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Eric J. Iversen

A patent share and citation analysis of knowledge bases and interactions in the Norwegian innovation system.

Eric J. Iversen
STEP
Storgaten 1
N-0155 Oslo
Norway

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Studies in technology, innovation and economic policy
Studier i teknologi, innovasjon og økonomisk politikk

Storgaten 1, N-0155 Oslo, Norway
Telephone +47 2247 7310
Fax: +47 2242 9533
Web: http://www.step.no/

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Preface

This article looks at the question of knowledge creation and distribution through the lens of patent-data. The purpose of this exercise is to provide a profile of Norwegian patenting activities as a proxy for knowledge-creation and knowledge-interaction in the Knowledge-System.

I wish to thank Aris Kaloudis (NIFU) for extensive assistance in assembling the data, and for helpful comments on analytical questions. Our co-authored work reflecting especially the citation-analysis of the present paper is to be found in a forthcoming book on the Norwegian innovation system.

The paper is a slightly revised version of a draft completed in the spring of 1998.

Oslo, December 1999

Eric J. Iversen

Abstract

This article was developed as part of a comprehensive project to 'map Norwegian knowledge bases' for the Norwegian Research Council; as such the use of patent-data complements other quantitative (CIS, bibliometric, input-output) as well as qualitative (industry-based case studies) approaches. In this context, Norwegian patenting in the US was used to proxy technical knowledge-creation while citations from these Norwegian patents were used to indicate interaction between knowledge-bases. The first section therefore consists of a straight-forward patent-share analysis in which Norwegian patenting (1990-1996) is indexed to the total population to suggest patterns of specialisation. Against this background, the knowledge-interaction section looks at two types of interaction. First it explores technological spillover as traced by first page patent-citations (by primary class). Secondly, it investigates technology-science links, as testified to by patent-citations to Non-patent-literature, mainly journals. In this way we measure dimensions of the main Norwegian knowledge bases as revealed by the patent-lens, as well as the strength of the main interactive links between such bases. In doing so it supplements the other sources investigated by this 'mapping project'.

Keywords: Innovation, Patent; Knowledge system; Innovation system; Norway

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Knowledge bases and interactions in the Norwegian innovation system: A patent share and citation analysis

Introduction

This article looks at the question of knowledge creation and distribution through the lens of patent-data. The purpose of this exercise is to provide a profile of Norwegian patenting activities as a proxy for knowledge-creation and knowledge-interaction in the Knowledge-System. The type of knowledge at issue here are mainly the *technical capabilities* that are manifested in inventions and which are made visible as 'utility patents'. We are interested in what technical areas Norwegian inventive agents demonstrate innovative technical competencies and how these competencies flow between such areas.

Data

Our analysis primarily utilizes the CNIDR database for first-page patents granted by the US Patent and Trademark Office (USPTO) for all levels of analysis. The focus is on patents that have at least one Norwegian address and that have been granted in the 80 month period between January 1990 and June 1996. Where appropriate, this period will be divided into a 48-month (1990-93) and a 30-month (1994-June 1996) tranche. In the main, utility patents[1] will be the unit of analysis, though in certain cases an aggregated set of design-patents will be introduced.

It is important to understand certain features about our unit of analysis, the patent. A patent is in effect a contract.[2] In general, the assignee(s) contract to reveal detailed information about their invention in return for conditional monopoly protection over that invention. This fundamental contractual relationship caters to the assignee(s)' basic desire to appropriate profits accruing to the invention and the system's basic

[1] In the US Patent system, there is a distinction between utility, design and plant patents. Utility patents can be granted for the novel and functional aspects of manufactured goods while design patents can be granted for their novel and ornamental aspects.

[2] Cf. Barré/Leville's discussion.(1995)

desire to have the details of the invention spread to others so that the system can build on new knowledge[3]. In this sense, the patent-system acts as an incentive-mechanism for the creation of new economically valuable knowledge and as a knowledge-distribution mechanism. As such it is a central element of the knowledge-infrastructure[4] that underlies the innovation system.

In line with the patent-system's role as a knowledge distribution-mechanism, the text of the patent-contract provides detailed technical information that is of interest for technicians working in the field, as well as other details that are of interest to those studying innovation systems. It is the latter type of information that we are concerned with. On the first page of a US patent, this information typically includes, among other details:

- the specifics about assignees/inventors; addresses provide can be used to identify agents of the Norwegian system;
- a detailed classification as to the technical field(s) to which the patent claims novelty (refer to a footnote, placed in the first paragraph, about other aspects of the contract);
- and a list of citations to other documents, including other patents and scientific literature. These citations are intended to establish the originality of the invention, and serve to identify the area8(s) of the technical art that it builds on (cf. the idea inherent in the patent system that knowledge builds on previous knowledge) and differentiates itself from these antecedents.

Approach and Issues

Our analysis uses this first page information to address our two central questions. In the three sections of this article, we will be using different facets of patent data to tell us about two integral processes in a knowledge-system: where technical knowledge is created and what interaction of areas of knowledge (both scientific and technical)

[3] For a seminal discussion of patents as a approrpiation/distribution regime see Arrow (1962). Note that a basic premise of the incentive aspect is based on assuring the inventor a chance to recoup the cost of his R&D investment. There are many other aspects of this contract, for example the criterion of novelty, non-obviousness as well as the payment of fees which are ignored in the for the moment.

[4] cf. Tassey (1991).

are involved. The first two types of information listed are employed in exploring the question of the creation of economically valuable knowledge by agents of the Norwegian system while the third category is used to address the question of this activities linkages to other bases for knowledge.

The three levels of empirical analysis are presented in three sections:

Section 1: Broad analysis of Norwegian patenting-activity: Description of the distribution of Norwegian patent-activity in the US, by technical field.

Section 2: Analysis of Norwegian patent-holders: Identification and description of the main Norwegian recipients of patents in the US, by technical field.

Section 3: Analysis of knowledge interactions: Identification and description of citations made by Norwegian patents (i.) to other patents and (ii.) to periodicals.

Our analysis bridges two traditions in the analysis of patent-data. To look at the question of knowledge creation we conduct a **patent-share analysis**, which will help identify important agents and technical areas of Norwegian inventive activity. To survey possible interactions between these areas, we also conduct a **patent-citation analysis.** These traditions build on the common idea that patents form an important if not unproblematic source of information about technical innovation.

Features of the Patent-lens

Our lens is patent-data, specifically patents that have been granted in the US to Norwegian agents in a reference period (1990-96). It is important always to bear in mind the inherent obscuring and magnifying qualities of this lens; we do not pretend to give a complete and accurate picture of the composition of the systemic "Norwegian knowledge base". As we will repeatedly emphasize, we map only those Norwegian knowledge bases that make themselves visible through patent-activity and, more specifically, only those that make themselves visible by patenting in the United States. A knowledge base in Norway must therefore pass a fairly stringent, partially sector-biased test to be noticed at all. The premise is that the knowledge bases this analysis reflects represent a robust, though not comprehensive set of mature areas in the Norwegian economy. In this, it is intended that this quantitative analysis will supplement and reinforce the other approaches in the mapping project, both quantitative (e.g. the related bibliometric analysis) as well as the more qualitative sections (e.g. the knowledge base studies).

Though we attempt to avoid the difficulties of using patent-data, we must inevitably say something about the inherent obscuring and magnifying qualities of this analytic lens. Without going into the discussion of the bias of patent-data[5], it should be recognized that not all technologies are patentable (i.e. certain types of software, though this is changing especially in the US) and not all inventive agents wish to patent their technologies. The propensity to patent in fact can in a significant way be;

- ♦ country-specific, where institutional and cultural conditions can influence if and how agents patent;
- ♦ actor specific, where the individual strategies and knowledge of the potential patent-applicant will influence his decision;
- ♦ and most systematically, sector-specific, where the cost structures of different industries will strongly condition the propensity to patent.

In addition, one has to consider the propensity of foreign nationals to patent in the US. In general, use of US patent activity is a tried and fairly true proxy for measuring a country's patenting activity. It is claimed that, "each country has the same propensity to patent in the USA in relation to the size of its innovative activities."[6] The main advantages include:

Patent granted in the US provide a comparable standard that corrects for institutional peculiarities found in different countries;

1. The US is the world's largest market. Therefore patents granted in the US pass a test not only of novelty but also of commercial viability. A sort of peer review

2. Patenting in the US involves relatively inexpensive processing charges and therefore does not necessarily exclude SMEs with viable patents.

There are some disadvantages that should be borne in mind:

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[5] Cf for a full discussion, see eg. Basberg (1984).

[6] Pavitt & Soete, 1980.

1. US patent-grants exhibit a time-lag of 3-9 years after application in addition to a lag after first priority. In the Norwegian case this is generally about a year. (cf. Basberg)

2. Patenting in the US assumes a certain international presence for the assignee, which can yield an over-representation of larger corporations (though this is not necessarily the case)

3. And, patenting in the US is susceptible to independent variables, such as export and macro-economic conditions[7].

1. Patent-share analysis

In the first area of analysis, patent-data is assembled for the period (January, 1990 to June, 1996) to reveal patterns in Norwegian patenting. We are especially interested in the distribution of Norwegian patents according to primary-class designation; their distribution according to industrial classification; as well as a sector-based analysis of the dominant Norwegian patent-assignees. In method, this analysis falls within the growing tradition of patent-count/patent share analysis, which avoids the often Procrustean exercise of using patent data as an indicator for the fleeting entities of technological change or 'innovation performance'.[8]

Instead, patent-data is presented to say something about patent-activity as such. This is because patent-activity is assumed to belie highly developed competencies at the level of assignee.

A patent that is granted has passed a rigorous test of novelty vis-à-vis the state-of-the-art in the relevant field such that a granted patent acts as proof-positive to the existence of knowledge bases. A granted patent not only demonstrates a working

[7] Basberg (1984) points out that, as indicated in Pavitt and Soete's (1980) analysis, exports to the US have historically not significantly influenced Norwegian patent-grants in the US. Sector R&D intensity and macro-economic conditions on the other hand have.

[8] For the difficulties and direction of such approaches; cf. Basberg (1988); and Archibugi/Pianti: (1996).

command of the state-of-the-art in a particular field[9] but (in cases where assignee is the site of development as well) also the ability to develop the field further.

The primary and secondary patent classifications in which Norwegian patents are granted are mapped in two stages to locate the technical competencies that are made visible in patent-data. In the first stage, the set of primary classes (US system), or the class that defines the principle content of the invention, is used to indicate the absolute rate and sector distribution of Norwegian patenting activity in our time-period. In the second stage, the secondary patent classes are used and the Norwegian production is seen in relative terms to the total population of patents granted in the US in a given year. Secondary classes, as will be seen, are assigned in many cases to specify other technical areas in which the invention's novelty claims relevance. This extended field of relevance indicates in certain measures both something about the research and development that went into the invention and/or something about where the invention might be used. Therefore, it gives us an extended idea of the knowledge bases that are important to Norwegian patentees. Further, this step from primary classes (principal knowledge bases) to secondary (ancillary knowledge bases) will lay the stepping stone to the subsequent section on knowledge-spillovers. In that section, we will extend the picture to explore the patent-classes that Norwegian grants cite as relevant knowledge bases.

1.1. Dominant agents.

Norwegian patenting in the US is dominated by a small concentration of actors. In this section, we explore the primary patent-grant data to identify important nodes in the network of Norwegian patent activity and to indicate in which technical areas the patenting behavior of these prominent agents is concentrated. (cf. Aris: Co-authorship of articles) The question of what degree this concentration influences the larger Norwegian profile will also be explored.

This section is based on a quantitative analysis of the number of patents in the US with Norwegian assignees as they are distributed in different branches. In cases

[9] This includes the cases of patent-assignees who do not develop the technology embodied in a particular pantent themselves, but acquire it from outside itself through another means.

where there are a number of assignees with Norwegian addresses, only the primary assignee is chosen. In cases where several co-assignees have different addresses, the one with a Norwegian address is used even when it is a secondary assignee. In this matrix, the names of Norwegian patent assignees in the US (90-94) will be included as will the respective number of their patents and their classification numbers. A further analysis of this list is important in providing a more general picture of patent distribution between industry fields.

1.1.1. Propensity to patent: large vs. small patentees

The size of the patentee is the first factor we will consider which influences the propensity to patent. A common assumption is that it is the largest entities, especially corporations, which patent most. This assumption is however not necessarily correct, when one looks at the total population of patent grants in the US.[10] At this level, it has been established that it is SMEs and not necessarily large companies that show the greatest patent intensities, though the margins are not large.[11]

These results are mainly based on all patenting activity in the US and thus principally reflect the activity of US SMEs. The case appears to be different for foreign patentees. In focusing on a small country's foreign patent-portfolio---especially one that reflects an apparent reluctance to patent in the US---we might expect to find a greater concentration in the size of firms. The chief reason for this is that foreign patenting entails that the assignee is large enough to command a certain presence in the US, either actively on the market or remotely. In the latter case, for ex. a licensing strategy, the firm has to have at least a large enough presence in the US to enforce encroachment on its patents.

A survey carried out in Norway in 1992 suggests that both very small and very large innovative companies indicate a greater than average propensity to apply for patents

[10] Results of this long-standing discussion have been mixed. Cf Scherer (1965,1984, 1991); Kamien/Schwarz (); Cohen (1987), Pavitt (1987) et alii for some important anchor-points.
[11] See eg- Scherer (1985) or Levin et al. (1987)

in general.[12] In looking at the absolute number of patent-grants in the US, however, it is generally the largest corporations that are registered.

Table 1.1: Dominant Norwegian assignees in the US in two periods; 1990-1993 and 1994 to June 1996

n	[illegible]	[illegible]		[illegible]		[illegible]		
	Grand Total	355	100,00%	279	100,00%	634	100,00%	
1	NORSK HYDRO A/S KONSERNET	61	17,18%	39	13,98%	100	15,77%	energy, aluminum chemicals, engineering
2	STATOIL A/S	30	8,45%	23	8,24%	53	8,36%	petroleum, petro-chemicals
3	TANDBERG DATA A/S	11	3,10%	30	10,75%	41	6,47%	computers,
4	HAFSLUND NYCOMED A/S KONSERNET	10	2,82%	27	9,68%	37	5,84%	pharmaceuticals, medical imaging
5	ELKEM A/S KONSERN	26	7,32%	3	1,08%	29	4,57%	Aluminum
6	GECO A/S KONSERNET	15	4,23%	8	2,87%	23	3,63%	seismology: seismic measurement software
7	KVÆRNER A/S KONSERNET	10	2,82%	12	4,30%	22	3,47%	wharf/shipping, petroleum, engineering
8	AKER A/S KONSERN	12	3,38%	1	0,36%	13	2,05%	engineering, concrete, oil rigs
9	KVERNELAND A/S	7	1,97%	4	1,43%	11	1,74%	
10	DYNO INDUSTRIER A/S	4	1,13%	6	2,15%	10	1,58%	explosives, chemicals, plastics
11	TOMRA SYSTEMS A/S	4	1,13%	4	1,43%	8	1,26%	production of bottle-return machines
12	ALCATEL KONSERNET NORWAY	4	1,13%	3	1,08%	7	1,10%	ICT, cables
13	NOPAPP INDUSTRIER	3	0,85%	4	1,43%	7	1,10%	Pulp, paper
14	FORSVARETS FORSKNINGSINSTITUTT	3	0,85%	3	1,08%	6	0,95%	military research
15	ROTTEFELLA A/S	2	0,56%	4	1,43%	6	0,95%	ski equipment
16	VINGMED HOLDING A/S	2	0,56%	4	1,43%	6	0,95%	medical technical equipment
17	SINVENT A/S	1	0,28%	4	1,43%	5	0,79%	
18	TRIOVING A/S	3	0,85%	2	0,72%	5	0,79%	Security equipment
		208	58,59%	181	64,87%	389	61,36%	

In our period, the 634 utility and design patents that were assigned in the US to Norwegians (at least one assignee with a Norwegian address) were granted to 192 patent-assignees. (unified up to the level of the corporation) Of these, 18 account for 63% of all patents while the top 8 dominant actors received 50% of these grants. By and large, these dominant 18 assignees are large entities, even by international standards, with considerable export markets in the US. This certainly pertains to the top ten whose activities such as industrial chemicals, data storage and Electro-metallurgy correspond with Norway's most important export sectors.[13] However, a closer analysis needs to be carried out before any conclusions on the size to patent-grant relationship can be drawn.

[12] Community Innovation Survey, 1992. Those that reported that patenting is very important or decisive to their innovations. Analysed first in Nås et al (1994). Scaled-data presented in V&T 1997.

[13] The third, forth and six largest exports to the US after oil. See Statistics Canada: Note however Basberg's finding, listed above, that US export markets do not constitute an active variable for Norwegian patenting-activity.

Significantly, all but one of these assignees are corporations: the only pure exception is a government military research institute (#14). In addition, SINVENT is a company that manages patents that come from a quasi-academic setting.(SINTEF) The top 8 include the largest Norwegian multinational corporations, including the state-owned petroleum concern, Statoil. Mechanical engineering, including oil-rigs, metallurgy, computers, pharmaceuticals and bulk-chemicals, scientific instruments and energy figure prominently in the activities[14] of these eight actors.

1.2. Dimensioning Norwegian knowledge bases with patent-data

The second section of the patent-count analyzes the way Norwegian patent-grants breakdown into different ‘technological fields; their rates over time and their distribution. The idea of technological field will be explored using different classification systems (US primary main-class, IPO primary main class, ISIC industrial classifications) and at a different level (including US secondary classes) for descriptive power. This will give a snapshot of total Norwegian patent-production.

An initial look at the size and distribution of patents granted in the US to Norwegians for the period 1990- (June) 1996 reveals a relatively small and concentrated set of patenting activity. This concentration raises the question of whether a pattern of sector specificity can be found in the Norwegian patenting activity. If so, identifying these would help isolate of important knowledge bases. In the following, we examine the profile of this activity by looking at the most prominent 25 classes found in Norwegian patent-grants.

On the issue of sample size, the constellation of Norwegian grants is indeed dwarfed within the total universe of all US patent grants. In a given year (1993), the Norwegian sample, including design patents[15], accounted for about a tenth of a percent of the 98,384 patents granted in that year. The reason for this apparent paucity of patent activity---which incidentally is also found historically even in comparison with other small economies (see Basberg)--- does raise interesting issues,

[14] The desciptions of industry are taken from the catalog , Norges største bedrifter. 1996

[15] Patents involving novel and ornamental inventions for manufacturing industry. Again, our focus is on non-ornamental, utility patents.

for example about whether there is a structural reluctance to patent on a national level[16]. This is however not at issue in this survey.

In mapping the absolute dimensions of the Norwegian patent-activity as positive evidence of the existence of aggregate knowledge bases we see an averaged patent-grant rate of about 7.9 patents per month over the 80 month period in question (when design-patents are included: or 7.5 without). If the data is divided into two periods 1990-3 and 1994-June 1996, a marked--but not necessarily significant--gain is seen, from 7.4 to 9.1 per month (or 7/month to 8.8 without). However, it should be noted that these rates are not necessarily meaningful, as they can reflect more about the Patent Office’s processing abilities than about Norwegian knowledge creation.

More interesting is the question of the orientation of these patents over longer periods of time. The distribution of the primary classes of these patents according to US patent class is indeed quite skewed, indicating a sector-specificity in Norwegian patenting activity. A set of 25 dominant classes, or about 16% of the 160 main-classes in which Norwegian patents are classed as primary, account for 50% of all Norwegian grants. This is our first indication that there exists identifiable patent-sensitive knowledge bases, an impression that we will see reinforced when looking back in time and when looking at the secondary patent-data. In the table below the profile of these numerically dominant main-classes is ranked for the period as a whole.

[16] The argument has run that there is indeed a reluctance and that this is related to ignorance among Norwegian innovators. Cf. Iversen. Referat (May 1995). cf Nås et al. 4/94 for a survey-based description of Norwegian preferences among a variety of appropriability mechanisms.

Table 1.2: Primary class distribution of Norwegian utility-patent grants in the US for 1990-June 1996: the most prevalent 25 primary main-classes.

	W ! n2 cl 22: n2-cl 22 i!ils	ao-3: [illegible]	ao-a3 2J s	a - a [illegible]	a -a 2J s	loi l ao-a	
	Grand Total	355	100.0%	279	100.00%	634	100.00%
1	424: DRUG, BIOAFFECTING AND BODY TREATING COMPOSITIONS	10	2.82%	19	6.8%	29	4.6%
2	405: HYDRAULIC AND EARTH ENGINEERING	21	5.9%	3	1.1%	24	3.8%
3	114: SHIPS	9	2.5%	14	5.0%	23	3.6%
4	367: COMMUNICATIONS, ELECTRICAL: ACOUSTIC WAVE SYSTEMS/DEVICES	17	4.8%	6	2.2%	23	3.6%
5	360: DYNAMIC MAGNETIC INFORMATION TECH	-	0.00%	19	6.8%	19	3.0%
6	166: WELLS	9	2.5%	9	3.2%	18	2.8%
7	514: DRUG, BIOAFFECTING AND BODY TREATING COMPOSITIONS	9	2.5%	6	2.2%	15	2.4%
8	423: CHEMISTRY OF INORGANIC COMPOUNDS	11	3.1%	3	1.1%	14	2.2%
9	137: FLUID HANDLING	9	2.5%	4	1.4%	13	2.1%
10	128: SURGERY	5	1.4%	7	2.5%	12	1.9%
11	75: SPECIALIZED METALLURGICAL PROCESSES, COMPOSITIONS	9	2.5%	3	1.1%	12	1.9%
12	204: CHEMISTRY: ELECTRICAL AND WAVE ENERGY	10	2.8%	1	0.4%	11	1.7%
13	435: CHEMISTRY: MOLECULAR BIOLOGY AND MICROBIOLOGY	5	1.4%	6	2.2%	11	1.7%
14	210: LIQUID PURIFICATION OR SEPARATION	7	1.9%	2	0.7%	9	1.4%
15	175: BORING OR PENETRATING THE EARTH	2	0.6%	6	2.2%	8	1.3%
16	414: MATERIAL OR ARTICLE HANDLING	5	1.4%	3	1.1%	8	1.3%
17	441: BUOYS, RAFTS, AND AQUATIC DEVICES	-	0.0%	8	2.9%	8	1.3%
18	52: STATIC STRUCTURES (E.G., BUILDINGS)	7	2.0%	1	0.4%	8	1.3%
19	73: MEASURING AND TESTING	3	0-.9%	5	1.8%	8	1.3%
20	219: ELECTRIC HEATING	4	1.1%	3	1.1%	7	1.1%
21	250: RADIANT ENERGY	5	1.4%	2	0.7%	7	1.1%
22	297: CHAIRS AND SEATS	5	1.4%	2	0.7%	7	1.1%
23	417: PUMPS	6	1.7%	1	0.4%	7	1.1%
24	53: PACKAGE MAKING	3	0.9%	4	1.4%	7	1.1%
25	60: POWER PLANTS	4	1.1%	3	1.1%	7	1.1%
	TOTAL	175	49.3%	140	50.2%	315	49.7%

1.2.1. Profiles of sector specialization: sector outlines

A preliminary, rough grouping reveals 5 broad activity-characteristics. These groups form a first impression of the industrial knowledge bases involved and their accuracy will be refined in presentation of the controlled industrial classifications below. In addition, the reader is referred to the knowledge base chapters of the Mapping-project book for greater focus.

1. *Engineering*: 119 patents (10 top-rankings: 1-3, 6, 15-9, 23-4). This populous group is indeed heterogeneous. It embraces mechanical activities such as; construction, including prominently offshore oil-rigs and oil-well activity, which correspond to the maturing petroleum activity in the Norwegian Sea[17]; ship-building and maritime equipment, a traditional Norwegian industrial activity; as well as technical and scientific instruments which may be better placed in the

[17] Cf. the Chapter on Petroleum-sector knowledge base.

second, third or fourth grouping. There are some signs that patenting in certain sectors of this group has dropped off in this period, indicating a potential maturation of the technology-potential of these areas. Breaking the set into two time periods, a marked decline is seen in percentages for pumps, static-structures and in the second most populous patent main-class and a traditional area of Norwegian patenting activity in the US, hydraulic and earth engineering. These apparently obsolescent areas include some traditional areas of engineering as well as some oil-industrial applications. Other areas of the former, e.g. ships and marine applications, however show growth as do some areas of the latter, e.g. boring, while others show stability, e.g. wells. It should be noted however, that because of the disappearingly small numbers in several cases, these figures are vulnerable to random variable conditions and should not necessarily be interpreted as strictly significant changes.

2. *Chemical/metallurgy and pharmaceuticals*: 101 patents (7 top-rankings: 1,7-8, 11-14). This second most populous group includes a meld of bulk-chemicals, metallurgy and pharmaceuticals. The first and second cases reflect other industries that are well developed and which have fairly long traditions in Norway. On the other hand, pharmaceuticals, itself a varied field, is an industry in a period of great innovation with robust representation by Norwegian firms. Looking tentatively at the apparent shift in grants over time, this characterization seems to be fairly well, though not unilaterally supported by the patenting activity. There is significant growth in certain areas of drugs, launching class 424 to the top of the list. In addition, there is a moderate advance of molecular biology in 435, but a slacking in another set of drug technologies in 514. In the more traditional chemicals and metallurgy area, which have strong borders with our groupings of engineering and energy, the indications are more resounding. Indications are that patenting activity is in decline across the board, in inorganic compounds, electrical chemistry (cf. Energy) and metallurgical processes.

3. *Information and Communication Technologies*: 42 patents (2 top rankings: 4-5) The ICT is also an industry undergoing a strong period of general innovation in which Norwegian actors have been relatively active. The clearest signal of the advent of the computer age is dynamic magnetic information technology, which

goes from not being on the chart in the first period to tying for first place in the second. Not everything is in growth on this front, however. The decline of analogue technologies seems to be indicated in the marked decline in electrical communications.

4. *Energy*: 34 patents (4 top-rankings: 9,19-20, 24) Sharing borders with the first two groups, Energy is an industry with a long history, especially in hydro-electric generation. There seems to be a certain stability in the relative percentages of these patent-activities, though the problem of too few data-points is especially keen here.

5. *Miscellaneous*: 15 patents. This final group includes consumer and medical products. In the latter case, medical products (e.g. bandaging) should be treated together with sections of scientific instruments which are classified under engineering. The presence of furniture products is indeed consonant with the impression of the Nordic design industry, though it should be noted that purely design-patents are not among the patents here. On the other hand, if the aggregate set of design patents were included here, an additional 31 dissimilar design patents would be included bringing this category to this list's top. This population of design patents incidentally diminished significantly across the period. (cf. above)

1.2.2. Historical perspective

This rudimentary presentation indicates some outlines of the types of knowledge bases that the lens of patent data is able to pick up in the Norwegian case. The impression is that of a fairly stable structure. However, there are signs that some newer growth technologies seem to be asserting themselves (ICT and certain segments of the pharmaceutical patents) in this structure while some of the more mature technological areas (segments of the mechanical engineering and chemicals branches) seem to decline. It should be noted that, this lens tends to magnify emerging technologies (for reasons of appropriability) in general and pharmaceuticals (for reasons of market-structure) in particular. The question of variable tendencies of different sectors to patent is important.

The time-series above however is too slight to give a reliable and robust picture for such tendencies. In the following table, the comparable ranking of Norwegian grants is shown for the 19-year period, 1962-1980. The first thing to notice is that the general patent intensity for Norwegian assignees has significantly increased, if patents granted is any measure. (see above) However, for the 17 most patent intense classes from 1962-1980 the rate of patent-grants per-month has in fact decreased in absolute terms. In 1962-1980 there were about 2 patents per-month granted in these classes while, for 1990-1996, this rate had decreased slightly, to a level of 1.8 per month.

If one concentrates on the 17 most intensive patent classes for the later period however, the rate has risen by almost 60% in absolute terms to an average of over 3 patents a month. However, it should be noted when making such comparisons that the certain institutional changes in the USPTO making a stringent comparison of these two time-sets impossible. Among other changes, certain classes have either ceased to be, been moved (cf. Class 13) or been added. In addition a major reform in 1976 makes comparison difficult.

Table 1.3:Historical comparison of the most frequently patented classes for Norwegian assignees: 1962-1980 and 1990-June, 1996

1962-1980		1962-1980	1990-June1996		Change in relative rates
RANK	Main US-Class number and Class Title	# of Patents	RANK	# of Patents	(pat/month)
[illegible]	[illegible]				58,89%
	[illegible]	38	3	3	68,29%
3	[illegible]	33	[illegible]	8	-32,59%
- -	[illegible]	33	[illegible]	[illegible]	-7,32%
2	[illegible]	3	[illegible]	8	-30,49%
6	280 LAND VEHICLES	31	28	6	-46,18%
7	264 PLASTIC AND NONMETALLIC ARTICLE SHAPING	29	57	3	-71,24%
8	[illegible]	i	[illegible]	[illegible]	23,58%
a	[illegible]	2	[illegible]	8	-11,02%
[illegible]	[illegible]		[illegible]	a	4,27%
[illegible]	[illegible]		8	[illegible]	76,94%
12	13: (373): ELECTRICAL FURNACES	22	76	2	-74,72%
[illegible]	[illegible]	o	a	[illegible]	80,73%
14--	102: AMMUNITION AND EXPLOSIVES	20	76	2	-72,20%
15--	248: SUPPORTS	17	71	2	-67,29%
16--	425: PLASTIC ARTICLE OR EARTHEN-WARE SHAPING OR TREATING	17	36		-67,29%
17--	156: ADHESIVE BONDING AND MISC. CHEMICAL MANUFACTURE	16	63		-47,87%
TOTAL		448		150	-6,90%

Based on OTAF, Patenting in the US by Residents of Norway, Special Report, Wash. DC: (1981): Found in Basberg (1984), p 197.

Notwithstanding, there seems to be a certain relative stability in the composition of the dominant patent-classes for the two periods. Notice first that ten classes that are found in the top 17 main classes of 1962-1980 remain in the top 25 for 1990-96. These are indicated in bold type, with their ranks and relative frequencies showing how they have changed positions. In particular, we notice that the first two classes listed have maintained their prominent position, though pole position in the newer time-period has been ceded to main-class 424 pharmaceuticals, which is not even found among the top classes in the older period.

If these classes' individual patent grant-per-month scores are measured, they remain relatively stable as a group but with large individual variations. The classes with asterices attached indicate those classes whose relative intensities have in fact increased through these two aggregated periods: two asterices indicate significant relative increases in the number of patents granted monthly in each of the classes.

This data provides a concept of the relative changes in Norwegian patenting. In reading it, the general increase of patenting activity mentioned above (60% as measured by the top 17 classes for each period) should be kept in mind. Among the classes seeing greatest individual increases, we discover several of the traditional areas of the engineering, chemicals and energy groups which we suggested were stagnating or decreasing in the periodization of 1990-3 and 1994-96. Especially, the intensity of metallurgical processes, inorganic chemistry and (from a lower base) fluid handling have improved significantly over time. Otherwise, the patenting intensities for the classes that were dominant in 1962-1980 testify to degree of decline of these classes that dropped out of the dominant class.

1.2.3. General propensity to patent, by sector.

The relationships that were indicated above between patent-activity and their prime industrial sponsorship is refined in this section. In the following table, the primary IPC classes listed in the US patent document are used to make the conversion to ISIC industrial classes[18]. All 603 patents(the 31 anomalous design patents are removed

[18] The MERIT concordance table (Verspagen, et al., 1994) is used to move between the International Patent Convention (IPC) classifications listed in the US patents and ISIC 2. Industrial Sectors. The correspondence, where dubious is manually checked by comparing patent title with industry name.

here) are captured in this classification. The complete data-set and the controlled conversion should give a more reliable picture of the industrial heritage of the 1990-6 data-set.

Table 1.4: Patent activity categorized by industrial sector: correspondence between primary IPC classes and ISIC 2 industrial sectors

ISIC:ISIC NAME	1990-3		1994-6		GrandTotal	
Grand Total	355	100,00 %	279	100,00 %	634	100,00 %
3820(except 3825):Machinery	67	18.87 %	42	15.05 %	109	17.19 %
3850: Professional & Scientific Instruments	44	12.39 %	49	17.56 %	93	14.67 %
3810 Metal products, ex. Machines	37	10.42 %	20	7.17 %	57	8.99 %
3522: Pharmacy; drugs and medicine	22	6.20 %	29	10.39 %	51	8.04 %
5000:Building and construction	31	8.73 %	16	5.73 %	47	7.41 %
3841:Shipbuilding	17	4.79 %	24	8.60 %	41	6.47 %
3825: Computers & office machines	8	2.25 %	30	10.75 %	38	5.99 %
3510+3520(except3522) : Chemistry, except pharmacy	27	7.61 %	9	3.23 %	36	5.68 %
Other: design patents	20	5.63 %	11	3.94 %	31	4.89 %
3900:Other industrial products (e.g. agriculture)	15	4.23 %	6	2.15 %	21	3.31 %
3600:Stone, clay and glass products	18	5.07 %	2	-.72 %	20	3.15 %
3830 (except3832): Electric mach., ex. Electronics	10	2.82 %	9	3.23 %	19	3.00 %
3832:Electronics	11	3.10 %	6	2.15 %	17	2.68 %
3710:Ferrous basic metals	10	2.82 %	6	2.15 %	16	2.52 %
3720:Non-ferrous basic metals	6	1.69 %	3	1.08 %	9	1.42 %
3100: Food, beverages, tobacco	5	1.41 %	3	1.08 %	8	1.26 %
3300:Wood and furniture	3	-.85 %	4	1.43 %	7	1.10 %
3843: Motor vehicles	1	-.28 %	6	2.15 %	7	1.10 %
3400:Paper, printing and publishing	3	-.85 %	3	1.08 %	6	-.95 %
3200:Textiles, clothes, etc.	-	-.00 %	1	-.36 %	1	-.16 %

Conversion to ISIC 2 from IPC primary class via Verspagen et al correspondence table. Correspondence hand checked

It should be noted that the classification of industrial sectors span three different levels of aggregation. The majority of the 20 categories in this table are at the 2-level of classifications (those with 2 zeros) which are the highest level of aggregation. In addition, these are mixed with the progressively narrower sub-classifications at the 3 (one zero) and 4-levels. This branching relationship is indicated by indentation. As a result the different classifications are not immediately comparable. For instance, putting all data on the same platform of the broadest group, the 2-level, would mean that industrial class 3800 (metal-products and machinery, incl. office machines) would claim 63% (i.e.. 381 patents); chemicals and pharmaceuticals (3500), 14% (i.e. 87 patents) and metallurgy (3700) a further 4% (i.e. 25 patents) of the total patent population.

As defined, however, the top-8 industrial activities claim fully 74% of the total activity. Seven of the eight are manufactures, with the remaining activity, 5000 building and construction, an activity with special applicability to the building of oil-rigs (5023) and the petroleum sector more generally. The mix of activities reflected here is interesting. Areas that are typically considered research-intensive and that are characterized by rapid diversification, such as pharmaceuticals, professional instruments and IT, are mixed with what at first blush seem to be less research intensive, less differentiating areas, such as machines, metal products and ship-building. This representation is considered more closely in the next section

1.2.3.1. A breakdown into high-, medium-, and low-tech industrial activities

In this section, the technology intensities of the fields in which Norwegian patents are granted are explored to give a profile of the knowledge bases involved. Are these knowledge bases high, medium or low-tech? The OECD classification of these manufacturing sectors is based principally on their average R&D intensities. Therefore, one would assume that patenting activity, which results from R&D, would reflect that: high-tech would be characterized by relatively higher patent intensities, medium by moderate patent intensities and correspondingly low levels for low-tech branches.[19] Of course, the sector propensity to patent needs also to be factored in, though this effect should in fact raise the high tech percentage. Nonetheless, patents granted to Norwegians in the US pay homage to high, medium and low tech research milieux in quite equitable shares.

The following three-tier table depicts the intensity of Norwegian patent activity for a selection of manufacturing sectors. Thus, class 5000 Construction as well as design patents are not included in this breakdown, leaving about 88% of the total patent population. The number of patents in the period 1990-6 whose main class correspond to those are presented as is their percentage of the total patent population. In addition, it is indicated whether patents in these respective classes appear to be increasing or decreasing across our two time-periods.

[19] That is of course assuming that other factors affecting appropriability and thus the propensity to patent are equal.

Table 1.5: Patent-count into ISIC.2. Sectors by high-, medium- and low-technology sectors in the OECD classification

	H! J lscJ olo l 2i !s2	� ! 2 �aa	� is i2	i. !	is i2	cJ s ! is i!
3522	Pharmaceuticals	24	51	2,125	8%	Increase
3825	Office & computing equip.	26	38	1,462	6%	significant increase
383 (ex. 3832)	Electrical machines(excl. comm.)	282	19	0,067	3%	Increase
3832	Radio, TV & Comm. Equipment	134	17	0,127	2.7%	significant decrease
385	Professional &Scientific Instruments	89	93	1,045	14.7%	significant increase
Total		555	218	0,393	34.4%	

l2lC cl 22s2	Ws ! lscJ olo l 2i !s2	� ! 2	� is i2	i. !	is i2	cJ s ! is i!
351/2 (ex 3522)	Chemicals excl. drugs	179	36	0,201	5.7%	significant decrease
3843	Motor-vehicles	131	7	0,053	1.1%	significant increase
3820 (ex 3825)	Machinery (ex. office)	1 004	109	0,109	17.2%	Decrease
3900	Other manufacturing	314	21	0,067	3.3%	significant decrease
TOTAL		1628	173	0,106	27.3%	

l2lC cl 22s2	ro lscJ olo l 2i !s2	� ! 2	� is i2	i. !	is i2	cJ s ! is i!
311/2	Food Manufacture	1 472	8	0,005	1.3%	Decrease
321	Textiles	302	1	0,003	0.2%	Increase
3300	Wood-products, incl. furniture	1 355	7	0,005	1.1%	increase
3841	Ship-building	504	41	0,081	6.5%	significant increase
360	Mineral/ceramic products	500	20	0,040	3.2%	significant decrease
371	Ferrous basic-metals	42	16	0,381	2.5%	decrease
372	Non-ferrous metals	55	9	0,164	1.4%	decrease
381	Fabricated metal-products	1 385	57	0,041	9%	decrease
3400	Paper , printing and publishing	1 760	6	0,003	%	increase
TOTAL		7 375	165	0,022	26.2%	

Oecd classification of High, medium and low according to ISIC rev. 2.

1.3. Sector distribution: a weighted profile of sector specialization.

In this section, the impression that the patent-count has given as to the range and concentration of Norwegian patenting knowledge bases is refined in two fundamental ways. First, secondary patent-classes of patent grants are added to the primary-classes used above in order to describe a more comprehensive picture of the range and types of patenting knowledge bases reflected in these grants. Second, the Norwegian patent population is indexed to the total population of US grants in order to distinguish to what degree the impression created by the patent-count above reflects the relative intensities of Norwegian patent-activity classes and to what degree it reflects the sensitivities of different classes of industrial activities to being patented.

The patent-count approach above approached the patent-grants through their current primary classes. Using the current primary-class means that one patent-grant is represented as being categorized under a single main-class that reflects the dominant field in which the invention is novel/applicable. In practice, a US patent (as opposed to a Japanese patent) can be granted with claims in a range of different classes (and sub-classes as well). Multi-class claims reflect the possibility that an innovation involves products or processes that are new to more than one field, for example a new ship construction (class 114) based on a new specialized metallurgical composition (75). The integration of these secondary classes gives a richer picture of the intensity and spread of knowledge bases behind the individual patents; it can also create better scope for identifying the potential user-industry.

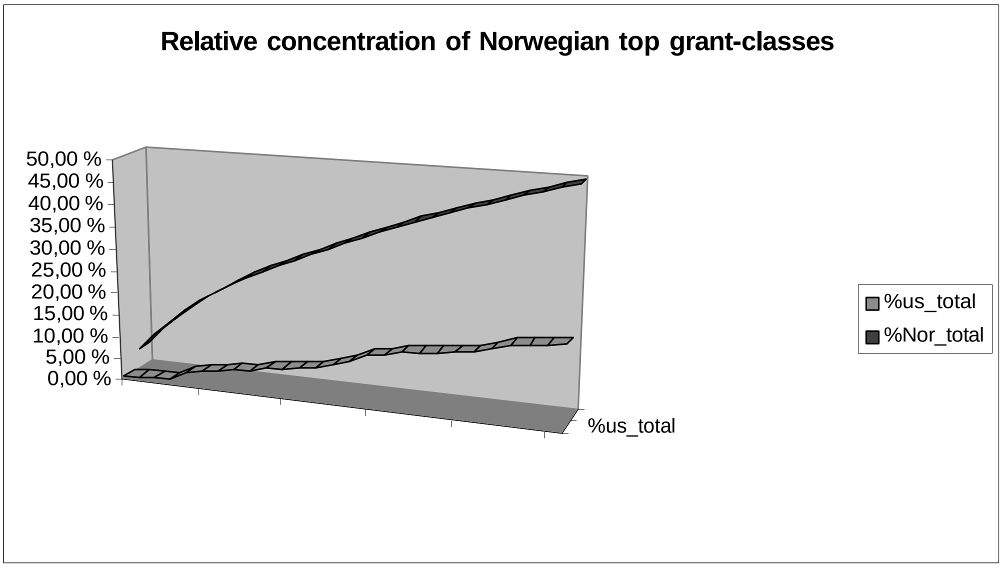
1.3.1. Comparative strength in the sector distribution of claims in Norwegian grants.

In 1993, 93,834 patents were granted in the US with a total of 173,251 claims in 390 main-classes[20], meaning that each patent granted held claims in 1.85 main-classes on average. Norwegian grants for the period 1990-3 reveal a slightly lower ratio of multiple claims, with the 355 patents (including design) holding 577 claims in a total of 163 main-classes (a ratio of 1.6 claims: 1 main-class).

Norwegian grant-claims, relatively few in number, are thus found in about 40% of the classes where claims were granted in the US. Here, they concentrate into a comparative pattern of specialization that is somewhat different in detail but not gist from the patterns revealed by our initial patent counts. The profile of the majority of Norwegian claims in the US (1990-1993) is clearly distinct from the profile of all patent-claims (here using a base-year, 1993). The figure below shows the 28 classes with the strongest Norwegian representation (according to the RTCA; see below) respectively as the percentage of all Norwegian patent-claims and of all patent-claims in US.

[20] There are about 400 patent main-classes currently in force. Of those, 11 had no grants for 1993. In addition, there are classes that have ceased to exist, such that Norwegian grants for this period include claims in 3 obsolete classe.

Figure 1: Profile of the classes in which Norwegians patent most in the US (top 50%: 1990-1993) in relation to the concentration in these classes for the all patents in the database (1993)



The incline of this chart clearly illustrates that the relative concentration of Norwegian claims is different from the total patents granted in the US.[21] The 28 classes that account for 50% of all Norwegian claims for the period are selected on the basis of whether Norwegian assignees are 'over-represented' in these classes. To measure this a specialization-index is used to compare the number and distribution of Norwegian claims against the number and distribution of all claims found in patents granted in the US: because each patent can have multiple claims in the same main-class but different sub-classes, a main-class is counted only once. The index, by which Norwegian activity in the classes are arranged, reflects the ratio between the percentage of all Norwegian claims (here the period 1990-3 is used) accounted by each class and the percentage of all claims for the total US population for that class (represented by 1993 grants). Used for example by Jacobsson and Philipson[22], this approach is based on a Revealed Technological Comparative Advantage (RTCA), of

[21] But what if the top US classes were presented; how strong would Norwegian patenting be in the most active classes overall? An initial look indicates that the top 50% of all claim-grants in the US are concentrated into 55 classes or 1/7th of the active classes. This is close to the Norwegian proportion of 1/6. These same classes account for 39% of the Norwegian total. As to the question of performance, the Norwegian claim-grants show an index of at least one for one of three of these classes.

[22] Jacobsson, S. & Joakim Philipson. Sweden's technological profile: What can R&D and patents tell and what do they fail to tell us? Technovation, 26 (5): 1996: 245-256. Another approach uses Chi-squared.

the sort that the OECD system generally applies to trade-data, and therefore implies a relative strength in performance for the classes with indexes greater than one.

Table 1.6: Weighted index. This index equals the Sum of Nor (class) in 1990-93 divided by the sum of All-US (class) in 1993 divided by all NOR/sum all US for respective years.

	Cr\f22	Cr\f22 lllrE	n2 lOl\fr	lOl\fr o l i!o (c l i!As	[illegible]Oi. Gli\f l[illegible]	[illegible]Oli o l i!o (c l i!As)	l [illegible]
1	114	SHIPS	279	0%	18	3%	19,37
2	367	COMMUNICATIONS, ELECTRICAL: ACOUSTIC	342	0%	18	6%	15,80
3	405	HYDRAULIC AND EARTH ENGINEERING	541	1%	26	11%	14,43
4	166	WELLS	567	1%	23	15%	12,18
5	175	BORING OR PENETRATING THE EARTH	276	1%	9	16%	9,79
6	266	METALLURGICAL APPARATUS	220	1%	7	18%	9,55
7	75	SPECIALIZED METALLURGICAL	339	1%	10	19%	8,86
8	423	CHEMISTRY OF INORGANIC COMPOUNDS	1071	2%	13	21%	3,64
9	204	CHEMISTRY: ELECTRICAL AND WAVE ENERGY	1087	3%	12	24%	3,31
10	414	MATERIAL OR ARTICLE HANDLING	811	3%	8	25%	2,96
11	137	FLUID HANDLING	1237	4%	12	27%	2,91
12	148	METAL TREATMENT	953	4%	9	29%	2,84
13	251	VALVES AND VALVE ACTUATION	670	5%	6	30%	2,69
14	52	STATIC STRUCTURES (E.G., BUILDINGS)	1024	5%	9	31%	2,64
15	106	COMPOSITIONS: COATING OR PLASTIC	800	6%	7	32%	2,63
16	536	ORGANIC COMPOUNDS 532-570 SERIES	816	6%	7	34%	2,58
17	417	PUMPS	705	7%	6	35%	2,56
18	436	CHEMISTRY: ANALYTICAL/IMMUN. TESTING	1024	7%	7	36%	2,05
19	426	FOOD OR EDIBLE MATERIAL	899	8%	6	37%	2,00
20	222	DISPENSING	921	8%	6	38%	1,96
21	219	ELECTRIC HEATING	1115	9%	6	39%	1,62
22	424	DRUG, BIOAFFECTING	1898	10%	10	41%	1,58
23	210	LIQUID PURIFICATION OR SEPARATION	1730	11%	9	42%	1,56
24	514	DRUG, BIOAFFECTING	3401	13%	15	45%	1,32
25	73	MEASURING AND TESTING	1918	14%	8	46%	1,25
26	128	SURGERY	2181	15%	9	48%	1,24
27	250	RADIANT ENERGY	1872	17%	7	49%	1,12
28	264	NONMETALLIC ARTICLE TREATING	2114	18%	7	50%	0,99

In identifying the 28 classes in which Norwegians can be said to specialize, only classes with at least 6 observations were counted in order to insure a minimum robustness and then only if they had an index of at least one. As defined, these 28 main classes account for 50% of the 577 Norwegian claims. In contrast to the primary Norwegian population, these same classes account for only 18% of the very much larger total of US grant-claims. The split becomes stronger as we move up the list: the top 22 classes represent 41% of the Norwegian but 10% of the US total; the top 13, 30% and 5% respectively, and the top 7 classes 19% and 1%.

1.3.2. Sector distribution among the 28 most represented classes

How then do the Norwegian data break down when secondary classes are included and the data is compared to the complete population? In general, the sector-characteristics of this data break down into the familiar areas of mechanical engineering, chemistry and pharmaceuticals, ICT, with representatives of the customer and medical products and Energy. The breakdown corresponds roughly to the trinity of traditional activities, petroleum, and emerging areas (data, pharmacy) that the absolute numbers indicated.

However, the introduction of secondary classes has caused a significant re-shuffle of the familiar classes, with some classes falling out of the list and others taking their place. In addition, the distribution is slightly spread out with the inclusion of secondary classes, which increases the number of active classes at the Norwegian level from 116 to 160. The fact that 28 classes make the top 50%, as opposed to 22 in our first approximation, indicates a minor flattening of this concentration from 1 out of 5 to 1 out of 6 classes being included in the top.

Notice first that the specialization-index of comparative strength ranges from one, indicating that performance of that class is proportionate to the population, to 19, indicating that the class is over-represented by a factor of 19. The indexes of the top 7 classes are distinctly higher than the rest of the list, with factors of over-representation greater than 8. In part, this reflects the moderate level for these classes at the US level, but moreover it demonstrates the importance of these activities for the Norwegian population.

1. *Engineering*: The introduction of secondary classes has particularly made the importance of the shipping knowledge bases more robust. Particularly, it shows that this "low tech" field pervades a greater percentage of the total patenting activity than our simple patent count revealed. At the same time, we recall from that exercise that shipping showed signs of comparative growth across our two periods. The importance of the oil-sector is likewise magnified in this data, as the oil related fields of hydraulic and earth engineering, wells and earth-penetration occupy 3 of the top 7. It should be noted that the correspondence between these fields and the oil sector is not as complete as that of ships to shipping: for example, activities such as tunneling through mountains, is hereby

wrongly ascribed to off-shore activities. Nonetheless, there is no loss of generality: the oil-sector is an important nexus for research as reflected in patent-data and other classes among the top 28, notably static-structures (viz. oil-rigs) are substantially ascribable to that maturing activity. The position of specialized measurement and testing equipment (514: cf. health-sector and oil sector) has slid down the list somewhat. At the same time the list has been added to by different types of generic processes, especially in the handling of different elements (metals, plastics, fluids (cf. oil and/or hydro-electric energy).

2. *Chemicals/metallurgy and pharmaceuticals*: The persuasiveness of metallurgy and chemicals classifications is also remarkable in this table. Together, they account for 7 of the top 28 classes, as reflected by the 1990-3 data. This illustrates more clearly the prominence of the traditional activities in Norway's patented research for that period. What it does not do, is integrate the 1994-6 data in which the increasingly prominent positions of pharmaceuticals might or might not have been corroborated here. As it is, the prominence of pharmaceuticals has been devalued in this list. Taken at face value, this devaluation indicates among other things the strong sector propensity to patent in this maturing field: the relatively greater propensity to patent for pharmaceutical inventions is cancelled out in this table.

3. *ICT*: The traditional activities of engineering and chemicals, when combined with the effects of the oil-sector dominate the list. However, as we noted above, the patenting time series indicates that these fields are the ones experiencing decreases or significant decreases in rates of primary-class patents. By not including the 94-6 data, the position of ICT is marginalized. The only high-tech classification that remains among these top 7 involves analogue communication technologies, which is the second strongest in comparative terms. As with many of the oil-related classes, we recall that this particular class was notable in the patent-count for the dissipation of patent intensities in between 1994-6. Therefore, the high index here might say more about the dropping off of activity at the aggregate level than a relative strength at the Norwegian one. Among the remainder of the list, we note that other ICT fields have fallen off the list (ex digital storage devices).

4. *Miscellaneous*: The miscellaneous category, in which consumer and medical products were classified has remained fairly stable. To it, it is interesting that food processing (cf. the aquaculture industry: chapter...) has entered as an area of comparative strength. The hydro-electric industry's traditional prominence is still represented by radiant energy, measuring instruments and fluid handling.

1.4. Combining dominant patent classes with Dominant assignees

In this section, the location of central knowledge bases is cross-referenced with the activities of the dominant Norwegian agents. The object is to understand more closely how the where and the who of Norwegian patenting activity is connected, and thereby get a better picture of the important nodes of the Norwegian knowledge base.

The following table aggregates the activities of the dominant classes up to ISIC industrial sectors, again ranking the most activity industrial knowledge bases. Across the horizontal axis, the 18 most prominent assignees are ranked in descending order. This table illustrates where and how the activities of these assignees influences the order to indicate important activity areas, while reducing the primacy of individual actors.

Table 1.7: Relationship between the dominant patent-actors (left to right) and dominant industrial activities in patenting (ranked in descending order), 1990-June 1996

\f22! ss2 (! !s)	loi l																				% OF TOTAL
Grand Total	634	100	53	41	37	29	23	22	13	11	10	8	7	7	6	6	6	5	5	389	61.4%
3820 (except 3825): Other machinery	109	16	11	1	-	1	-	6	2	10	-	7	2	3	1	-	-	3	-	63	57.8%
3850: Instruments	93	8	7	5	13	-	18	-	-	-	2	1	1	1	1	-	5	1	1	64	68.8%
3810: Metal products, ex. Machines	57	13	2	-	-	6	-	7	-	-	-	-	-	-	-	-	-	-	3	31	54.4%
3522: Pharmacy	51	10	2	-	24	1	-	-	-	-	3	-	-	-	-	-	1	-	-	41	80.4%
5000: Building and construction	47	5	13	-	-	-	-	3	8	1	-	-	-	-	-	-	-	-	-	30	63.8%
3841: Shipbuilding	41	2	10	-	-	-	3	3	1	-	-	-	-	-	-	-	-	-	-	19	46.3%
3825: Computers & office machines	38	-	-	31	-	-	-	-	-	-	1	-	-	-	-	-	-	-	1	33	86.8%
3510+3520 (except 3522): Chemistry, except pharmacy	36	16	2	-	-	4	-	1	-	-	3	-	-	-	-	-	-	-	-	26	72.2%
Design patents	31	-	-	-	-	-	-	1	-	-	-	-	-	2	-	4	-	-	-	7	22.6%
3900: Other industrial products (e.g. agriculture)	21	1	1	-	-	-	-	-	-	-	-	-	-	-	-	2	-	1	-	5	23.8%
3600: Stone, clay and glass products	20	9	-	-	-	5	-	-	-	-	1	-	-	1	-	-	-	-	-	16	80.0%
3830 (except 3832): Electric mach., ex. Electronics	19	1	3	3	-	1	-	1	2	-	-	-	2	-	3	-	-	-	-	16	84.2%
3832: Electronics	17	-	2	-	-	-	2	-	-	-	-	-	2	-	1	-	-	-	-	7	41.2%
3710: Ferrous basic metals	16	5	-	-	-	10	-	-	-	-	-	-	-	-	-	-	-	-	-	15	93.8%
3720: Non-ferrous basic metals	9	7	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	8	88.9%
3100: Food, beverages, tobacco	8	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	25.0%
3300: Wood and furniture	7	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	14.3%
3843: Motor vehicles	7	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	57.1%
3400: Paper, printing and publishing	6	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	16.7%
3200: Textiles, clothes, etc.	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.0%

IPC primary class to ISIC through MERIT Correspondence-system.

As we noted in section 1.1, the 18 assignees that dominate Norwegian patenting in the US account for about 61% of the total number of Norwegian patents issued there. In the table above, we find that these 18 account for at least this percentage for 9 of the 21 industrial categories or at least 50% for 12. The activities of the remaining 144 patentees with less than 5 grants however is what defines the general ranking shown above in numerical terms. These small assignees as a group patent most often in machinery, instruments and metal products, while shipbuilding and the general design category are also well represented in relative terms. There are a few areas where the small actors are marginalized. On the one hand, the emerging technologies of ICT and pharmaceuticals are almost exclusively the domain of the larger group and then, the concentration of two firms is key. On the other, the more traditional areas of basic metals are also dominated by a small set of the most prominent assignees.

At the same time, the table shows that the activities of these firms are distributed considerably across different categories. Indeed, just as with the data at the national level, knowledge bases at the firm level are diverse, though this diversity has its patterns as in the national case. The degree to which the respective corporate patent portfolios are concentrated varies according to activity. In general, agents involved in what we have termed traditional industries, for example Kværner or Norsk Hydro display fairly distributed knowledge bases, while those firms involved in what we termed 'emerging technologies', for example Tandberg or Nycomed, illustrate fairly focused knowledge bases. In the first case, these umbrella-MNCs (esp. Norsk Hydro) incorporate a large number of different entities with fairly specific competencies. The effect for corporations like Hydro is a broad network of thematically related activities. These may have been created through growth or acquisitions, and can be illustration by the extension from traditional fertilizer-chemistry into the emerging technologies category of pharmaceuticals.

In addition to the two emerging technologies mentioned, another field in which an individual among the most prominent patentees shows a large degree of concentration is GECO, which was bought up by international Schlumberger Ltd. in the 1980s. Again, the field is a high-technology field, namely scientific instruments and involves a somewhat younger and smaller company involved in the offshore industry.

2. Knowledge-Interactions and Patent citations

Having identified the Norwegian patents granted in the US, we concentrate our analysis on those patents and those publications Norwegian US patents cite. The purpose of this citation-analysis is to indicate the most important knowledge-sources for patenting firms in Norway, as they can be proxied by patent-citations. This analysis is divided into two parts. In the first, we will focus on the patent-classes Norwegian patents cite. In this part, we conclude the broadening focus of knowledge bases we started at the end of the last section when we moved from primary-class to secondary-class. An analysis of patterns in the class citing-patent class cited matrix will reveal important cliques of co-operation. Such patterns, will be analyzed in terms of disembodied knowledge spillovers between the technical patent-classes involved.

The second part is based on a patent class citing-publication cited matrix. The cited publications are sorted and categorized at a scientific field level according to ordinary bibliometric classification systems (i.e. Science Citation Index). This analysis describes the proximity of patent classes to scientific knowledge bases, and identifies areas of knowledge-interactions between what Bell/Callon call the technological and science-poles.

2.1. Disembodied Knowledge-spillovers and patent citations

The analysis of knowledge-spillovers[23] typically posits an interdependency between the R&D carried out in one field of technology and activities in other fields. The interaction between fields, whether they be in the form of the user-producer relationship of the technology, or the research co-operation of different areas, creates a uni- or multi-directional learning vector in which knowledge flows from the one area to the other. This knowledge may be embodied in a technology which is in some form bought[24] or this knowledge may flow in a disembodied form (e.g., from the research infrastructure, via the range of researcher competencies).

This exchange of knowledge between fields acts as an inter-sector learning process. This process is important for the economy as it contributes to the 'virtual circle of the generation and distribution of economically valuable knowledge' (David/Foray). By implication, it is important in the context of the mapping project as mapping this inter-sector learning process shows what knowledge bases are important as feeds for other central areas of economically valuable knowledge which we proxied in part one.

[23] In the sense established by Griliches and followed up in different ways notably in the analysis of Scherer (1982), Putnam & Evenson (1986), Jaffe (1986) and, more recently Grupp & Schmoch (1992) and Verspagen (1995).

[24] This entails the other sort of spillover in Grilliches' classification, a rent-spillover. Cf. Hauknes in the Mapping book.

These knowledge-interactions can and have been explored through patent-citations. The basis is that patents in given classes typically refer to other patents in order to establish the prior art of the technology that is relevant to them. Often these patterns are found in other patent-classes, testifying to the fact that technologies are not monolithic entities that fit neatly into the categories provided. Patterns in the way patent classes reference one-another have been used to construe such patterns of disembodied spillovers (cf. Grupp/Schmoch, Verspagen) at aggregate levels; to demonstrate the dimensions of "technological neighborhoods" among proximal patent classes (cf. Jaffe); or, in network analysis, to show the relationship between "science- and technology poles" and how skills can be mapped internationally. (Bell&Callon: OECD: 1991)

Here we apply different aspects of these approaches in mapping dimensions of a country's 'knowledge system'. This gives a more robust picture of the types of technologies and thus competencies that hide behind the formalized patent classification systems.

For the citation analysis, the first page citations that the patent-office examiners make to other patents are used, as are references to other publications such as journals, books and trade-literature. These first-page references is almost without exception the preferred source of this type of data and can be expected to account for around 70% of all patent references listed by the patentee as prior art in the subsequent pages of the application. In processing the citation-data, the bibliometrics program Ucinet, has been used.

2.2. Knowledge-interaction in Norwegian patents

During the period 1990-1996, Norwegian assignees are found in 160 patent classes, or about a quarter of the 405 classes currently in use by the USPTO. In this section we see how these patents cite other patents in that same selection of classes. Norwegian patents actually cite a much larger population of patents, indicating that they draw on a broader range of knowledge-sources. In total 305 classes are cited by Norwegian patents. The majority of these include low levels of citations (below 5) and 50 of these are defunct

A more fundamental reason for excluding these citation in favor of focusing on the citations between the 160 classes is to distil out interactions between areas of the Norwegian knowledge base. We are interested in exploring how Norwegian knowledge creation draws on knowledge bases within the Norwegian system. The interaction between knowledge bases that are geographically proximate has been shown to be important (cf. Jaffe: Jaffe, Tratenjenberg & Henderson). The idea that knowledge-creation occurs within ’neighborhoods’, both in the sense of a certain degree of technological kinship (that there are generic aspects to the technology, that allow for combinations) and of a geographic proximity, is indeed intriguing and apt to have significant consequences for policy-makers. But again the limitations to the descriptive power of patent-data must be kept well in mind.

2.2.1. The parameters of Norwegian citation-interaction

The total population:

The Norwegian population of 160 classes makes a total of 3,287 citations both to themselves and to other patent-classes. In examining this population, however, we are most interested in those knowledge bases that fulfil two criteria: those that involve classes that we can track and those that cite outwardly.

The data-set to be examined encompasses 107 citing-classes with a total of 1086 citations to 123 classes outside themselves. This leaves four types of citing classes; those that belong to obsolete classes, those that exclusively cite themselves, those that exclusively cite outside classes and, the majority, those that cite both internally and externally.

Removing obsolete classes:

The need for us to be able to identify technical activity of the individual class entails first that a population of 11 classes, which are no longer current in the USPTO categories, fall out of our count. With them 135 citations are lost, of which only 35 are to outside classes (i.e. @ 3%). These citations are to older patents, some going back to the early part of the century, whose activities (apparently, mostly within mechanical engineering) have been integrated into other classes inasmuch as the scope for novelty is seen to persist by the patenting office.

Classes that exclusively cite themselves

The second criterion, that the classes cite outside classes, means that a further population of 44 citing classes is excluded involving 317 citations. These exclusively self-referential classes pose an interesting population in themselves, as they indicate research activities that ostensibly access knowledge only from within a thin, closed area.

Many of these introverted classes are isolated in a single technology area, III. Mechanical engineering. Here, eleven classes account for 95 of the together 312 citations; 54 of these involve a single class, 383 ‘flexible bags’, where Norsk Hydro account for the 6 patents in question. Other introverted classes are 434 `learning materials’, found under Instruments, with 33 self-references and 70, locks, (III. Mechanical engineering) with 28 self references. A common element for these introverted classes is the concentration of assignees, usually one actor.

Classes that exclusively cite outside classes:

Excluding those classes that do not cite at all, this leaves 107 of our frame of 160 classes that cite outside themselves. Interestingly, 13 of these cite exclusively outside classes, in which 83 citations (or 7.3% of the total outward-bound citations) are involved. The majority of these fall into two technology areas: Chemicals, where fine chemicals and pharmaceuticals are dominant (37 citations) and Instruments where medical and measurement technologies (19) are noted.

These extroverted classes signal the generally outwards-oriented citation patterns of the drugs and the medical areas. To a certain degree this has to do with the patent-intensive nature of pharmaceuticals; as noted, the patent propensity for drugs and chemicals in general is high. Moreover, the apparent extrovertedness has to do with the propensity to access knowledge from outside, especially through interaction with science-intensive bases (cf. Reference to other publications, below)

2.3.Technical-spillovers

In this section, the classes that cite outside classes are investigated. Citations made by the 107 citing classes to the 123 cited classes in this community are aggregated up into 6 Technical Areas. In total 1,089 outward citations connect the citing-cited classes. This means that 1/3 of the knowledge that Norwegians access from within the Norwegian knowledge-community emanates from sources outside the ’original’ patent-class. The remaining 2/3 of the citations are the self-referencing patent-classes.

What areas generate knowledge and what areas access knowledge based on citation patterns?

Table 2.1: Cited-Citing matrix: Flows between Knowledge-Generating areas (i.e. Cited Technical Area) and Knowledge-Receiving areas as percentage of all inter-class citations. (N=1,089)

	CITING TECHNICAL AREAS								
	I	II	III	IV	V	VI		% generated	net
CITED TECHNICAL AREA									
I ELECTRICITY: ELECTRONICS	13,8%	3,8%	0,1%	0,9%	1,3%	0,0%		,8%	6,1%
II INSTRUMENTS	1,4%	5,7%	1,9%	0,6%	1,4%	0,2%		11,2%	,5%
III CHEMISTRY: PHARMCEUTICS	0,3%	0,7%	18,4%	3,6%	0,7%	0,3%		24,0%	,6%
IV PROCESS ENGINEERING	1,1%	0,1%	2,5%	2,7%	1,7%	0,0%		8,1%	5,4%
V MECHANICAL ENGINEERING, MACHINERY	0,9%	3,8%	1,1%	3,6%	16,9%	1,7%		28,0%	11,1%
VI CONSUMER GOODS, CIVIL ENGINEERING	0,3%	0,3%	1,6%	0,3%	3,2%	3,3%		8,9%	5,6%
							60,7%		
% total citations Received	17,7%	14,3%	25,5%	11,7%	,3%	5,5%			
Net	3,9%	8,6%	7,2%	9,0%	8,4%	,2%			

This matrix indicates each area’s knowledge-generation activity as a percent of the total citations generated (i.e. cited areas; down the y-axis) as against its knowledge-consumption patterns (i.e.. citing activity; across the x-axis). There are several general aspects to take off the top before exploring the interrelationships in greater detail below.

- A first interesting aspect is that all areas produce citations that are accessed by most of the other areas. The inverse is also the case: all areas access from the other areas, though for Civil Engineering & Consumer Goods this activity is limited. We will examine strong-linkages between these areas below.

- Secondly, it should be noted that a total of 123 classes are cited while only 107 cite in the six areas. There is therefore a structural skewness in the table, through which each class is expected to cite an average of 1.15 other classes. The citing-class/cited class ratio will vary according to each area, giving a first indication of the citation-activity of that area. The fact that more classes are cited than cite indicates that a greater range of knowledge sub-areas generate citations than receive this knowledge.

- Thirdly, intra-area flows (i.e. diagonal) account for over 60% of the total flows between different classes. Removing these, not unimportant flows, reveals each area's net generating activity (last column) as against its net recipient activity (last row). We will consider both the most significant intra-area flows as well those of inter-area linkages.

- Lastly, three areas emerge when comparing the cited-to-citing ratio of each area as net generators of knowledge spillovers and three as net-recipients. It should be noted that these areas are not isomorphic, and include a different number of classes in the Norwegian case. This introduces the question of scope to the citation question (# of classes generating or receiving) in addition to that of scale (i.e.. # of citations generated or received)

Some basic observations about the different Technical Areas are made in annex 1.. In particular, a detailed survey is provided as to the scope and scale of each area's citations, the degree of extrovertedness or introvertedness of the individual areas and aspects of their intra-area citation activity.

2.4. Knowledge interaction between areas

In this section we are interested in linkages between Technical Areas

- where the flows are robust in absolute terms (the interaction between the Technical Areas comprises at least 5% (54 citations) of the total);

- where the strongest linkage between the areas makes up a significant percentage of the outward flow for the area that primarily generates;

- and where the strongest linkage makes up a significant percentage of the inward flow of the recipient area.

There are five significant linkages connecting Technical Areas in the Norwegian system. The five most interactive areas are shown in the table below. These are ranked according to total volume flowing in both directions between the pairs. The 'total link' column indicates the percentage of citation involved in the interaction. The dominant generator of the spillovers is Technical Area 1, where the percent of the total going to Technical Area 2 is noted in the Flows 1-2 column. Flows moving in the other direction are indicated in subsequent column.

Table 2.2: The Five most interactive technical knowledge bases: % of all citations between patents of different classes

	lscJ !c l \f s [illegible]	lscJ !c l \f s	:lo 2: : o \f s [illegible]io	:lo 2: : o \f s io [illegible].	loisl l!ul<
1	Chemicals and Pharmaceuticals	Process-Engineering	3,6%	2,5%	6,1 %
2	Machinery and Mech. Engineering	Process-Engineering	3,6%	1,7%	5,3 %
3	Electronics and Electricity	Instruments	3,8%	1,4%	5,1 %
4	Machinery and Mech. Engineering	Instruments	3,8%	1,4%	5,1 %
5	Civil Engineering & Consumer Goods	Machinery and Mech. Engineering	3,2%	1,7%	5,0 %
					26,6 %

These five interactive pairs account for 27 % of the total citations, or nearly 70% of all inter-area citations in the Norwegian population. One area dominates the table. The broad Machinery and Mechanical Engineering Area is involved in three of the five pairs, twice as lead generator of knowledge spillovers and once as prime recipient. In addition, two areas emerge as important prime recipients of knowledge spillovers. The most important is Process-Engineering which as we have seen accesses knowledge from Chemicals and Pharmaceuticals and from Machinery and Mechanical Engineering. The other is Instruments. In both cases, these outside areas each generate more spillovers than the area itself. In total

- ♦ Chemicals & Pharmaceuticals + Process-Engineering pair is not the most significant in numerical terms, the two-way interaction between the pair is the strongest.
- ♦ Machinery and Mechanical Engineering + Process-Engineering
- ♦ Electronics and Electricity + Instruments
- ♦ Machinery and Mechanical Engineering + Instruments

- Civil Engineering & Consumer Goods + Machinery and Mechanical Engineering.

2.4.1. Strong areas of interaction at the class level

In the next step, all citations made by Norwegian patents were analyzed in order to identify especially strong linkages between different individual classes. Here the analysis included all 3234 citations made by the Norwegian patents, distributed over a total of 305 cited classes. To identify strong linkages, we looked for groups of classes, or ‘clans’[25], that systematically appear in citing-cited pairs in the Norwegian patent citations. These clans are sets of classes who interact together in the way they cite and are cited. This interaction can be construed as a close knowledge interaction between specific technical areas which generate and access knowledge from each other.

In this analysis, we looked for clans of at least 4 inter-linking member-classes. Analysis was conducted using the bibliometric program UCINET. Using this method, two major constellations were identified; one involving pharmaceuticals and the other Mechanical engineering.

2.4.1.1. Clans involving pharmaceuticals

The first involves pharmaceuticals, where three clans emerged with a common center at US class 424; DRUG, BIOAFFECTING AND BODY TREATING COMPOSITIONS. These clans demonstrate first and foremost the strong intra-area ties found above in the Chemicals and Pharmaceuticals Technical Area. In the first clan, strong linkages within the active sub-area of pharmaceutics and cosmetics are demonstrated. Here, drug compositions are linked to edible materials (e.g. pills, capsules) and chemical apparatus (e.g. for the shaping of the pills, capsule).

The second clan indicates a slightly different pattern of intra-area interaction. In relation to 424, Class 435 is used in the production drug or bio-affecting composition and may be used in in-vitro diagnostic tests using enzyme tagging. Therefore, Class 435 may sometimes be classified under Instruments. Like the first clan, Clan two seems to involve the production and packaging of pharmaceuticals. Here however, a tie is made to a separate subclass, *Organic fine chemicals*, which is a broader science-based area. The third clan combines the activities above with one that is more expressly testing one of testing. Here the link between the composition, the production, the coating and testing of the drug is seen. This sheds light on the strong connection found between Chemicals and Pharmaceuticals and Instruments above, especially when 435 can sometimes classify under Instruments.

Table 2.3: "Clans" of patents involving medical technologies

bJ cs i!c l2 l 2i s i2			
Clan 1			
424	DRUG, BIOAFFECTING AND BODY TREATING COMPOSITIONS	III. CHEMISTRY: PHARMACEUTICALS	11. PHARMACEUTICS, COSMETICS
425	PLASTIC ARTICLE OR EARTHENWARE SHAPING OR TREATING: APPARATUS	III. CHEMISTRY: PHARMACEUTICALS	11. PHARMACEUTICS, COSMETICS
426	FOOD OR EDIBLE MATERIAL: PROCESSES, COMPOSITIONS, AND PRODUCTS	III. CHEMISTRY: PHARMACEUTICALS	14. AGRICULTURE, FOOD CHEMISTRY
514	DRUG, BIOAFFECTING AND BODY TREATING COMPOSITIONS	III. CHEMISTRY: PHARMACEUTICALS	11. PHARMACEUTICS, COSMETICS
Clan 2			
424	DRUG, BIOAFFECTING AND BODY TREATING COMPOSITIONS	III. CHEMISTRY: PHARMACEUTICALS	11. PHARMACEUTICS, COSMETICS
435	CHEMISTRY: MOLECULAR BIOLOGY AND MICROBIOLOGY	III. CHEMISTRY: PHARMACEUTICALS	14. AGRICULTURE, FOOD CHEMISTRY
514	DRUG, BIOAFFECTING AND BODY TREATING COMPOSITIONS	III. CHEMISTRY: PHARMACEUTICALS	11. PHARMACEUTICS, COSMETICS
530	CHEMISTRY: NATURAL RESINS OR DERIVATIVES; PEPTIDES OR PROTEINS;	III. CHEMISTRY: PHARMACEUTICALS	9. ORGANIC FINE CHEMISTRY
Clan 3			
424	DRUG, BIOAFFECTING AND BODY TREATING COMPOSITIONS	III. CHEMISTRY: PHARMACEUTICALS	11. PHARMACEUTICS, COSMETICS
435	CHEMISTRY: MOLECULAR BIOLOGY AND MICROBIOLOGY	III. CHEMISTRY: PHARMACEUTICALS	14. AGRICULTURE, FOOD CHEMISTRY
436	CHEMISTRY: ANALYTICAL AND IMMUNOLOGICAL TESTING	II. INSTRUMENTS	7. ANALYSIS, MEASUREMENT, CONTROL TECHNOLOGY
530	CHEMISTRY: NATURAL RESINS OR DERIVATIVES; PEPTIDES OR PROTEINS;	III. CHEMISTRY: PHARMACEUTICALS	9. ORGANIC FINE CHEMISTRY

2.4.1.2. Heterogeneous Clans involving Engineering

The second constellation involves a more heterogeneous set of technical areas and sub-areas, involving materials engineering. These clans overlap Process-Engineering, Machinery and Mechanical Engineering and Civil Engineering & Consumer Goods to include elements from metal-working, metallurgy, machine tools, surface coating, transport and most centrally static-structures.

[25] We use the Ucinet bibliometric programme to locate these so-called clans.(Cf. Borgatti, Everett & Freeman) Analysis of a clan gives infomration about how often cited-citing patent pairs are found together. We have constructed a chain of mutually-citing pairs of at least 4 links that show close links.

The pivot point however is in Civil Engineering & Consumer Goods. This point involves Static-structures, a class which we observed in reference to the oil-industry above. The clans here should be seen in light of the strong interactions involving Machinery and Mechanical Engineering, Process-Engineering and Civil Engineering & Consumer Goods.

Clan 1 demonstrates a connection between Process-Engineering, Civil Engineering & Consumer Goods and Chemicals and Pharmaceuticals. Clan 2 involves the same constellation, but substitutes metal-working for advanced metallurgy. In both cases, the connection involves building components (e.g. panels, building modules), forming solids (e.g. casting in concrete and processes and compositions involving metals or specialized metals. One application for the relationship between composition, components and shaping such as it appears here is the construction of oil-rigs, especially using concrete (cf. Aker Engineering).

The third clan in this constellation builds again on the linkages between Machinery and Mechanical Engineering and Civil Engineering & Consumer Goods and Machinery and Mechanical Engineering and Process-Engineering. Upon closer investigation, it appears that the link between static-structures and transport, while significant for the transport citations, involves a small set of such citations.

Table 2.4: "Clans" of patents involving Engineering technologies

Mecharical and Process Engineering			
US-Class	US Class title	Techrical Area	Techrical Sub-areas
52	STATIC STRUCTURES (E.G., BUILDINGS)	VI. CONSUMER GOODS, CIVIL ENGINEERING	30 CIVIL ENGINEERING, BUILDING, MINING
75	SPECIALIZED METALLURGICAL PROCESSES,	III. CHEMISTRY: PHARMCEUTICS	13. MATERIALS, METALLURGY
264	PLASTIC AND NONMETALLIC ARTICLE SHAPING OR TREATING: PROCESSES	IV. PROCESS ENGINEERING	18. MATERIALS PROCESSING, TEXTILES, PAPER
428	STOCK MATERIAL OR MISCELLANEOUS ARTICLES	IV. PROCESS ENGINEERING	17. SURFACE TECHNOLOGY, COATING
Clan 2			
29	METAL WORKING	V. MECHANICAL ENGINEERING, MACHINERY	21. MACHINE TOOLS
52	STATIC STRUCTURES (E.G., BUILDINGS)	VI. CONSUMER GOODS, CIVIL ENGINEERING	30 CIVIL ENGINEERING, BUILDING, MINING
264	PLASTIC AND NONMETALLIC ARTICLE SHAPING OR TREATING: PROCESSES	IV. PROCESS ENGINEERING	18. MATERIALS PROCESSING, TEXTILES, PAPER
428	STOCK MATERIAL OR MISCELLANEOUS ARTICLES	IV. PROCESS ENGINEERING	17. SURFACE TECHNOLOGY, COATING
Clan 3			
52	STATIC STRUCTURES (E.G., BUILDINGS)	VI. CONSUMER GOODS, CIVIL ENGINEERING	30 CIVIL ENGINEERING, BUILDING, MINING
53	PACKAGE MAKING	V. MECHANICAL ENGINEERING, MACHINERY	24. HANDLING, PRINTING
296	LAND VEHICLES: BODIES AND TOPS	V. MECHANICAL ENGINEERING, MACHINERY	26. TRANSPORT
428	STOCK MATERIAL OR MISCELLANEOUS ARTICLES	IV. PROCESS ENGINEERING	17. SURFACE TECHNOLOGY, COATING

2.5. Technology-Science Linkages

Having considered knowledge spillovers between different areas (and sub-areas) of technical knowledge, this last section takes a look at involvement of science bases in technical innovation. This involvement or interaction is proxied by citations made between Norwegian patents in our period and Non-patent literature (NPL). The basis of such an approach was pioneered by Carpenter, Cooper & Narin (1980) in identifying science intensive areas of technology, and followed up notably by the Narin et al. and by the ISI group[26].

Following parts of this literature, the assumption of this section is that the way patents make reference to NPL, especially scientific journals, can indicate knowledge transfer (i.e.. spillovers) between typically ‘scientific’ knowledge and more typically technical applications. In investigating the Norwegian citations to NPL this assumption will need to be qualified significantly. We will first consider the

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[26] For an overview of the field, see eg. Scmoch, Strauss, Grupp & Reiss (in cooperation with Narin & Olivastro) Indicators of the Sceintific Base of European Patents. CEC Monitor EUR 15330 EN. Research Evaluation (1993).

relationship between science and technical bases as it can be proxied before investigating Norwegian citations to ‘science literature’ more closely.

2.5.1. The relationship between science technical bases: Using citations to non-patent citations

In all, only about 30% of the Norwegian patents in our period cited ‘other references’. These 183 patents cited journals, books, and a variety of more commercial literature (eg. trade literature, conference proceedings) a total of 716 times. The question is whether all of these citations represent knowledge linkages between scientific and technical knowledge areas. To evaluate this question we must first establish to what degree citations to NPL can reflect such linkages.

2.5.2. Qualifications of the use of NPL citations

The relationship between citing-patents and cited Non Patent Literature offers a suggestion of a knowledge link but not necessarily a direct indication of science involvement in the citing technical field. It is therefore necessary to appreciate; that (i) NPL citations can indicate less a link to science knowledge bases than a pragmatic link in the examination process and that we need therefore to differentiate the type of links made, and (ii) that second citations can, to the degree to which they do indicate scientific linkages, distort such links. We must be aware that the citation/patent might inflate the true nature of the links.

2.5.2.1. The examination process

What types of Non-patent literature (NPL) citations can reflect scientific knowledge flows? Consider first why NPL is used in the examination of patent application. Grupp and Schmock indicate that such citations are not systematically used in the examination process. In their study, they found that examiners use NPL in clearing patent applications for several reasons.[27] A main motivation for using this kind of reference is that the patent’s prior art cannot be investigated by reference to patent documents and NPL is resorted to in order to establish novelty and/or degree of inventiveness. Reasons for this may be that;

[27] Greg Aharonian’s service PAT-News has observed for ex. that those filing software patents deliberately avoid citing prior-art, thus influencing the citations that are found by the Examiner.

- Patents do not cover the area and non-patentable research results become central to establishing novelty. The examiner has no recourse to patents and must therefore cite NPL.

- The specific area in question is evolving so quickly that the lag in published patent documents from foreign patent offices prohibits reference to relevant patents. In this case, primarily the inventor's own published scientific papers are used.

- A company has earlier published its results in a journal (perhaps its own) to protect novelty instead of pursuing a patent. Subsequently, patents that are sought drawing on the idea(s) published in the journal. (Cf. Trade literature in the table below). Conference-proceedings can also be relevant in this connection.

Another problem that NPL is used to solve in the examination process are those cases in which prior-art exists in the form of patents, but such patents cannot be referenced because of language barriers.

- Reference to Japanese language patent documents is difficult, and the examiner therefore uses an English abstract service. In reality the reference is to a patent despite the fact that the reference is in form of a publication (cf. The "Other" column in the table below).

A last case where NPLs come into play is that where the prior-art is not patentable, though essential to establishing novelty and/or degree of inventiveness.

- The reference is to an idea that is itself not patentable, but nonetheless essential to the patent application in question. The examiner cites reference books (eg. an encyclopaedia) to establish the relationship.

The most robust connection between Non Patent Literature and the Scientific involvement in technical innovation is therefore to be found in the second motive listed above (i.e.. that publication gap in patents is significant given the pace of change in the sector). Citations made based on motive 4 and 3 are least relevant as indicators of spillovers from scientific research. In addition to journals, however, reference books and other books can also be a clear pointer to flows emanating from scientific sources. We are therefore most interested in citation patterns involving journals as well as books as indicators of science-technology links.

2.5.2.2. Distortion

In examining the Norwegian pattern, however, a second caveat should be mentioned. This is that the link to scientific knowledge bases can be distorted in the citation profiles. Especially one should be weary of the inflating effect of multiple citations by individual patents. In our set, one patent had a total of 38 citations to NPL. Grupp, Reiss & Schmoch (1990) indicate that frequency of reference is not necessarily an indication of scientific intensity, but that individual patents with large NPT citation trails can destabilize the citation populations. In this study, however we do not attempt to correct for this effect. Having investigated the citations to journals in this light, the number of citation a patent cites does indeed correlate with the types of knowledge the patent draws on.

2.6. Profile: Breakdown into different categories of Non-patent Literature References

This subsection presents what types of non-patent literature the industrial sectors cite. In following table, a raw distribution of the 716 NPL citations is given. It is broken down according to the ISIC classification of the citing class as above[28] and according to the type of NPL based on manual categorization. The table reveals that nearly 50% of all NPL citations involve combined linkages between two industrial sectors and two types of citation.[29]

[28] Here again we revert to the ISIC concordance table used above. This is because we can verify the citing class.

[29] The distribution is not corrected for distortions caused by extensive citation by individual patents.

Table 2.5. Distribution of 716 NPL citations made by 183 Norwegian patents between 1990-1996: Knowledge-receiving patents broken down according to ISIC classes and NPL according to type of publication.

121C lll\t'WE	JOURNALS	COllll:..b ElC	[illegible]OC BOOt<2	H\t'lllDBOOt<2	l [illegible]DE r1l.	OlHE	[illegible] 1Ol\t'r
Chemistry, except pharmacy	15	4	5	3	2	16	45
Computers & office machines	14	3	8	1	9	11	46
Electric mach., ex. Electronics	3	0	5	3	7	2	20
Food, beverages, tobacco	1	0	0	0	0	1	2
Motor vehicles	0	0	0	0	0	1	1
Pharmacy	166	12	26	7	6	5	222
Building and construction	0	1	0	0	0	0	1
Electronics	4	2	1	0	0	1	8
Ferrous basic metals	1	1	0	0	1	1	4
Instruments	153	21	18	8	14	5	219
Metal products, ex. Machines	12	3	1	0	5	2	23
Motor vehicles	0	0	0	0	0	1	1
Non-ferrous basic metals	8	0	5	0	0	0	13
Other industrial products	2	1	3	1	5	5	17
Other machinery	7	2	16	3	6	10	44
Paper, printing and publishing	0	0	0	1	20	0	21
Shipbuilding	2	1	0	0	3	1	7
Stone, clay and glass products	0	0	0	0	1	0	1
Not identified	7	0	3	1	8	0	19
1Ol\fr [illegible]o s s s cs2	3a3	2 [illegible]	a [illegible]	8	8i		i [illegible]

2.6.1. Important Recipients of Scientific Spillovers

The two industries that dominated as recipients of spillovers from non-patent literature are Pharmacy (222 citations) and Instruments (219). Together they claim over 60% of such citations, dominating citations to especially journals and books. The reason for this concentration is not simple and must involve several factors. The main factors however must include the proximity to a so-called science-base of these technologies, their complexity, their growth and thus their stronger than average need to differentiate the individual technologies from the fields' prior-art. To illustrate, notice the differences between citations received by Pharmacy and those by Chemicals (45) or between those received by Instruments and the other categories involving machinery, including Computers and Office Machines (46). These differences are disproportionate, suggesting that there is something extraordinary both in the science-based element of these fields and, perhaps moreover, in their need to differentiate from the state of the art. This latter feature indicates these are technologies that are growing quickly.[30]

In contrast, note that the traditional technological areas such as Shipbuilding, or Building and Construction, which dominate the patent citations, cite very few non-patent sources: it is perhaps more surprising that the do site some. Particularly the broad field of Other Machinery (44) is remarkable here.

2.6.2. Important sources of Scientific spillovers.

The degree to which these citing industries are concentrated correlates with the concentration of what types of NPL are accessed. Citations to journals and books (handbooks + books) are the preferred sources of the dominant fields of Pharmacy and Instruments and therefore also account for the majority of citation generation activity. Over 65% of the NPL-citations are made to these sources. In addition to these dominant fields, only Chemicals, Computers, certain Metals and Other machinery make reference to these. A closer look at what type of journals are cited will be conducted in the next section (2.8)

The most important source for non-patent citations for three of the other industries is meanwhile, trade-literature. The Paper and Publishing industry is, perhaps not surprisingly, over-represented in this respect with 20 of its 21 citations going to this source. Electronics and Other Machinery also cite trade-literature most often. But what does that tell us? Certainly non-objective trade-press does not include the same type of knowledge that a peer-review article would. Yes, but that does not rule out that the trade press is an important way for firms involved in certain technologies to keep themselves oriented in their fields and learn about the latest developments. For some industries trade-literature might therefore perform a parallel function to the codification of knowledge in industry-specific journals and should not be discounted out of hand. Especially in cases where inventors of the state of the art have previously adopted a policy of secrecy to protect their innovations. (cf. reason 5 from Grupp and Schmoch, above) In addition, the delay between the invention and its codification in a patent or an article might be considerably longer than that of the

[30] Another feature might be that relevant technologies are difficult to codify in a patent and therefore necessitate more extensive body of reference.

press-reports (cf. the press's role in the launch of Mercedes' reinvention of the automobile)

2.7. Focus on references to scientific journals

Nonetheless, journals undoubtedly provide the most reliable indication of spillovers of scientific knowledge. This in turn raises the question of what types of scientific knowledge Norwegian patented technologies rely on. In the final table, we break down the 393 citations to journals according to field in order to indicate where the most important scientific knowledge spillovers emanate. The cited journals are associated to scientific field through the Science Citation Index classification system.

Table2.5: Norwegian patent citation to journals: Classified according to SCI correspondence between journals and scientific field

1:.		� Ol L l.
	Grand Total	393
1	Chemistry	101
2	Biology & Biochemistry	90
3	Clinical Medicine	87
4	Engineering	34
5	Multidisciplinary	23
6	unknown	14
7	Material science	11
8	Immunology	8
9	Physics	7
10	Computer Sciences	7
11	Non-refereed journals	5
12	Geo-sciences	4
13	Geophysics	3
14	Pharmacology	3
15	Education	1

Norwegian patents in our period cite 13 different scientific fields. In addition there are 5 references to non-refereed journals and 14 to journals that could not be classified, as well as an umbrella group titled 'multi-disciplinary with 23 references. The question then becomes; what is the interrelationship between these knowledge generating areas and the knowledge recipients?

In terms of scientific knowledge, the NPL citations can be broadly grouped into three, not discrete natural science areas: biology, chemistry and physics. In addition, a considerable number of citations are found either in unknown or 'multi-disciplinary' categories which can be seen as overarching the population. The breakdown into these fields and their areas of application can be presented in this way:

I. Chemical sciences and their applications:

Chemistry: Theory and its application in industrial chemicals, such as bulk chemicals

Biochemistry: Theory and its application essentially to drugs and instruments.

II. Biological sciences

This group can be said to involve essentially Medical Sciences. These include areas of Chemistry, Immunology, Pharmacology, Biology/Biochemistry and Clinical Medicine. Again the application is to drugs and instruments.

III. Physical and Earth Sciences and their applications;

Physics; Theory and its application to Engineering, Materials, Computer sciences and Earth sciences, especially geo-physics. Industrial applications include civil-engineering, specialty-machinery and seismic instruments.

IV. Others

Multi-disciplinary and educational devices.

The conclusion is that the citation-generating areas mirror the dominant citation-receiving areas above. It is therefore not surprising that a range of medical sciences are prevalent in the population. In addition to a sub-areas of Chemistry (eg. Fine Chemicals), the predominance of the fields of *biochemistry*, *clinical medicine, immunology, and pharmacology* accords with the fact that Pharmacy and to a lesser degree, Instruments, are dominant recipients of science spillovers. Engineering, Material Science and Computer Science attest to connections with Instruments as well as the more specific fields of Metals, Machinery and Computers.

3. Conclusion

In this report, we have explored the questions of knowledge-creation and knowledge-distribution in the Norwegian case using patent-data as our lens. Our analysis of patent-data to identify and explore these phenomena has significantly conditioned the type of knowledge we observed (i.e.. technical competencies) and how we have observed it. It is therefore necessary that the results be read with some understanding of what patent-based information can tell us. We have therefore included considerable material concerning the application of the patent-share and patent-citation types of analysis that have laid the basis for the two sections of this study. Moreover, this analysis is meant to supplement the case-studies, historical studies, and more closely aligned, bibliometrics and technology-spillovers sections of the wider Mapping-Project.

3.1. Knowledge-Creation

3.1.1. Agents

In terms of knowledge-creation, we noted a marked concentration as to the types of agents involved. Large corporations rooted in a range of traditional industries dominate the knowledge bases that are visible through patent-counts. Especially, the diversified, multi-national Norsk Hydro Concern figures prominently with 16% of Norwegian patents granted in the US in our period. A second group of dominant actors include smaller, newer more niche-oriented companies involved for example in computers (Tandberg Data), drugs and imaging equipment (Nycomed), specialty instruments (GECO), or Ski-equipment (*Rottefella*). A third group that overlaps the first two should be mentioned. Companies oriented around the offshore oil-business goes through the list, with Statoil as its largest representative.

3.1.2. Industrial activities and patents

The patents issued to Norwegian assignees significantly reflects the industries of the these dominant firms. When the primary patent classes of Norwegian patents was connected to industrial activity the following technical knowledge bases were especially dominant: machinery, professional instruments, metal products, drugs and medicines, Construction, Shipbuilding and Computers. A glance back in time (to

1960: allowing for comparison difficulties) reveals that certain knowledge bases especially concerning machinery/civil engineering and ship-building have figured prominently in Norwegian patenting activity in the US for long periods of time. Around such base technologies however the orientation of the most prominent knowledge bases has changed; with new technologies entering into(eg. pharmaceuticals)and some exiting (eg. metals) from the view of the patent-lens.

3.1.3. Specialization in Norwegian patent-claims

Norwegian patenting in the US demonstrated comparative strengths in many of these industrial activities. Norwegian patent claims in 1990-93 showed a pattern of specialization in ship-building, oil related engineering, certain areas of chemistry and some process-engineering including metal-working. In these areas, Norwegian patent claims were over-represented in terms of the total body of Norwegian patents granted in the US.

3.2. Knowledge-interactions

In the second part of our analysis we looked at how the knowledge bases that became visible in the patent-share analysis above might interact with each other to create ‘knowledge spillovers’. Here we used first-page citations first to other patents, to illustrate technology-linkages, and second to journals and other types of publications, to indicate linkages with ‘science-bases’.

3.2.1. Technology-linkages

In our citation-analysis we found five significant linkages between those areas in which Norwegians were granted patents in the US in our time-period and those areas which those patents cited. The technical area that was most central to these interactions was Machinery and Mechanical Engineering, which generated significant knowledge-spillovers to both Process-Engineering and to Instruments and which received spillovers from Civil Engineering. The inter-relationship between Chemicals +Pharmaceuticals and Process-Engineering is however the strongest, whereby a high level of mutual citation indicates that each knowledge-area contributes significantly to the other. The most significant generators of knowledge after Chemicals and Machinery are Electronics + Electricity and Civil Engineering.

In addition to Process-Engineering, the most significant recipient of technical knowledge is Instruments.

3.2.2. Science-based linkages

The citations between patents and scientific journals emphasized the roles of Instruments and Pharmaceuticals. These two areas are far and away the most-citing of non-patent-literature, indicating a closer tie to more science-based knowledge bases. Three types of scientific-knowledge are important to both these and other technical areas that rely on scientific knowledge; Chemical Sciences and their applications; Biological Sciences; Physical Sciences and their applications. In our survey of these areas, these knowledge sources were mainly accessed by patents involved in Pharmaceuticals, Chemistry, Instruments, Clinical Medicine, and Oil-related engineering.

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Storgaten 1, N-0155 Oslo, Norway
Telephone +47 2247 7310
Fax: +47 2242 9533
Web: http://www.sol.no/step/

STEP group

STEP-gruppen ble etablert i 1991 for å forsyne beslutningstakere med forskning knyttet til alle sider ved innovasjon og teknologisk endring, med særlig vekt på forholdet mellom innovasjon, økonomisk vekst og de samfunnsmessige omgivelser. Basis for gruppens arbeid er erkjennelsen av at utviklingen innen vitenskap og teknologi er fundamental for økonomisk vekst. Det gjenstår likevel mange uløste problemer omkring hvordan prosessen med vitenskapelig og teknologisk endring forløper, og hvordan denne prosessen får samfunnsmessige og økonomiske konsekvenser. Forståelse av denne prosessen er av stor betydning for utformingen og iverksettelsen av forsknings-, teknologi- og innovasjonspolitikken. Forskningen i STEP-gruppen er derfor sentrert omkring historiske, økonomiske, sosiologiske og organisatoriske spørsmål som er relevante for de brede feltene innovasjonspolitikk og økonomisk vekst.

The STEP-group was established in 1991 to support policy-makers with research on all aspects of innovation and technological change, with particular emphasis on the relationships between innovation, economic growth and the social context. The basis of the group's work is the recognition that science, technology and innovation are fundamental to economic growth; yet there remain many unresolved problems about how the processes of scientific and technological change actually occur, and about how they have social and economic impacts. Resolving such problems is central to the formation and implementation of science, technology and innovation policy. The research of the STEP group centres on historical, economic, social and organisational issues relevant for broad fields of innovation policy and economic growth.