. The latter findings can be interpreted along several lines. This could be an indication of industrial lock-in, since there is very limited knowledge input from external partners. If so, this confirms the findings from Leydesdorff and Park (2014), that a high level of synergy may be interpreted as a sign of lock-in. There is also a possibility that the dominating maritime offshore industries in Møre og Romsdal build their competitive advantages on innovation speed, rather than through the use of intellectual property rights. It is also possible that U.S. patents are not so relevant in industries where the main competitors come from South East Asia.

Differences in attitudes among industries towards patenting may also be an explanation. If the typology of Jensen et al. (2007) is used, the industry in Rogaland is clearly STI-dominated, but DUI-dominated in Møre og Romsdal (Isaksen 2009). The arguments from Fitjar and Rodríguez-Pose (2013), that STI firms learn from consultants and researchers, whereas DUI firms learn more informally from customers and suppliers, may be relevant for explaining the lack of international co-inventors in Møre og Romsdal. The suggestions from Strand and Leydesdorff (2013) that the industrial counties along the west coast of Norway bypass national knowledge institutions by direct contact with international knowledge institutions and customers seems to find support in our findings from Rogaland, but not for Møre og Romsdal.

When it comes to differences between the geographical distributions of national and international patents, we find that the university cities and the counties dominated by high-tech industries are more internationally oriented in their patent strategies. This can be interpreted as an indication of a more international flow of knowledge to and from these 'knowledge hubs' in the major university cities such as Trondheim and Oslo. It can also be argued that since high-tech companies are dominated by an STI mode of learning, they compete on global arenas and therefore need to protect their technology with international patents. These findings support the findings from Brechi and Lission (2009) that academic co-inventors exchange information with more people and organizations compared to non-academic co-inventors. However, a more detailed analysis of the co-inventors' links to academic institutions remains to be performed.

Do the regions with the most technology-dominated synergy have the highest patent activities? The pattern seems to be that the counties with technology-dominated Triple Helix synergy, such as Rogaland and Sør-Trøndelag, are more international in their patenting strategies. However, there seems to be a condition that technology dominated TH synergy must be matched with strong knowledge institutions (see Table 1). This confirms the findings from Fitjar and Rodríguez-Pose (2013), that knowledge institutions play a vital role in regional development. These knowledge institutions are expected (based on previous arguments) to have a high number of international collaborators through their academic networks. The findings from Fitjar and Rodríguez-Pose (2013) that engagement with extra-regional actors are more conductive to innovation than collaboration with local partners are supported, given that a more international patent strategy is accepted as an innovation indicator. The findings from Robin and Schubert (2013) that firms cooperating with research institutions enhance their product innovation capabilities, also confirms the important role of co-location with knowledge institutions for patenting patterns. They also show that the innovation output from cooperation with institutions with a more applied research focus is higher than cooperation with a more theory-focused institution. As noted by Furman et al. (2002) the quality of the links between knowledge institutions and the industry cluster are of vital importance for the innovation capacity. A lack of links may lead to research lock-in as described in Narula (2002). In their study of knowledge-intensive firms in Norway, Isaksen and Onsager (2010) found that the small urban regions and the rural regions have a higher share of innovating, knowledge-intensive firms than the large urban regions. This could be interpreted as another sign of research lock-in where cooperation with local firms is more important than cooperation with more academically oriented institutions in the university cities.

The use of both firm level and patent data together provides a broader and more informed picture of the innovation systems under analysis. The firm-level data are closely linked to the structure of the industry-sector, whereas the patent data appears to be more linked to the knowledge infrastructure. The use of both national and international patent data broadens the picture of the innovation activity in the regions and the nation. Synergy decomposition may reflect to some degree the organization of co-inventor networks. For example, Rogaland is a more technology dominated county than Møre og Romsdal, where geography is more important. Since Rogaland is less tied to geographical components, its activity should also be more internationally-oriented. In turn, analysis of co-inventor networks may give information about the county's economic organizations (a high number of co-inventors located in the Houston area indicates county oil and gas industry domination and the link between the Norwegian and U.S. oil and gas industries). This indicates a sector dominated co-inventor network. This is in sharp contrast to the broad international networks found in Sør Trøndelag, where the synergy level is low, but where the technological component is dominant.

This study has a number of limitations and identifies a number of possibilities for further research along various tracks. The sensitivity of the industry structure, as well as the industry code classification, on the synergy calculations should be investigated in order to demonstrate that the findings are stable. The patenting patterns are expected to differ across both industry sectors and academic fields and this should also be accounted for.

The national context should be broadened in forthcoming studies, preferably by including data and results from Sweden, or other small open economies where synergy calculation already exists. This in order to isolate the characteristics of the national innovation system. A further analysis of the co-inventor networks, focusing on the institutional level rather than just geography could give further insight into the role of the actual knowledge institutions. The co-inventors affiliation to universities and/or research institutes and/or consulting firms may give an even better overview of the knowledge spillover effects of the different institutions.

Acknowledgments This paper was presented at the DISC conference in Daegu, South Korea in December 2014 and we acknowledge comments and feedback from several colleagues in the discussion. We thank two anonymous reviewers and the Editor for insightful comments and suggestions for improvements of the manuscript. Inga Ivanova acknowledges support of the Basic Research Program at the National Research University Higher School of Economics (NRU HSE) and the Global Competitiveness Program of the Government of the Russian Federation.

Appendix

See Table 3.

Table 3 Correspondence of high level aggregation to NACE Rev 1.1 and NACE Rev. 2 classifications (http://epp.eurostat.ec.europa.eu/cache/ITY_OFFPUB/KS-RA-07-015/EN/KS-RA-07-015-EN.PDF; http://www.ine.es/daco/daco42/clasificaciones/cnae09/estructura_en.pdf)

High level aggregation	NACE Rev.2	NACE Rev.1.1
(1) 1–5; 74.14; 92.72	(A) 1, 2, 5; Agriculture, forestry and fishing 1; 2; 5; 74.14; 92.72	(A) 01 Agriculture, hunting and related service activities (A) 02 Forestry, logging and related service activities (A) 05 Fishing, fish farming and related service activities
(2) 10–41; 01.13; 01.41; 02.01; 51.31; 51.34; 52.74; 72.50; 90.01; 90.02; 90.03	(B) 10–14 Mining and quarrying 10–14	
	(C) 15–37 Manufacture 15–36; 01.13; 01.41; 02.01; 10.10; 10.20; 10.30; 51.31; 51.34; 52.74; 72.50	
	(D) 40 Electricity, gas and steam 40;	(B) 10 Mining of coal and lignite, extraction of peat (B) 11 Extraction of crude petroleum and natural gas, service activities incidental to oil and gas etc. (B) 12 Mining of uranium and thorium ores (B) 13 Mining of metal ores (B) 14 Other mining and quarrying
	(E) (+4) 41 Water supply, sewerage, waste 41; 37; 90 14.40; 23.30; 24.15; 37.10; 37.20; 40.11; 90.01; 90.02; 90.03	
(3) 45; 20.30; 25.23; 28.11; 28.12; 29.22; 70.11	(F) 45 Construction 45; 20.30; 25.23; 28.11; 28.12; 29.22; 70.11	
(4) 50–63; 11.10; 64.11; 64.12	(G) 50-52 Wholesale and retail trade: repair of motor vehicles and motorcycles 50–2	
	(H) 60–63 Transportation and storage 60–63; 11.10; 50.20; 64.11; 64.12	
	(I) 55 Accommodation and food service activities 55	(C) 15 Manufacture of food products and beverages (C) 16 Manufacture of tobacco (C) 17 Manufacture of textiles (C) 18 Manufacture of wearing apparel, dressing and dyeing of fur

Table 3 continued

High level aggregation	NACE Rev.2	NACE Rev.1.1
		(C) 19 Tanning and dressing of leather, manufacture of luggage, handbags, saddlery, harness and footwear (C) 20 Manufacture of wood and of products of wood and cork, except furniture (C) 21 Manufacture of pulp, paper and paper products (C) 22 Publishing, printing and reproduction of recorded media (C) 23 Manufacture of coke, refined petroleum products and nuclear fuel (C) 24 Manufacture of chemicals and chemical products (C) 25 Manufacture of rubber and plastic products (C) 26 Manufacture of other non-metallic mineral products (C) 27 Manufacture of basic metals (C) 28 Manufacture of fabricated metal products, except machinery and equipment (C) 29 Manufacture of machinery and equipment n.e.c. (C) 30 Manufacture of office machinery and computers (C) 31 Manufacture of electrical machinery and apparatus n.e.c. (C) 32 Manufacture of radio, television and communication equipment and apparatus (C) 33 Manufacture of medical, precision and optical instruments, watches and clocks (C) 34 Manufacture of motor vehicles, trailers and semi-trailers (C) 35 Manufacture of other transport equipment (C) 36 Manufacture of furniture, manufacturing n.e.c.

Table 3 continued

High level aggregation	NACE Rev.2	NACE Rev.1.1
(5) 64, 72; 22.11; 22.12; 22.13; 22.15; 22.22; 30.02; 92.11; 92.12; 92.13; 92.20	(J) 64,72 Information and communication 64; 72; 22.11; 22.12; 22.13; 22.15; 22.22; 30.02; 92.11; 92.12; 92.13; 92.20	
(6) 65–67; 74.15	(K) 65–67 Financial and insurance activities 65–67; 74.15	
(7) 70;	(L) 70 Real estate activities 70	
(8) 71–74; 01.41; 05.01; 45.31; 63.30; 63.40; 64.11; 70.32; 75.12; 75.13; 85.20; 90.03; 92.32; 92.34; 92.40; 92.62; 92.72	(M) (+10) 71,73 Professional, scientific and technical activities 73; 74; 05.01; 63.40; 85.20; 92.40	
	(N) (−2) 74 Administrative and support service activities 71; 01.41; 45.31; 63.30; 64.11; 70.32; 74.50;74.87; 75.12; 75.13; 90.03; 92.32; 92.34; 92.62; 92.72;	
(9) 75–85; 63.22; 63.23; 74.14; 92.34; 92.62; 93.65;	(O) 75 Public administration and defense: compulsory social security 75	
	(P) 80 Education 80; 63.22; 63.23; 74.14; 92.34; 92.62; 93.65	
	(Q) 85, 90,91 Human health and social work activities 85; 75.21	

Table 3 continued

High level aggregation	NACE Rev.2	NACE Rev.1.1
(10) 92–99; 01.50;29.32; 32.20; 36.11; 36.12; 36.14; 52.71; 52.72; 52.73; 52.74; 72.50; 75.14; 91;	(R) 92 Arts, entertainment and recreation 92; 75.14	
	(S) (+2) 93 Other service activities 93; 91; 01.50;29.32; 32.20; 36.11; 36.12; 36.14; 52.71; 52.72; 52.73; 52.74; 72.50	
	(T) 95 Households as employers activities 95	
	(U) 99 Extraterritorial organizations and bodies	
	Unspecified	(C) 37 Recycling
		(D) 40 Electricity, gas, steam and hot water supply
		(E) 41 Collection, purification and distribution of water
		(F) 45 Construction
		(G) 50 Sale, maintenance and repair of motor vehicles and motorcycles, retail sale of automotive fuel (G) 51 Wholesale trade and commission trade, except motor vehicles and motorcycles (G) 52 Retail trade, except motor vehicles and motorcycles, Repair of personal and household goods
		(I) 55 Hotels and restaurants
		(H) 60 Land transport, transport via pipelines (H) 61 Water transport (H) 62 Air transport (H) 63 Supporting and auxiliary transport activities, activities of travel agencies
		(J) 64 Post and telecommunications
		(K) 65 Financial intermediation, except insurance and pension funding

Table 3 continued

High level aggregation	NACE Rev.2	NACE Rev.1.1
		(K) 66 Insurance and pension funding, except compulsory social security
		(K) 67 Activities auxiliary to financial intermediation
		(L) 70 Real estate activities
		(M) 71 Renting of machinery and equipment without operator and of personal and household goods
		(J) 72 Computers and related activities
		(M) 73 Research and development
		(N) 74 Other business activities
		(O) 75 Public administration and defense, compulsory social security
		(P) 80 Education
		(Q) 85 Health and social work
		(Q) 90 Sewage and refuse disposal, sanitation and similar activities
		(Q) 91 Activities of membership organizations n.e.c.
		(R) 92 Recreational, cultural and sporting activities
		(S) 93 Other service activities
		(T) 95 Activities of households with employed persons
		(U) 99 Extra-territorial organizations and bodies

References

Abramson, N.: Information Theory and Coding. McGraw Hill, New York (1963)

Almeida, P., Kogut, B.: Localization of knowledge and the mobility of engineers in regional networks. Manag. Sci. **45**(7), 905–917 (1999)

Asheim, B.T., Coenen, L.: Knowledge bases and regional innovation systems: comparing Nordic clusters. Res. Policy **34**, 1173–1190 (2005)

Asheim, B.T., Isaksen, A.: Location, agglomeration and innovation: towards regional innovation systems in Norway? Eur. Plan. Stud. **5**(3), 299–330 (1997)

Balconi, M., Breschi, S., Lissioni, F.: Networks of inventors and the role of academia: an exploration of Italian patent data. Res. Policy **33**, 127–145 (2004)

Benner, M., Sandstrøm, U.: Institutionalizing the Triple Helix: research funding and norms in the academic system. Res. Policy **29**(2), 291–301 (2000)

Bettencourt, L.M.A., Lobo, J., Strumsky, D.: Invention in the city: increasing returns to patenting as a scaling function of metropolitan size. Res. Policy **36**, 107–120 (2007)

Breschi, S., Lissioni, F.: Mobility of skilled workers and co-invention networks: an anatomy of localized knowledge flows. J. Econ. Geogr. 1–30 (2009)

Carlino, G.A., Chatterjee, S., Hunt, R.M.: Urban density and the rate of invention. J. Urban Econ. **61**, 389–419 (2007)

Choi, S., Yang, J.S.W., Park, H.W.: Quantifying the Triple Helix relationship in scientific research: statistical analysis on the dividing pattern between developed and developing countries. Qual. Quant. **49**, 1381–1396 (2015)

de Nooy, W., Mrvar, A., Batagelj, V.: Exploratory Social Network Analysis with Pajek. Cambridge University Press, Cambridge (2011)

Etzkowitz, H., Leydesdorff, L.: The Triple Helix—University-industry-government relations: a laboratory for knowledge-based economic development. EASST Rev. **14**, 14–19 (1995)

Etzkowitz, H., Leydesdorff, L.: The dynamics of innovation: from National Systems and 'Mode 2' to a Triple Helix of university-industry-government relations. Res. Policy **29**(2), 109–123 (2000)

Eurostat 2012. http://ec.europa.eu/eurostat/statistics-explained/index.php/R_%26_D_expenditure (2012). 10 Apr 2016

EU 2014. http://ec.europa.eu/growth/industry/innovation/facts-figures/scoreboards/index_en.htm (2014)

Fitjar, R.D., Rodríguez-Pose, A.: Firm collaboration and modes of innovation in Norway. Res. Policy **42**(1), 128–138 (2013)

Furman, J.L., Porter, M.E., Stern, S.: The determinants of national innovation capacity. Res. Policy **31**, 899–934 (2002)

Grillitsch, M., Nilsson, M.: Innovation in peripheral regions: do collaborations compensate for lack of local knowledge spillovers? Ann. Reg. Sci. **54**, 299–321 (2015)

Gulbrandsen, M., Smeby, J.C.: Industry funding and university professors' research performance. Res. Policy **34**, 932–950 (2005)

Ivanova, I., Strand, Ø., Leydesdorff, L.: Synergy cycles in the Norwegian innovation system: the relation between synergy and cycle values (in preparation)

Ivanova, I., Leydesdorff, L.: Rotational symmetry and the transformation of innovation systems in a Triple Helix of university-industry-government relations. Technol. Forecast. Soc. Change **86**, 143–156 (2014)

Isaksen, A.: Innovation dynamics of global competitive regional clusters: the case of the Norwegian centers of expertise. Reg. Stud. **43**(9), 1155–1166 (2009)

Isaksen, A., Onsager, K.: Regions, networks and innovative performance: the case of knowledge-intensive industries in Norway. Euro. Urban Reg. Stud. **17**(3), 227–243 (2010)

Isaksen, A., Karlsen, J.: Can small regions construct regional advantages? The case of four Norwegian regions. Euro. Urban Reg. Stud. **20**(2), 243–257 (2012)

Jaffe, A.B., Tratjienberg, M.: Patents, Citations, and Innovations: A Window on the Knowledge Economy. MIT Press, Cambridge (2002)

Jensen, M.B., Johnson, B., Lorenz, E., Lundvall, B.Å.: Forms of knowledge and modes of innovation. Res. Policy **36**, 680–693 (2007)

Jung, K., Park, H.W.: Interactions among Networks in the age of "Big Data": social, knowledge, and triple-helix networks. J. Contemp. East. Asia **13**(1), 1–4 (2014)

Khan, G.F., Park, H.W.: Triple Helix and innovation in Asia using scientometrics, webometrics, and informetrics. Scientometrics **90**, 1–7 (2012)

Kim, J.K.: A hyperlink and semantic network analysis of the Triple Helix (University-Government-Industry): the interorganizationel communication structure of nanotechnology. J. Comput. Med. Commun. **17**, 152–170 (2012)

Kwon, K.-S.: Are scientific capacity and industrial funding critical for universities' knowledge transfer activities?—a case study of South Korea. J. Contemp. East. Asia **10**(1), 15–23 (2011)
Kwon, K.-S., Martin, B.R.: Synergy or separation mode: the relationship between the academic research and the knowledge-transfer activities of Korean academics. Scientometrics **90**, 177–200 (2012)
Lengyel, B., Leydesdorff, L.: Regional innovation systems in Hungary: the failing synergy at the national level. Reg. Stud. **45**(5), 677–693 (2011)
Leydesdorff, L., Bornmann, L.: Mapping (USPTO) patent data using overlays to Google Maps. J. Am. Soc. Inf. Sci. Technol. **63**(7), 1442–1458 (2012)
Leydesdorff, L., Dolfsma, W., van der Panne, G.: Measuring the knowledge base of an economy in terms of triple-helix relations among 'technology, organization, and territory'. Res. Policy **35**(2), 181–199 (2006)
Leydesdorff, L., Ivanova, I.: Mutual redundancies in inter-human communication systems: steps towards a calculus of processing meaning. J. Am. Soc. Inf. Sci. Technol. **65**(2), 386–399 (2014)
Leydesdorff, L., Meyer, M.: Triple Helix indicators of knowledge-based innovation systems: introduction to the special issue. Res. Policy **35**(10), 1441–1449 (2006)
Leydesdorff, L., Park, H.W.: Can synergy in triple-helix relations be quantified? a review of the development of the triple-helix indicator. Triple Helix J. Univ. Ind. Gov. Innov. Entrep. **1**(4), 1–19 (2014)
Leydesdorff, L., Persson, O.: Mapping the geography of science: distribution patterns and networks of relations among cities and institutes. J. Am. Soc. Inf. Sci. Technol. **61**(8), 1622–1634 (2010)
Leydesdorff, L., Strand, Ø.: The Swedish system of innovation: regional synergies in a knowledge-based economy. J. Am. Soc. Inf. Sci. Technol. **64**(9), 1890–1902 (2013)
Meyer, M., Grant, K., Morlacchi, P., Weckowska, D.: Triple Helix indicators as an emergent area of enquiry: a bibliometrical perspective. Scientometrics **99**, 151–174 (2014)
Narula, R.: Innovation systems and 'inertia' in R&D location: Norwegian firms and the role of systemic lock-in. Res. Policy **31**, 795–816 (2002)
Park, H.W.: An interview with Loet Leydesdorff: the past, present, and future of the Triple Helix in the age of big data. Scientometrics **99**, 199–202 (2014)
Ranga, M., Etzkowitz, H.: Triple Helix systems: an analytical framework for innovation policy and practice in the knowledge society. Ind. High. Educ. **27**(3), 237–262 (2013)
Research Concil Of Norway.: (RCN) Science and Technology Indicators for Norway 2014. 978-82-12-03364-1 (PDF). http://www.forskningsradet.no/servlet/Satellite?blobcol = urldata&blobheader = application%2Fpdf&blobheadername1 = Content-Disposition%3A&blobheadervalue1 =+attachment%3B + filename%3D%2220141Komplettrapportendelig201410.pdf%22&blobkey = id&blobtable = MungoBlobs&blobwhere = 1274505537435&ssbinary = true. Accessed by 10 Oct 2014
Reis, J., Tereso, J.D.: Map of Norwegian counties. http://no.wikipedia.org/wiki/Norges_fylker#mediaviewer/File:Norway_counties.svg. Accessed by 10 Oct 2014
Reve, T., Sasson, A.: Et kunnskapsbasert Norge (Norwegian)/A knowledge-based Norway. Universitetsforlaget, Oslo (2012)
Robin, S., Schubert, T.: Cooperation with public research institutioins and success in innovation: evidence from France and Germany. Res. Policy **42**, 149–166 (2013)
Rodríguez-Pose, A.: Do institutions matter in regional development. Reg. Stud. **47**(7), 1034–1047 (2013)
Shelton, R.D., Leydesdorff, L.: Publish or patent: bibliometric evidence for empirical trade-offs in national funding strategies. J. Am. Soc. Inf. Sci. Technol. **63**(3), 498–511 (2012)
Simmie, J.: Innovation and urban regions as national and international nodes for the transfer and sharing of knowledge. Reg. Stud. **37**(6&7), 607–620 (2003)
Stek, P.E., van Geenhuizen, M.S.: Measuring the dynamics of an innovation system using patent data: a case study of South Korea, 2001–2010. Qual. Quant. **49**, 1325–1343 (2015)
Storper, M.: The Regional World: Territoriel Development in a Global Economy. Guilford Press, New York (1997)
Strand, Ø., Leydesdorff, L.: Where is synergy indicated in the Norwegian innovation system? Triple-Helix relations among technology, organization and geography. Technol. Forecast. Soc. Change **80**, 471–484 (2013)
Strand, Ø.: Industrial rights as quality indicators of the regional innovation systems in Norway. In: Amdam, J., Helgesen, Ø., Sæther, K.W. (eds.) Det mangfaldige kvalitetsomgrepet, Fjordantologien 2013, pp. 335–356. Forlag1, Ålesund (2014)