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Internationalization of innovative activities in Norway

US patents involving Norwegian inventors and assignees

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SNF

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Abstract

Purpose: To investigate the international connectivity of innovation activity in Norway.

Design: We use patent data from the United States Patent and Trademark Office (USPTO) to examine the level and international pattern of innovative activity in the Norway.

Findings: The number of US patents registered on firms and individuals referring to Norway have increased significantly over the last 40 years. So has also the share of patents that have an international connection.

Originality/value: Provide empirical data on patented innovations concerning the small, open economy of Norway.

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Introduction

Business have become more international in many respects. This holds for Norway as well as for other industrialized economies around the world. Firms have particularly changed with regard to what extent they operate value-generating activities in other countries than the country from which they originate. They have increasingly become multinational enterprises. This significant change, which implies that a larger share of the employment in large firms is in entities which they have located abroad, is clearly documented for Norway and other Nordic countries (Braunerhjelm et. al., 2010). This also means that new opportunities for learning and improvements of products and working processes may arise, which should be reflected in how innovative activities are conducted.

Innovation is recognized as a potential source for firms to achieve competitive advantage relative to competitors (Porter, 1985). Innovation can be achieved through two types of mechanisms: either through in-house research or as a result of 'a dynamic interplay between, and transformation of, tacit and codified forms of knowledge as well as a strong interaction of people within organizations and between them' (Asheim and Gertler, 2005, p. 294). In particular, for the latter type the presence of innovation networks that emerge through frequent relations between firms and their suppliers, customers, and R&D partners, is necessary.

In this paper, we aim to investigate the international pattern of innovation in Norway as it is revealed in patent data from the United States Patent and Trademark Office (USPTO). Even though patents and trademarks are territorial and must be filed in each country where protection is sought, the Patent Cooperation Treaty streamlines the process of filing patents in multiple countries. By filing one patent application with the U.S. Patent and Trademark Office, U.S. applicants can concurrently seek protections in up to 143 countries[2]. Thus, US patents are an

[1] We are grateful to Sven Haugland for constructive comments and suggestions on an earlier draft.
[2] https://www.uspto.gov/patents-getting-started/international-protection/protecting-intellectual-property-rights-ipr

important reference when firms strive to protect their intellectual property rights throughout most of the world.

In the next section we briefly consider the literature on how the internationalization of firms may affect processes of innovation. Then we present methods and data for our analysis of the internationalization of innovative activities in Norway. The empirical section consists of four parts. We start by considering innovative activities in Norway in an international perspective, and continue by focusing on the growth in patents and their international connectedness as far as US patents involving actors residing in Norway are concerned. Then we investigate the development concerning the international dispersion of co-inventors in these patents and the distribution of the co-inventors across countries. The fourth part focuses on the top patenting firms in Norway and the international dispersion of co-inventors in their US patents.

Innovation processes and the internationalization of firms

It is generally acknowledged that innovations require both the exploitation of in-house resources and the inputs from being connected to innovation networks, which enable external sourcing of knowledge and ideas (Cantwell and Santangelo, 1999). Thus, developing collaborative innovation strategies and collaborating with a wide range of external actors and sources becomes more and more common for firms that want to achieve and sustain competitiveness (Laursen and Salter, 2006). In this paper we particularly have the international aspects of this innovative activity in mind.

Internationalization occurs at the firm level in almost all countries of the world, in several industries and at least among major firms. Strictly speaking, this may challenge one major line of thought regarding innovation for the last 30 years, which has centered around the concept "National innovation system" (see Lundvall, 1992; Nelson, 1993; Freeman, 1995). It is at least reasonable to question whether the internationalization of firms will affect systems of innovation in the sense that corporations are key actors in innovations that take place. Carlsson (2006) reviewed the literature from this perspective. Despite a large literature on the internationalization of economic activities at the corporate level, also with respect to R&D, this has been limited studies on internationalization of innovation systems as such. While innovation

activities as R&D are becoming increasingly internationalized, policy recommendations seem to retain the importance of national institutions to support innovative activity.

In this paper, we aim to use US patent data to investigate internationalization of innovative activities in Norway. Previously there have only been a few studies touching upon this question empirically. Studies have addressed the foreign share of R&D in Norwegian firms (Narula, 2001; Heum and Ylä-Anttila, 2000), and more recently Fitjar and Huber (2015) explicitly addressed the role of regional, national and international networks in different types of innovation. Qiu et.al. (2017), focusing on design patents has applied a similar approach to study international collaboration related to innovation processes in Norway by making use of patent data.

From other countries, there are several contributions using data on patents to analyze the internationalization of innovation processes, or inventive activity. Picci (2010) used patent data for the years 1990-2005 from the European Patent Office. He found that internationalization had steadily increased over time, however, still being rather low, and that bilateral collaboration across countries are positively affected by proximity in terms of geography, language and culture. In that sense, his findings resemble the Uppsala model with regard to internationalization of firms in general (Johanson and Vahlne, 1977). Lee et.al. (2016) used patent data to analyze differences with regard to how the same four industries in Japan, Germany and Denmark was connected to the global innovation system. Xiang et.al (2013) have done it with data on patents of Chinese assignees to show how information on co-inventors will complement data on patent citations to get a better understanding of international collaboration with regard to innovation.

Methods and data

We apply patent data to investigate trends concerning growth and internationalization of innovative activity in Norway. Previous studies of innovation have widely adopted the use of patents as an indicator of innovation outcomes (Zahra and Nielsen, 2002; Narin, Noma, and Perry, 1987). Patents are used as an indicator for the output of innovation activities, while indicators like R&D expenditure and R&D staff are used as the innovation input (Kim and Lee,

2015). Concerns of using patents as proxies of innovation rises such as (1) process innovations are neglected (Kemp et al., 2003), (2) patent counts do not separate significant from incremental innovations (Zahra and Nielsen, 2002), and (3) some patents do not generate new products (DeCarolis and Deeds, 1999).

These concerns do not have severe impact on our study as we are focusing on the level and international pattern of innovative activity. Thus, we think it is justified to use patents as an indicator of innovation, because the research focus is on inter-collaboration regarding innovations instead of innovation performance. In that respect patents serve as a valuable source of information when investigating the international connectivity of innovative activities of firms.

Patents as indicator of innovative activity

We use patent data from the United States Patent and Trademark Office (USPTO) to examine the level and pattern of innovative activities in the Norway[3]. Patents can be considered to represent stocks of organizational knowledge, because they can be seen as 'physical, codifiable manifestations of innovative ideas, techniques, and products that embody the knowledge of one or several employees' (DeCarolis & Deeds, 1999). Using patent analysis as a method to monitor technology and knowledge trends, analyze innovation patterns and develop knowledge strategies, has been commonly applied, as patents are an effective indicator of commercialized technology (Kim and Lee, 2015). It is also proved adequate to use information on patent co-inventorship as an indicator when studying knowledge exchange within inventor networks across space (Ejermo and Karlsson, 2006).

It is, however, worth noting that using basic patent counts as a single indicator may not represent a full measurement of innovation (Lanjouw and Schankerman, 2004). By relying on patent data

[3] When studying innovation by focusing on patenting in Norway, another relevant database could have been the one from European Patent Office (EPO). As some firms only file their patent in EPO, it is argued that the EPO may be a better choice when (1) the firm's products or technologies are expected to be marketed in Europe rather than in the USA; (2) the size of markets adopting those technologies is larger in Europe than in the USA; (3) products in technological fields close to those of the patents are mostly manufactured in Europe; (4) end-user product/services only for domestic market may be satisfied with filing in their own country, or (5) they supply their products to domestic arms of global companies (Kim and Lee, 2015). Research of US patent data do, however, have long traditions. The USPTO database contains rather large amounts of information on inventions around the world, starting in the 1960s. Thus, it is regarded as a good indicator of innovative activities (Kim and Lee, 2015). Furthermore, there is no reason to expect that patent data from EPO will reveal different trends than the patent data from USPTO when considering the growth and international connectivity of innovative activities in Norway.

to capture innovation and knowledge flow, we leave out other forms of proprietary knowledge and innovation, such as process innovation (Lanjouw and Schankerman, 2004). Moreover, patents might be an imperfect source of information for cross-cluster teams, because the international patent collaborations may not necessarily measure knowledge flows (Bergek and Bruzelius 2010). Sometimes, individuals who work in maintenance, service, or helping the patent application procedures are listed as inventors in patent data (Bergek and Bruzelius 2010). This is a potential limitation of using patents as a measure of international collaboration (Bergek & Bruzelius, 2010). Nevertheless, with these cautions in mind we still regard patent data to be a good indicator to reveal to what extent innovative activities in firms are internationalized.

Data in the analysis

The US patent data includes information on individuals who have contributed to the invention that is granted a patent, who we regard as the inventors, and the assignee(s) to which the rights of the patented innovation is transferred. As our research questions deal with the collaboration and network involving innovative activities in Norway, we have selected US patents where either the assignee or at least one of the inventors are listed with Norway as country of residence. This approach has been widely applied in studies that examine the international knowledge sourcing and innovation network (Perri, Scalera and Mudambi, 2017; Lee, Mudambi, and Cano-Kollmann, 2016; Scalera, Mukherjee, Perri and Mudambi, 2014).

Focusing on patenting as an activity of innovation, we have chosen to sort these patents concerning Norway by the year when the patent application was filed, and not by the year the patent was granted. The result is a data set of 11,486 patents filed between 1971 and 2015, and granted by August, 2016. To be more specific, the data concerning Norway consists of 7,485 patents where assignees and at least one of the inventors have Norway as country of residence, 762 patents with Norwegian assignees involving no Norwegian inventors, and 3,239 patents with foreign assignees involving inventors residing in Norway.

This data set is used to map how the volumes and pattern of innovative activities in Norway has developed. We use the number of patents to document how the volume of innovative activities has developed over time.

Information on the nationality of inventors and assignees in each patent is used to investigate to what extent innovative activities have become more internationalized. A patent is defined as internationally connected if either an inventor or an assignee is registered with a country of residence other than Norway. This reflects one aspect of internationalization. We also consider the dispersion of co-inventors across countries, which better reflects to what extent collaboration regarding innovative activities is internationalized.

It has to be emphasized that our data are right-censored, since a substantial share of the patent applications submitted in the last 3-4 years before the cutoff date of August 23, 2016 are likely to be granted after the cutoff date. The lag between the application and the grant of a patent averages around 3 years, with many patents taking even longer. In sum, when using data organized according to the application date we need to be aware that these data are incomplete for the last 3-6 years before the cutoff date, i.e. presumably after 2010. Thus, we can realistically assume that our data are practically complete for the first 40 years (1971–2010) and suffers from an increasing number of "still missing" observations, as we get closer to the cutoff date of August 23, 2016.

This means that presenting data through to 2015, the final 2011–2015 period has some truncation issues. This is of particular concern when considering the growth in the number of granted patents. It ought to have less if any impact when considering trends in the pattern of international connections in the granted patents, and probably also none regarding the general picture of how the internationalization of innovative activities are revealed.

Norway's innovative activities in an international perspective

Norwegian business has traditionally held strong positions in raw material based industries. These industries are in general characterized by rather low R&D-intensity, and as patenting often is linked to R&D, they are not intense in patenting activities either. They also score rather low on product innovations. As these industries are of far greater importance for the constitution of the national economy in Norway than for most other countries, Norway figures rather low compared to other countries when national aggregates of innovative activities are considered. Thus, even though GDP per capita according to the World Bank is higher in Norway than in

most countries in the world[4], Norway in 2016 ranks as #12 among European countries according to European Innovation Scoreboard (European Commission, 2017). Among the West-European countries only Ireland and France are slightly behind.

The same pattern is revealed when considering US patents by country of origin. As the innovation process involves actors in several countries, it is not obvious what a patent's country of origin actually is. USPTO determines the country of origin by the residence of the first-named inventor in the patent application. This definition is used to compare the magnitude of US patents originating in Norway with US patents originating in other countries.

Table 1 lists the Top 4 countries of origin of US patents and the Nordic countries. Information in the table is based on a more extensive list of US patents by country of origin in Appendix 1. For each of the selected countries we have listed the number of patents granted in this period, calculated the number of patents relative to the population of the country, and estimated a growth rate with respect to US patenting. The growth rate is estimated by using information in Appendix 1 on the annual grant of patents by country for the 14 years 2002-2015. To consider how growth in patenting differs between the countries in question, we have simply calculated the ratio between the number of patents granted to a country in the second half of this period (2009-2015) with the number of patents granted in the first half (2002-2008).

Ranked according to the country of origin for US patents Norway is listed as #24 with altogether 7,294 granted patents over the years 1991-2015. Comparing with the other Nordic countries, Denmark is registered with twice as many, Finland with almost three times as many, and Sweden with 5 times more.

Also when measuring the number of patents over the years 1991-2015 in per cent of the population of the countries in 2015, the level of patenting activity in Norway is significantly lower than what is recorded for the other Nordic countries and the top 4 countries on the list. Comparing Norway with the Nordic countries, the relative level of US patents is almost twice as high in Denmark, and more than two and a half time as high in Sweden and Finland. When comparing to the countries on the top of the list, USA and Japan have 5 times as many patents as Norway in relative terms.

[4] Statistics on GDP per capita measured in purchasing power parity and current international $ ranks Norway ahead of the US. In Europe Norway is only surpassed by Luxembourg and Switzerland.

Table 1. US patents granted 1991-2015 by country of origin

Rank	Country of origin	Patents	Per million capita	2009-2015 / 2002-2008
1	USA	2,420,865	7.4	1.41
2	Japan	901,207	7.1	1.38
3	Germany	273,220	3.3	1.37
4	South Korea	165,414	3.3	2.60
..	..	..	..	..
13	Sweden	37,633	3.9	1.53
16	Finland	20,424	3.7	1.36
20	Denmark	14,846	2.6	1.76
24	Norway	7,294	1.4	1.82

Source: Extracted and calculated from USPTO, *Technology Assessment and Forecast report,* Patents Granted By Date of Patent Grant (Granted: Jan 01,1991 – Dec 31, 2015)

Nevertheless, Norway has in the most recent years experienced higher growth rates in the number of granted US patents than all the other countries listed in Table 1 except for South Korea. For Norway, this higher growth occurs from rather low levels of patenting activity.

The purpose of this paper, is not, however, to compare innovative activities across countries, but to use the US patent data to investigate how the volume of patents from Norwegian inventors have developed over time, and to what extent patenting activities have become more international.

Growth in US patents and international connectivity

When analyzing the growth and international pattern in US patents with respect to Norway, we do not apply the country of origin approach as in the previous chapter. As described in the chapter on methods and data, we select data according to a somewhat wider definition and include all US patents where an assignee or an inventor are listed with Norway as their country of residence.

Volume growth and international connectivity

To the extent patenting reflects innovative activities, Figure 2 clearly documents a remarkable growth in such activities over the 40 years since the early 1970s. The figure shows the number

of granted US patents for 5 year time cohorts according to the year of patent application. As the lag between application and grant of a patent averages around 3 years and we only have patents granted by August 2016, the information on patents granted for applications filed at least since 2011 are increasingly incomplete. Thus, with reference to our previous discussion in connection with the data applied, we choose to concentrate on the development in granted patents for applications made between 1971 and 2010 when considering the growth in patenting activity.

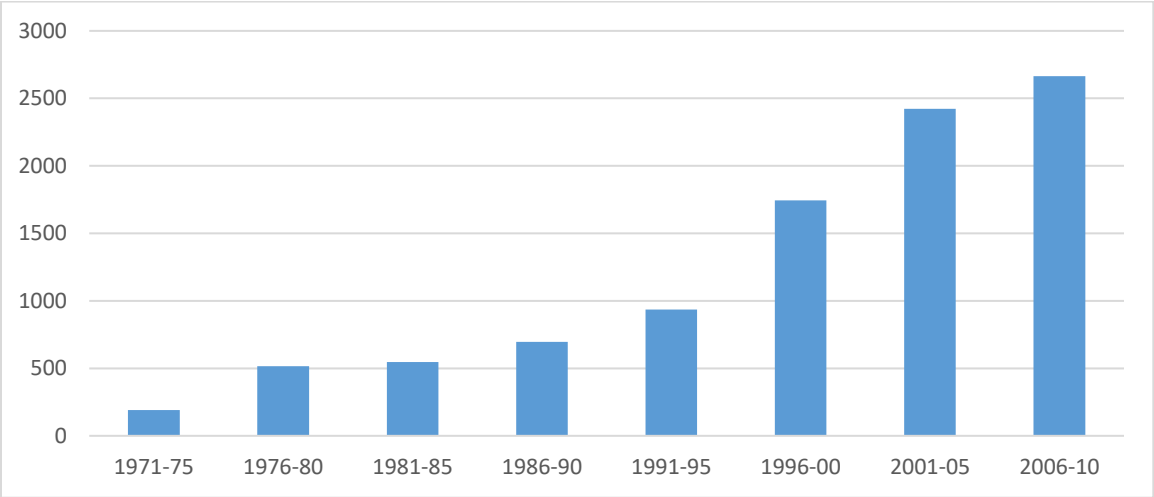


Figure 1. Number of US patents involving actors in Norway by year of application, 1971-2010

It is evident that the number of patents has increased significantly, from 190 in the first half of the 1970s to 2,665 for the years 2006-2010. Over the 20 years from the mid-1970s through the first half of the 1990s the number of US patents involving inventors or assignees residing in Norway increased with some 80 %, from 516 in 1976-1980 to 935 in 1991-1995. Since then, this number has almost tripled to 2,665 for the years 2006-2010.

We expect that this growth will continue also in the next 5 year period, 2011-2015. According to information provided later (Table 2) there are 1,771 patents granted by the cutoff date, August 2016, which were applied for during the years 2011-2015. To reach the level of granted patents filed during the previous period, 2006-2010, the number registered so far has to grow by 50 %. We assume this will be the case as we have no information which may indicate that the number of patent applications should have been reduced, and as the average time it takes to grant a patent is 3 years. This means that only patents filed for previous to September 2013 meet this average time requirement. Proceedings to grant a patent may depart significantly from the average, which means that even some patents applied for in 2011 may still be under

consideration, and that the number of undecided patent applications is increasing for every year up to 2015, when probably most of the applications are still under consideration.

Table 2 provides more detailed information on the number of US patents involving inventors and assignees residing in Norway and their international connection. An internationally connected patent is defined as a patent where at least one inventor or one assignee is located abroad, i.e. has listed another country than Norway as her country of residence.

Table 2.Volume and international connectivity. *Granted US patents involving actors in Norway by year of application, 1971-2015.*

PERIOD	NUMBER OF PATENTS	NUMBER OF INTERNATIONAL CONNECTED PATENTS	PERCENTAGE OF INTERNATIONAL CONNECTED PATENTS
1971-1975	190	35	18,4
1976-1980	516	81	15,7
1981-1985	546	108	19,8
1986-1990	697	167	24,0
1991-1995	935	278	29,7
1996-2000	1744	680	39,0
2001-2005	2422	1020	42,1
2006-2010	2665	1326	49,8
2011-2015	1771	1058	59,7
IN SUM	11486	4753	41,4

As the number of patents involving actors in Norway has increased steadily over time, the number of patents which have an international connection, has also increased. In fact, it has increased more rapidly, which means that the share of internationally connected patents also has risen over time, from 18.4 % in 1971-1975 to 59.7 % in 2011-2015. The internationalization envisaged in the share of patents with relations to at least one inventor or assignee located abroad, has been quite evident since the early 1980s, and it has been particularly strong over the last 20 years.

Growth and international connectivity by industry

In table 3, the number of patents and the percentage of international connected patents are listed by industry according to the industry classification of Hall, Jaffe and Trajtenberg (2001).

Patents are categorized into six patent classes[5], reflecting different industrial areas. These are patents in chemicals, computers & communication, drugs & medical, electrical & electronic, mechanical, and others. The number of granted patents applied for in 2011-2015 is presented in brackets as a significant share of the patents filed during this period are still under consideration. As pointed out earlier, we do not expect that this severely affects the share of internationally connected patents that finally will be recorded, which means that the share registered so far should be quite comparable with the recorded shares for the previous 5 year periods.

The computer & communication industry has experienced the most significant growth, and in particular since the mid-1990s, resembling the growth of information and communication technology around the world. The computer & communication industry is also the most internationally connected industry among the six. According to OECD reports, the information related industry in Norway holds some strong positions, with traction from commercialization, universities, public labs and government support (OECD, 2013, 2016).

On the other hand, the number of patents in the mechanical category has increased more slowly. Patens in the mechanical area also show a more limited involvement in international innovation networks, as reflected by the ratio of internationally connected patents.

It is nevertheless evident that there has been a growth in the number of awarded patents in all industries for every 5-year period from 1971 through 2005. For the industrial areas of computer & communication and of electric & electronic growth in the number of patents also continued in the following 5 year period, 2006-2010.

For all the industries there is also evident that the share of internationally connected patents is larger towards the end of the 1971-2015 period compared to what it was in the beginning. However, even though the share of internationally connected patents in general have increased for all industries, there is not a steady increase for every 5 year period for any of them.

[5] List of United States Patent Classification (USPC) class numbers and titles: https://www.uspto.gov/web/patents/classification/selectnumwithtitle.htm

Table 3. Number of patents and international connected patents in different industrial areas by year of application, 1971–2015

	CHEMICAL		COMPUTERS & COMMUNICATION		DRUGS & MEDICAL		ELECTRICAL & ELECTRONIC		MECHANICAL		OTHERS	
PERIOD	Number of patents	% international connected patents	Number of patents	% international connected patents	Number of patents	% international connected patents	Number of patents	% international connected patents	Number of patents	% international connected patents	Number of patents	% international connected patents
1971-1975	36	13,9	13	46,2	6	33,3	20	40,0	51	3,9	57	19,3
1976-1980	102	11,8	10	50,0	17	17,6	57	24,6	127	11,8	191	16,2
1981-1985	76	25,0	37	29,7	26	23,1	49	30,6	127	18,9	148	19,6
1986-1990	114	32,5	54	18,5	56	26,8	66	28,8	139	29,5	228	18,9
1991-1995	149	45,0	81	12,3	155	53,5	79	13,9	193	21,8	242	24,4
1996-2000	244	48,0	246	65,0	243	48,6	166	41,6	282	24,1	454	29,3
2001-2005	356	45,5	495	63,6	328	45,7	301	36,5	322	35,7	492	29,7
2006-2010	281	48,0	649	71,8	252	42,5	366	57,4	238	31,1	467	40,7
2011-2015	(64)	57,8	(207)	83,1	(60)	50,0	(130)	80,0	(52)	42,3	(111)	47,7

International dispersion of co-inventors

A patent assignee, which is granted the right to a patent, does not necessarily participate directly in the innovative activities leading up to something that may be patented. This means that the innovative activities may be conducted by inventors located in Norway, while the patent may be considered as internationally connected simply because these inventors work in a company that is owned by a foreign firm, which also is listed as (one of) the assignee(s) for the patent. This is not actually reflecting the magnitude of cross-border collaboration as part of the innovation process. To get a better understanding of to what extent internationalization is a matter for the innovative activities data should rather be on the networks of co-inventors that are involved in the process leading up to a patent. Then networks may be considered as international when the co-inventors in a patent reside in different countries, and it is more international the more equally inventors from different countries take part in this process.

US patents involving actors residing in Norway

In order to cultivate the innovative process as such, we measure the international connectivity of patents by calculating the international dispersion index following Hannigan et al. (2016) and Lee et al. (2016). This index focuses on the inventors in the patent. It is calculated as one minus the sum of the squares of the shares of inventors in each country over the total number of inventors listed on the focal patent. In other words:

$$\text{International dispersion} = 1 - \sum_{i=1}^{N} S_i^2$$

where S_i equals the share of inventors located in country i and N equals the number of countries where the inventors are located for each focal patent. Conceptually, this index captures how dispersed inventors are across countries. If all the inventors on a focal patent are located in a single country, the index will be 0. Inventors will be more dispersed as the dispersion index increases asymptotically towards 1.

In Table 4 the international dispersion index for is calculated for the inventors in US patents involving an assignee or an inventor residing in Norway. Calculations are done for each of the nine 5 year-periods between 1971 and 2015.

Table 4. International dispersion of co-inventors. *Granted US patents involving actors in Norway by year of application, 1971-2015.*

PERIOD	INTERNATIONAL DISPERSION
1971-1975	0,0317
1976-1980	0,0384
1981-1985	0,0424
1986-1990	0,0618
1991-1995	0,0776
1996-2000	0,1020
2001-2005	0,1041
2006-2010	0,1233
2011-2015	0,1391

It is rather evident that the international dispersion of inventors in the innovative activities leading to a US patent concerning Norway has increased over time. It has increased continuously for every 5 year period since 1971. This is presumably a general trend with growing internationalization of economic activities for the major firms of almost all countries around the world. It is also consistent with the findings of Picci (2010), who analyzed patent applications filed at any patent office in the European Union, in the United States and in Japan between 1990 and 2005. He documented that the degree of internationalization with respect to these patents had increased steadily since the early 1990s, but that the degree of internationalization still is rather low.

The international dispersion index we have calculated is the same as in Lee et.al. (2016) who investigated the connectivity to the global innovation system in four industries with reference to Denmark, Germany and Japan over the period 1975-2004. Except for the electronics industry in Denmark, they document the same trend of growing international dispersion in all the four industries for the three countries in question.

This trend is also evident in Table 5, listing the lowest and highest value on the international dispersion index for the four industries in each of the three countries for different time periods according to Lee et.al. (2016). However, as the figures on international dispersion of co-

inventors in US patents for Norway is not directly comparable to those for Denmark, Germany and Japan, it is harder to compare how the level of international dispersion differs between these countries. Still, comparing information in Table 5 on Norway with information for (almost) similar time periods in Table 6, it seems rather clear that the international dispersion index for Norway is significantly higher than what is revealed for Japan, and presumably at the same level as for patenting in Denmark and Germany.

Table 5. International dispersion of co-inventors in granted US patents for Denmark, Germany and Japan. *Highest and lowest in four industries by year of application, 1975-2004.*

	Denmark	Germany	Japan
1975-1984	0.008-0.055	0.010-0.040	0.001-0.013
1985-1994	0.050-0.091	0.027-0.081	0.003-0.022
1995-2004	0.061-0.150	0.052-0.151	0.006-0.038

Source: Extracted from Table IV, V and VI in Lee et.al (2016).

Thus, while the relative number of US patents was much lower for Norway than for all of these countries (cfr. Table 1), evidence suggests that the relative importance of internationally composed networks is of the same magnitude for innovative activities leading up to US patents in Norway, as in Denmark and Germany.

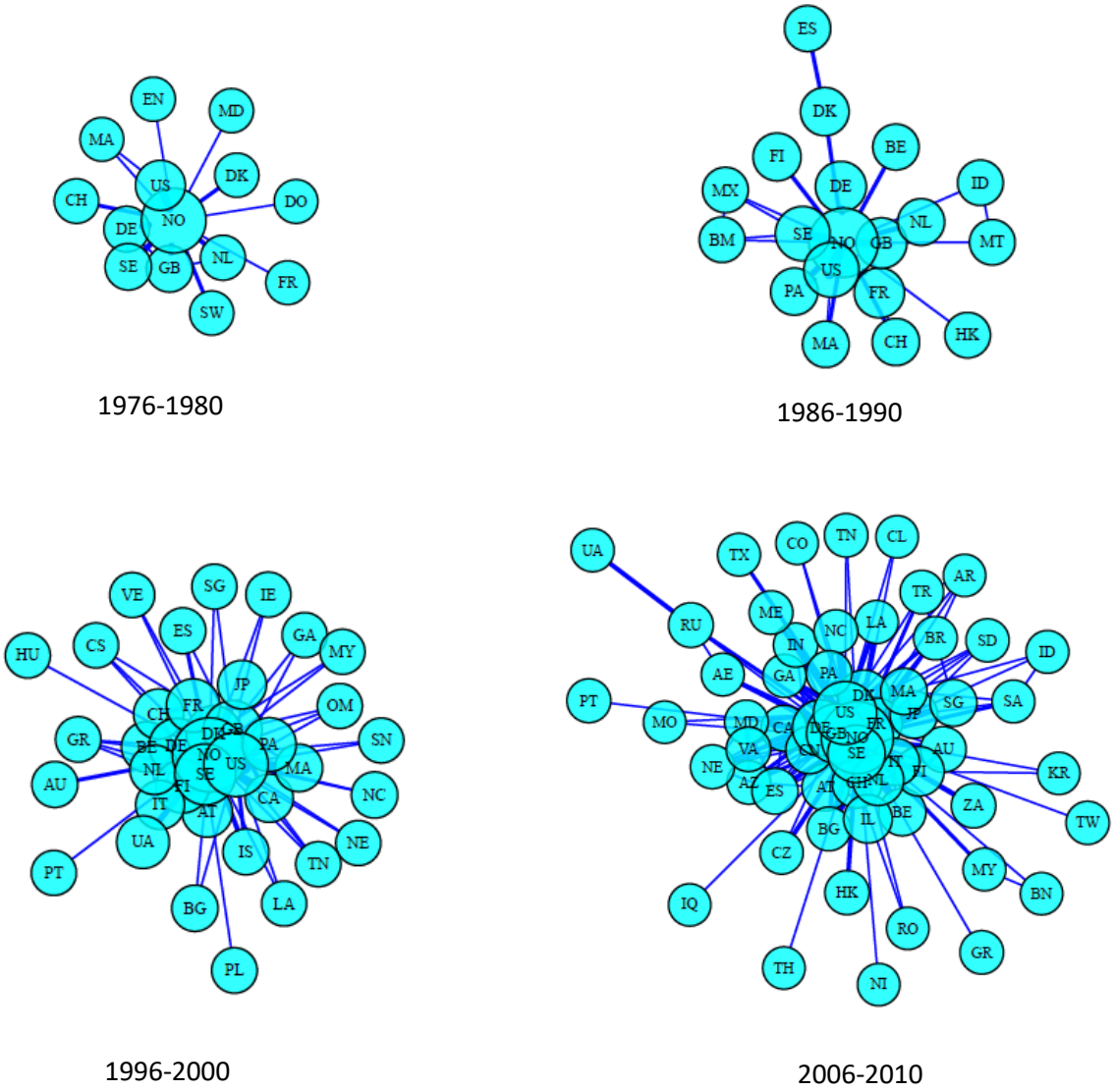
Expansion of international co-inventor networks

Since knowledge creation and innovation rely on a combination of local and global linkages (Lorenzen and Mudambi, 2013), we want to explore in greater detail what countries that actually are the location of foreign inventors which collaborate with inventors in Norway. We also want to explore to what extent the importance of such cross-border interactions have changed over time. Due to the general trend of internationalization, we expect that firms in their innovative activities increasingly have come to rely on both local and distant knowledge pools.

The geographic maps of inventors' distribution shed more light on how the knowledge connections emanating out of Norway directly link to knowledge centers and innovative capabilities in other countries. Figure 2 displays the global distribution of inventors contributing to Norway's US patents, covering the 5 year periods 1976-1980, 1986-1990, 1996-2000 and 2006-2010, which is the latest 5 year period where we have a complete picture.

Our analysis so far shows that innovative activities in Norway, as measured by the number of awarded US patents, have increased over the last four decades. We have also found that international connections and the international dispersion of co-inventors in patenting activity in Norway is growing. When it comes to international knowledge flows with regard to these patents, collaboration primarily takes place with colleagues in the US, and with British and Swedish inventors.

Figure 2. International network of inventors in Norway's US patents. *Granted patents filed 1976-1980, 1986-1990, 1996-2000 and 2006-2010.*



Each circle in the figure represents the location of foreign inventors by country. The size of the circle can be interpreted as the frequency inventors from that country is listed as one of the

inventors in patents where innovative capabilities in Norway are involved. The linkages among circles are built by the collaboration of innovation activities.

From the figure it is quite evident that innovative activities in Norway increasingly take place in international networks, where inventors interact across national borders. By 2006-2010 inventors in Norway had established linkages to inventors in more than 50 countries, which is an extensive growth comparing to the situation in 1976-1980 when there only were linkages to inventors in 13 countries.

The international connections to the US, UK and Sweden have in relative terms been quite significant throughout the whole period. As foreign inventors involved in Norway's US patents has increased in number, and also been located in many more countries, the international reach of innovative activities in Norway has expanded. When considering this for all the 5-year periods starting with 1971, as is shown in Appendix 2, broadening of international inventor networks started spilling over from the US, UK and Sweden from 1980s, with increasingly closer interrelations with inventors in other European countries as Germany, France and Denmark in the years to follow. The global reach of these networks is, however, still predominantly with a rather limited number of OECD countries.

Top patenting firms in Norway

Patenting activities are unevenly distributed among firms. Table 7 shows the 30 firms which most frequently are listed as the assignee in Norway's US patents. The firms are ranked according to the number of patents granted during the period 1971-2015. The top 30 assignees account for nearly 30% of Norway's US patents over this period.

As industrial restructuring is a never-ending process, firms' structure and the names of a firm are continuously subject to change. Mergers and acquisitions mean that firms that used to be independent entities throughout this period may have become an entity within a larger corporation. Thus, by the end of the period there are linkages between the assignees that are important to take into consideration, which mean that concentration of patent rights is higher than what is revealed with the individual firm data in Table 7. For instance, #3 WesternGeco is a company in the Schlumberger Corporation, listed as #5, and the General Electric Corporation

is represented by #6 Nycomed Imaging, #13 GE Healthcare, #17 General Electric Company, #27 Vetco Gray Scandinavia, #28 Amersham Health, and # 29 Baker Hughes Inc.

Table 7 also shows the assignee's country of residence and the share of internationally connected patents. There are 12 assignees with a foreign country of residence, while Norway is the country of residence for 18 of the Top 30 assignees.

Table 6. Top 30 assignees in Norway. *Country of residence, number of US patents and international dispersion. 1971-2015.*

No.	Patent assignee	Residence	Number of patents	International connected, %
1	Norsk Hydro	Norway	383	23.8
2	Statoil	Norway	304	12.2
3	WesternGeco	UK	249	100.0
4	PGS Geophysical	Norway	199	79.2
5	Schlumberger Technology Corp	France	173	100.0
6	Nycomed Imaging	Norway	163	58.9
7	Atmel Corp	US	130	100.0
8	LM Ericsson	Sweden	124	100.0
9	Cisco Technology	US	119	100.0
10	Elkem	Norway	113	21.2
11	Tandberg Data	Norway	96	4.2
12	Tandberg Telecom	Norway	93	39.8
13	GE Healthcare	Norway	89	41.6
14	Thin Film Electronics	Norway	82	91.4
15	Borealis Technology OY	Finland	82	100.0
16	Haliburton Energy Services	US	74	100.0
17	General Electric Company	US	71	100.0
18	Ekornes	Norway	66	0.0
19	Sinvent	Norway	64	7.8
20	Tomra Systems	Norway	60	6.7
21	ABB Research	Switzerland	59	100.0
22	Laerdal Medical	Norway	54	12.9
23	Arm Ltd	UK	50	100.0
24	Optoplan	Norway	49	0.0
25	Rottefella	Norway	49	8.2
26	Siemens	Germany	49	100.0
27	Vetco Gray Scandinavia	Norway	48	0.0
28	Amersham Health	Norway	47	66.0
29	Baker Hughes Inc	US	47	100.0
30	Kverneland Group	Norway	45	2.2

When an assignee is residing in another country than Norway, all the patents ascribed to this assignee are by definition classified as internationally connected. Thus, the international connectivity is 100% for all the 12 assignees with another country location than Norway. For the 18 assignees residing in Norway, the share of internationally connected patents vary between 0 and almost 80%. For 8 of them the share is less than 10%.

International dispersion in patents among the top patenting firms

As already mentioned, the measure of international connectivity does not really capture to what extent firms develop technology by establishing and engaging in international inventor networks. The international dispersion index of co-inventors is a more relevant measure in that respect. In Table 8 the top 30 assignees in Table 7 are ranked according to how they score on the international dispersion index. This index is calculated according to the countries of residence for the inventors in each patent for these assignees.

There are evidently significant differences between the firms with respect to the international composition of inventors behind the patents, for which they are the assignee. The estimated international dispersion index varies from assignees holding no patents with any international connection at all to indices suggesting rather extensive international collaboration.

The scores on the international dispersion index further suggests that the innovation processes leading to US patents differs between firms depending on whether the assignee of the patent is a firm registered abroad or in Norway. At least among the top assignees it seems quite evident that US patents involving inventors residing in Norway to a much larger extent are developed in international networks of inventors when the assignee is a foreign firm. The international dispersion index for the 12 foreign assignees ranges from 0.0486 to 0.3445 with an arithmetic average of 0.2192. For the 18 Norwegian assignees on the top 30 list this index ranges from 0 to 0.2282 with an arithmetic average of 0.0631.

Table 7. Top 30 assignees in Norway ranked according to international dispersion of co-inventors in their patents.

No.	Patent assignee	Residence	International dispersion
1	Schlumberger Technology Corp	France	0.3450
2	Haliburton Energy Services	US	0.3445
3	Baker Hughes Inc	US	0.3332
4	Borealis Technology OY	Finland	0.2917
5	General Electric Company	US	0.2428
6	Thin Film Electronics	Norway	0.2282
7	ABB Research	Switzerland	0.2235
8	Arm Ltd	UK	0.2161
9	WesternGeco	UK	0.1856
10	Atmel Corp	US	0.1690
11	Nycomed Imaging	Norway	0.1631
12	Amersham Health	Norway	0.1506
13	LM Ericsson	Sweden	0.1425
14	GE Healtcare	Norway	0.1378
15	PGS Geophysical	Norway	0.1146
16	Cisco Technology	US	0.0873
17	Tandberg Telecom	Norway	0.0597
18	Norsk Hydro	Norway	0.0566
19	Elkem	Norway	0.0541
20	Siemens	Germany	0.0486
21	Statoil	Norway	0.0464
22	Rottefella	Norway	0.0408
23	Laerdal Medical	Norway	0.0316
24	Sinvent	Norway	0.0228
25	Tandberg Data	Norway	0.0150
26	Tomra Systems	Norway	0.0148
27	Vetco Gray Scandinavia	Norway	0.0000
27	Ekornes	Norway	0.0000
27	Optoplan	Norway	0.0000
27	Kverneland Group	Norway	0.0000

It seems evident that patents relating to Norway with foreign assignees have more internationally dispersed co-inventor networks than patents with a Norwegian assignee. In fact, there is only one Norwegian assignee among the 10 highest ranking assignees according to the index on international dispersion of co-inventors with respect to their patents.

There are more frequent international collaboration in the innovative activities among foreign firms which engage in patenting in Norway. Furthermore, foreign firms may also tend to engage local inventors to perform the innovation activities in order to localize their products. We should, however, bear in mind that it is for such multinational corporations, Bergek and Bruzelius (2010) question the relevance of using patents with multiple inventors from different countries as an indicator of international R&D collaboration, simply because inventors are mobile across countries, which means they may keep their home country residence while working abroad.

Closing remarks

In this working paper we have examined the international connectivity of innovation activities in Norway based on the USPTO patent dataset. In line with previous research, we find that the level of patenting in Norway is low compared to what it is in other Nordic countries, both in absolute and relative terms. However, in terms of the international connectivity of innovation activities, our data indicates that patenting activities in Norway are more internationally dispersed than what is revealed with the similar indices at the industry level with regard to US patents of Japan, and at the similar level as in Germany and Denmark. This is in line with previous studies which find that internationalization of technology development tend to be higher in smaller countries (Guellec and de la Potterie, 2001).

Further, our analysis clearly shows that innovative activities and their international connectivity in Norway have increased steadily and rather significantly over the last four decades. When it comes to patenting we find that Norway throughout the whole period since 1971 has had the strongest knowledge linkages to the US. There are strong linkages to actors in UK and Sweden. Over time linkages have been extended to an increasing number of countries, first throughout Europe and later throughout the world. In the period of 2006-2010, inventors in Norway had established linkages to inventors in more than 50 countries, which is an extensive growth

compared to previous decades. Most of the collaboration is, however, with rather limited number of countries within the OECD area.

The level of international connectivity shows great variance in different industries. In the case of Norway, the computer & communication industry is the most internationally connected, while patenting in the mechanical area shows the least involvement in international innovation networks.

We also find that the international pattern with regard to the patenting activities are unevenly distributed between firms depending on whether a firm registered abroad or in Norway is registered as the assignee for the patent. Our data shows that when a foreign firm is listed as an assignee for a patent, the patenting process seems to involve more dispersed co-inventor networks internationally than patenting with a Norwegian assignee, even when this domestic assignee also is a multinational enterprise. It is a matter for future research to investigate the macro impacts of such differences further.

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Appendix 1: US patents by country of origin, 1991-2015.

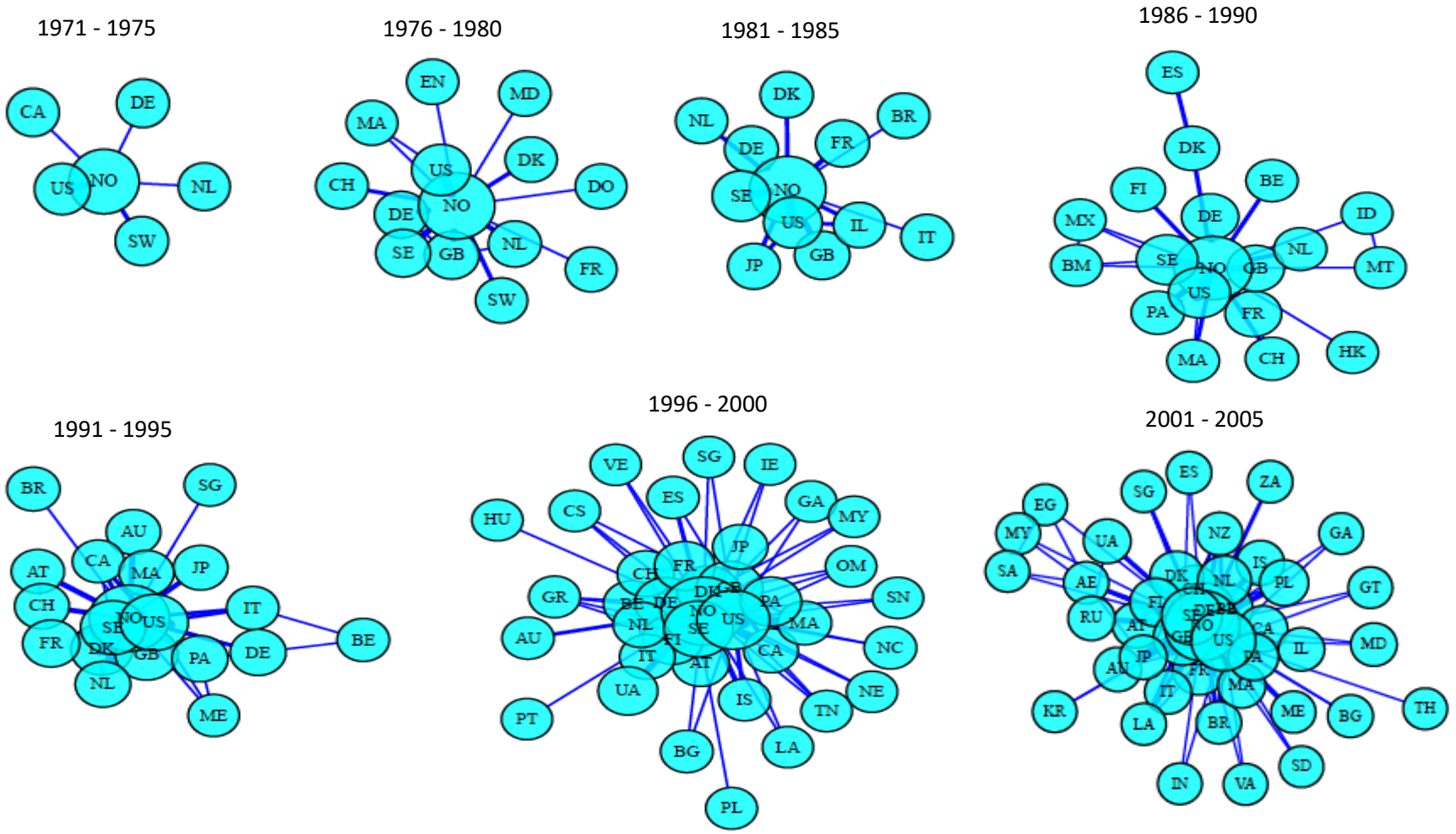
---- Technology Assessment and Forecast Report ----

ALL PATENTS, ALL TYPES REPORT — Page A1- 1

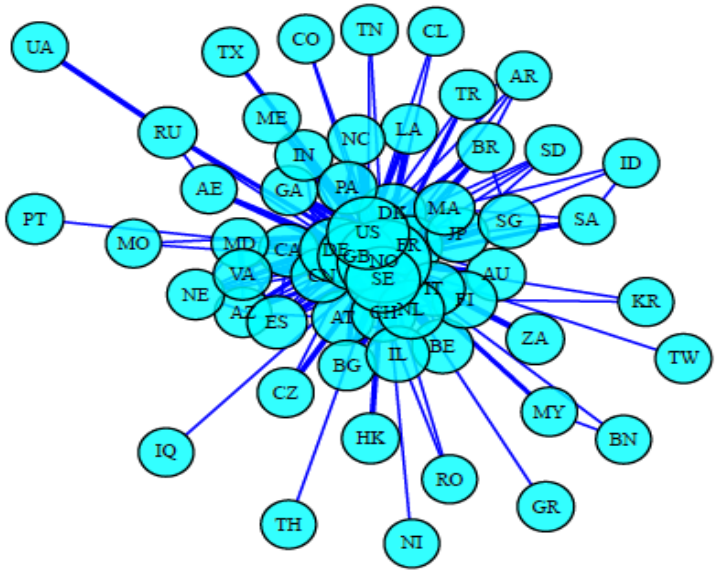
---- Patents Granted By Date Of Patent Grant (Granted: Jan 01, 1991 - Dec 31, 2015) ----

	NUMBER OF PATENTS															
	Pre 2002	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Total
Total	1490330	184424	187048	181319	157741	196437	182928	185244	191933	244358	247728	276796	302962	326038	325979	4681265
U.S. Origin	826450	97125	98590	94128	82586	102267	93690	92001	95038	121178	121257	134194	147666	158713	155982	2420865
Foreign Origin	663880	87299	88458	87191	75155	94170	89238	93243	96895	123180	126471	142602	155296	167325	169997	2260400
JAPAN	296057	36339	37248	37030	31833	39411	35941	36679	38066	46977	48256	52773	54170	56005	54422	901207
GERMANY	93250	11957	12140	11367	9575	10889	10012	10085	10352	13633	12967	15041	16605	17595	17752	273220
KOREA, SOUTH	21921	4009	4132	4671	4590	6509	7264	8730	9566	12508	13239	14168	15745	18161	20201	165414
TAIWAN	33471	6730	6676	7209	5995	7920	7491	7781	7781	9636	9907	11624	12118	12255	12575	159169
FRANCE	38616	4421	4126	3686	3106	3856	3720	3813	3805	5100	5023	5857	6555	7103	7026	105813
CANADA	32237	3857	3894	3781	3177	4094	3970	4125	4393	5513	5756	6459	7272	7692	7492	103712
UNITED KINGDOM	34951	4187	4024	3891	3551	4321	4027	3832	4004	5028	4908	5874	6551	7158	7167	103474
ITALY	17144	1962	2022	1946	1591	1899	1836	1916	1837	2254	2333	2546	2930	3033	3090	48339
CHINA, PEOPLE'S REPUB	971	390	424	596	565	968	1226	1851	2262	3301	3786	5335	6597	7921	9004	45197
NETHERLANDS	12348	1681	1570	1537	1200	1647	1596	1725	1558	1920	2048	2193	2571	2842	2788	39224
SWITZERLAND	14521	1532	1433	1405	1106	1388	1280	1403	1454	1889	1865	2039	2466	2601	2841	39223
SWEDEN	12514	1824	1629	1388	1189	1360	1278	1260	1231	1594	1863	2264	2431	2946	2862	37633
ISRAEL	6430	1108	1260	1092	976	1325	1219	1312	1525	1917	2108	2598	3152	3618	3804	33444
AUSTRALIA	7338	992	1049	1093	1032	1538	1545	1613	1550	2079	2215	1786	1924	2019	1917	29690
FINLAND	5426	856	944	954	751	1005	943	908	997	1232	1023	1138	1297	1465	1485	20424
BELGIUM	6027	801	727	678	577	720	624	605	707	896	958	1004	1148	1305	1225	18002
INDIA	748	267	356	376	403	506	578	672	720	1137	1259	1734	2474	3044	3415	17689
AUSTRIA	4668	559	639	575	492	626	554	575	767	905	927	987	1136	1281	1262	15953
DENMARK	4367	559	611	530	473	546	511	566	537	766	840	978	1109	1263	1190	14846
CHINA, HONG KONG S.A.	3482	589	681	642	596	755	765	738	595	718	658	745	756	818	793	13331
SINGAPORE	1255	421	460	485	377	469	451	450	493	633	696	841	857	1010	1048	9946
SPAIN	2469	358	358	312	318	381	363	418	403	492	565	728	772	857	912	9706
NORWAY	1968	261	279	255	242	272	286	297	292	448	412	474	520	601	687	7294
RUSSIAN FEDERATION	1173	203	203	173	154	176	193	181	204	287	307	339	432	447	483	4955
IRELAND	907	142	182	197	169	198	161	188	189	275	319	357	460	490	515	4749
NEW ZEALAND	1037	173	165	192	143	173	165	169	198	232	255	293	299	320	352	4166
BRAZIL	859	112	180	161	98	148	118	133	148	219	254	256	286	362	381	3715
SOUTH AFRICA	1300	123	131	115	108	127	116	124	139	142	144	158	181	181	199	3288
MALAYSIA	292	62	63	93	98	131	173	168	181	224	181	219	230	271	267	2653
MEXICO	695	105	93	102	95	88	90	77	80	115	117	153	204	222	203	2439
HUNGARY	594	48	72	52	48	49	55	72	48	98	111	113	141	170	158	1829
SAUDI ARABIA	122	10	19	15	18	20	20	31	23	58	61	173	239	294	364	1467
CZECH REPUBLIC	144	31	44	32	28	37	41	56	50	81	97	133	176	203	206	1359
ARGENTINA	419	58	70	50	29	47	53	42	50	59	51	67	80	81	72	1228
LUXEMBOURG	450	52	53	55	49	49	66	35	56	44	47	49	62	57	62	1186
POLAND	133	13	19	19	25	31	39	68	43	56	81	96	113	184	223	1143
Others (145)	3576	507	482	436	378	491	468	545	591	714	834	1010	1237	1450	1554	14273
Ownership:																
U.S. Corporations	648867	81109	82805	80000	70942	88182	81130	80981	84195	107344	108951	121377	135074	146859	144504	2062320
U.S. Government	12047	946	891	859	713	815	739	693	710	937	928	1003	1060	1034	1007	24382
U.S. Individuals	195514	17497	16900	15181	12785	15253	13771	13068	12703	16059	14873	16126	17362	17847	17868	412807
Foreign Corporations	562798	76855	78686	78571	67952	85844	81535	85164	89192	113766	117209	131785	142540	153223	155579	2020699
Foreign Government	3104	115	89	81	58	60	76	37	109	188	174	256	204	324	364	5239
Foreign Individuals	68000	7902	7677	6627	5291	6283	5677	5301	5024	6064	5593	6249	6722	6751	6657	155818

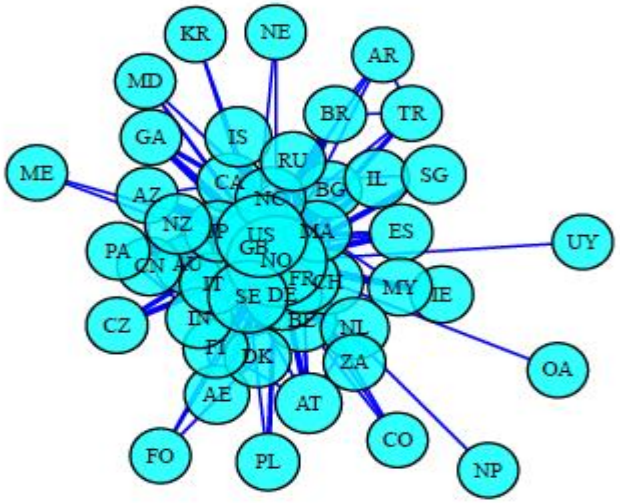
Appedix 2: International network of inventors in Norway's US patents. 5 year periods, 1971-2015.



2006 - 2010



2011 - 2015



Country codes

Country code	Country name	Country code	Country name	Country code	Country name
AE	Arab Emirates	**FI**	Finland	**NP**	Nepal
AT	Austria	**FR**	France	**NR**	Nauru
AU	Australia	**GB**	United Kingdom	**NZ**	New Zealand
BE	Belgium	**GR**	Greece	**OA**	African Intellectual Property Organization (OAPI)
BG	Bulgaria	**GT**	Guatemala	**OM**	Oman
BM	Bermuda	**HK**	China, Hong Kong S.A.R.	**PL**	Poland
BN	Brunei	**HU**	Hungary	**PT**	Portugal
BR	Brazil	**IE**	Ireland	**RO**	Romania
BS	Bahamas	**IL**	Israel	**RU**	Russian Federation
CA	Canada	**IN**	India	**SA**	Saudi Arabia
CH	Switzerland	**IQ**	Iraq	**SC**	Seychelles
CL	Chile	**IS**	Iceland	**SE**	Sweden
CN	China, Peoples Republic of	**IT**	Italy	**SG**	Singapore
CO	Colombia	**JP**	Japan	**SN**	Senegal
CS	Czechoslovakia	**KR**	South Korea	**TH**	Thailand
CY	Cyprus	**LT**	Lithuania	**TR**	Turkey
CZ	Czech Republic	**LU**	Luxembourg	**TW**	Taiwan
DE	Germany	**MN**	Mongolia	**UA**	Ukraine
DK	Denmark	**MX**	Mexico	**US**	United States of America
DO	Dominican Republic	**MY**	Malaysia	**UY**	Uruguay
EG	Egypt	**NL**	Netherlands	**VE**	Venezuela
ES	Spain	**NO**	Norway	**ZA**	South Africa

In this working paper we aim to investigate the international pattern of innovation in Norway as it is revealed in patent data from the United States Patent and Trademark Office (USPTO). The empirical section consists of four parts. We start by considering innovative activities in Norway in an international perspective, and continue by focusing on the growth in patents and their international connectedness as far as US patents involving actors residing in Norway are concerned. Then we investigate the development concerning the international dispersion of co-inventors in these patents and the distribution of co-inventors across countries. Finally, focus is on the top patenting firms in Norway and the international dispersion of co-inventors in their US patents.

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