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An excursion into the patent-bibliometrics of Norwegian patenting

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This paper makes the assumption that Norwegian patenting in the US reflects a quasi-universe of Norwegian technological capabilities. Based on this assumption, the paper combines a "patent-bibliometrics" and a "technometrics" approach to study other relevant bodies of knowledge these capabilities build upon. In order to study interactions at the "science-technology-innovation interface", the paper maps the citation patterns that radiate from the patent population (1990-96) to other areas of technology (patent-citations) and to science-bases (citations to Non-Patent Literature or NPL). The study identifies important technology-technology links that involve machinery, process-engineering and chemical and significant science-technology links that involve pharmaceuticals and instruments.

Introduction

In the context of the "globalizing economy", the role that country-specific factors play in the promotion of innovation has, somewhat paradoxically, attracted increased theoretical attention. The proposition that economic performance depends to a significant degree on the capabilities of individual nations to generate and assimilate new technological knowledge has been demonstrated by an increasing body of economic research. In this context, an important area of inquiry that continues to exercise economists of different stripes involves the systemic relationships between knowledge that is generated in one sector of the economy and knowledge-bases elsewhere. Whether it is in terms of "technological externalities", "learning" or "clusters", spillover-effects have been repeatedly acknowledged as playing an important role in innovation and the economy otherwise.

This paper draws on the considerable tradition of "technometrics"[1] and "patent bibliometrics"[2] to address spillover-effects in a Norwegian context. We set out to map interactions between important Norwegian knowledge-bases in technological space.

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We examine spillovers at what has been called "the science-technology-innovation interface",[3] in order to map potential channels of "knowledge-spillovers" in the Norwegian case. Both technology-links and science-based links are mapped.

Object and approach

In the globalizing climate of the "knowledge economy", the development of new knowledge is assuming an increasingly important role and so is the question of who controls such knowledge. The literature shows that, while the developer of such new knowledge may seek to appropriate exclusive profits from his invention, some of it will ultimately "spill over" to other actors, including imitators.[3] In general terms, the advantage of such unintended knowledge-spillovers will tend to spread through a circle of actors who are brought together by forces of geographic (e.g., national) and/or technological proximity. Therefore, the occurrence of knowledge-spillovers at the "science-technology-innovation interface" will, in a certain sense, facilitate a process of collective learning among these actors.

Analysis of knowledge-spillovers 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 in the form of the relationship between the user and producer of the technology, research co-operation of different areas or some other link–entails an exchange of knowledge between fields. It is as an inter-sector learning process in which the national level is important, for example due to common science and technology institutions. In a National Systems of Innovation set of terms, the "nation (acts) as a framework for interactive learning."[4]

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. Patterns in the way patent classes reference one-another have been used to construe such patterns of disembodied spillovers[5] at aggregate levels; to demonstrate the dimensions of "technological neighborhoods" among proximal technological areas;[6] or, in network analysis, to show the relationship between "science- and technology poles" and how skills can be mapped internationally.[7]

Data and method

Country-level patent data provide a tried, if not entirely true method for mapping areas of knowledge-interactions. The strength of a patent as a proxy for spillovers is that it embodies technological competencies that claim commercial potential and substantial novelty. For our analysis, it is important to emphasize however that the novelty criteria of patenting does not mean these competencies emerge in a vacuum. There are spillover-effects and indeed learning-effects involved. Antecedent and parallel bodies of knowledge can be traced by the references individual patents make to (i) other patents and (ii) other references, such as scientific journals.

Mapping these references can be used to indicate the wider knowledge-bases that the patent-applicants draw upon. The assumption that patents are a proxy for a population's technological capabilities is a strong one that needs to be vigorously qualified. The litany of weaknesses and biases implied by patent-data is well-known[8] but certain features should be recalled here. Not all technologies are patentable and not all inventive agents wish to patent their technologies. In fact, the propensity to patent can, to a significant degree, be country-specific, actor specific, and most systematically, sector-specific. Further, the motivations for first-page citations, especially of NPL, do not necessarily indicate spillover effects.[9]

Our analysis utilizes the US database for first-page of (utility) patents granted by the US Patent and Trademark Office (USPTO). The focus is on the 603 patents that have at least one Norwegian address for assignees and that have been granted in the 80 month period between January 1990 and June 1996. Thus, 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 are included.

The rationale for using patenting in the US stems from the hypothesis that, "each country has the same propensity to patent in the USA in relation to the size of its innovative activities."[10] The major strength of using patenting and US patenting in particular is that they have passed a (fairly) 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 technological capabilities. A knowledge-base in Norway must therefore pass a fairly stringent, partially sector-biased test to be noticed at all using this unit of analysis. The premise is that the knowledge-bases this analysis reflects represent a robust, though not comprehensive set of mature technological capabilities in the Norwegian economy.

The main advantages of the foreign-patenting-in-the-US approach can be summarized as follows:

- Patents granted in the US provide a comparable standard that corrects for institutional peculiarities found in different countries;
- 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;
- Patenting in the US involves relatively inexpensive processing charges and therefore does not necessarily exclude small and middle-sized enterprises that have viable patentable ideas but that cannot afford to pay high fees to protect them.

There are also some important disadvantages that should be borne in mind.

- US patent-grants exhibit a time-lag of 3 or more years after application in addition to a lag after first priority. In the Norwegian case this is generally about a year according to *Basberg*;[11]
- 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);
- Patenting in the US is susceptible to independent variables, such as export and macro-economic conditions, although *Basberg* demonstrated that the former does not play a significant role while the latter does in the Norwegian case (12);
- And, of special importance for the citation analysis, there tends to be an English-language bias in establishing prior-art through references to scientific literature.

There are three areas of this study:

(i) A Citation-matrix analysis to study technology-technology links underlying Norwegian patent-activity. Here, citations that the US patent-office examiners make to other patents on the first-page of granted patents are used to assemble a 6×6 technology flow matrix. In this analysis, the technological area of cited patents are understood as representing knowledge-bases that generate new knowledge and that flow over to the technological area of the citing patent. "Technical Areas" are defined through the OST/ISI Correspondence Table.[12]

(ii) A Network-analysis to identify "clans" of patenting activity at a disaggregated level. We use the UCINET network program[13] to locate so-called clans at disaggregated levels. This analysis tells us 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.

(iii) A Citation-analysis of Non-Patent Literature (NPL), especially scientific journals, to study technology-science links that underlie Norwegian patenting. The basis of such an approach was pioneered by *Carpenter, Cooper & Narin*[14] in identifying science intensive areas of technology, and followed up notably by the *Narin* et al. and by the ISI group.[15] The Merit Concordance Table[16] is here used to establish industrial affiliation of citing patents.

Results and discussion

Of the 405 patent-classes active in the US system, the 603 Norwegian patents in this study are found in 160. Within this range, Norwegian patenting shows tendencies towards specialization. Twenty-five 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 indicates that there exists identifiable patent-sensitive knowledge bases.

Norwegian technological competencies appear through the patent-lens to be relatively stable. *Basberg*[11] presents evidence of the top classes in which Norwegians were granted patents in the US in the period of 1962-1980. A comparison of this profile with that of our period of 1990-1996 reveals that 10 of the top 15 dominant classes in the first period remain in the top 25 classes in the second. The degree of continuity is especially high in the areas of "hydraulic and earth engineering" and "ships". Further, the importance of these stable technological capabilities is corroborated[17] by a Revealed Technological Advantage (RTA) analysis.* This analysis demonstrates that the ten classes that top the earlier and later period all continue to show evidence of Norwegian specialization in the later period. Again the areas of "earth engineering" and ship-building are the two classes in which Norwegians exhibit the greatest degree of specialization in relationship to the total universe of US patenting.

The patent-specialization pattern that is indicated by this population corresponds with rudimentary evidence from the general Norwegian industrial structure and with trade-statistics. A look at the industrial activities of the dominant Norwegian assignees of the patent-population, for instance, indicates a fairly close correspondence with Norwegian exports to the US. Norwegian patenting in the US is dominated by several large corporations whose activities such as industrial chemicals, data storage and electro-metallurgy correspond with prominent Norwegian export sectors.** However, a closer analysis needs to be carried out before any conclusions on the size to patent-grant relationship can be drawn.

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* For the application of the RTA approach to patenting, see Ref. 18.

** The third, forth and six largest exports to the US after oil. See Statistics Canada. Note however *Basberg*'s finding (1984) that US export markets do not constitute an active variable for Norwegian patenting activity.

To give a general illustration of how well patenting corresponds to the industrial structure of Norway, Table 1 associates Norwegian patents with ISIC industrial sectors using the Merit Correspondence Key,[16] which are given in descending order. Noting that this correspondence combines different levels of aggregation, we can nonetheless get a picture of the respective size of the industrial sectors. Table 1 reveals that of the top 15 patenting industries listed below, all but one is also among the largest 20 industries in the Norwegian economy, ranked by industrial value-added.* In addition several of these sectors are among the fastest growing in the period between 1985-1993. Notable among these are the foods and beverage sector, shipping professional & scientific instruments and computers & office machines. Note that Machinery includes oil-rigs.

Table 1
Patenting and Industrial Structure: Rankings of the 15 most patenting industrial sectors (1990-96) in terms of their importance in the Norwegian economy (1992): Rankings of the different industrial levels are in terms of industrial value-added

Industrial Sector (ISIC 2)	Patents 1990-1996*	Industrial size: rank** (1992)
3820(except 3825):Machinery	109	1
3850: Professional & scientific instruments	93	19
3810 Metal products, ex. Machines	57	6
3522: Pharmacy; drugs and medicine	51	15
5000:Building and construction	47	N/A
3841:Shipbuilding	41	3
3825: Computers & office machines	38	37
3510+3520 (except3522) : Chemistry, except pharmacy	36	9
3900:Other industrial products (e.g., agriculture)	21	N/A
3600:Stone, clay and glass products	20	20
3830 (except3832): Electric mach., ex. Electronics	19	7
3832:Electronics	17	13
3710:Ferrous basic metals	16	13
3720:Non-ferrous basic metals	9	8
3100: Food, beverages, tobacco	8	2

Source: Statistics Norway and The Step-Group.
*Number of patents granted from 1990-June 1996, arranged by number.
**ISIC, ranked from largest (=1) for the respective level of aggregation (2-, 3- and 4-level). Ranked by industrial value-added in market prices.

* We emphasize that the Table 1 does include several levels of aggregation which makes comparison difficult. The ranking of the industrial sector is therefore made both for the 3 and the 4 level. Table 1 is presented here for illustrative purposes only.

Technological capabilities and knowledge spillovers

The knowledge-bases in which Norwegians demonstrate innovative technological capabilities do not exist in isolation. Significant interaction takes place between these knowledge-bases and this interaction supports the Norwegian knowledge-system as a whole. In the following, the interaction that occurs between those knowledge-bases that generate technological spillovers and those that receive them in the Norwegian case is studied.

The following 6×6 matrix presents the references made by patents to other patents that are outside the citing class but still among the 160 classes in which Norwegian patents were granted in the period. 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 knowledge-community emanates from sources outside the "original" patent-class. The remaining 2/3 of the citations are the self-referencing patent-classes.

Table 2
Cited-Citing matrix: Flows between Knowledge-Generating areas and Knowledge-Receiving areas as percentage of all inter-class citations. (N=1,089)

	CITING TECHNICAL AREAS								
CITED TECHNICAL AREA	I %	II %	III %	IV %	V %	VI %	Dia-gonal	% gene-rated	% Net citations generated
I ELECTRICITY: ELECTRONICS	13.8	3.8	0.1	0.9	1.3	0.0		19.8	6.1
II INSTRUMENTS	1.4	5.7	1.9	0.6	1.4	0.2		11.2	5.5
III CHEMISTRY: PHARMACEUTICS	0.3	0.7	18.4	3.6	0.7	0.3		24.0	5.6
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
Diagonal							60.7		
Total Citations Received, % of total	17.7	14.3	25.5	11.7	25.3	5.5			
Net Citations Received (minus inter-area citations): % of total	3.9	8.6	7.2	9.0	8.4	2.2			

In this context, it is interesting to identify the areas that generate knowledge and those that access knowledge as revealed by the citation patterns. The matrix in Table 2 describes 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 observations that can be made on this relation:

- 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., the diagonal) account for over 60% of the total flows between different classes. If we remove the flows that occur within the diagonal, we get a picture of the percentage of total citations that each area generates for or receives exclusively from, other technical areas. The percentage of citations generated for application in other areas is a net value that is provided in the last column; likewise, the last row provides the net percentage of citations that each area received from outside areas. We will consider both the most significant intra-area flows as well those of inter-area linkages.
- Lastly, three technical areas emerge as providing more citations to other areas than it receives from these and are therefore labeled "net generators of knowledge spillovers". The other three are "net-recipients". It should be noted that these areas are not isomorphic but are composed of a different number of classes.

In order to identify "significant" linkages between Technical Areas, several conditions had to be met. In this study, significant linkages are those, (i) in which flows are robust in absolute terms (the interaction between the Technical Areas comprises at least 5% or 54 citations of the total); (ii) in which the strongest linkage between the areas makes up a significant percentage of the outward flow for the area that primarily generates; and, (iii) in which the strongest linkage makes up a significant percentage of the inward flow of the recipient area. According to these conditions, five significant linkages connect areas of technological capabilities in the Norwegian system. These are ranked according to total volume that flows between the pairs in both directions.

- Chemicals & Pharmaceuticals + Process-Engineering pair. Although the one-way link 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.

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 Table 2. The broad Machinery and Mechanical Engineering Area is involved in three of the five pairs, twice as the prime 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. It 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.

Strong areas of interaction at the class-level

Much of the interaction between these areas involve a relatively small number of patent-classes which are very active in accessing knowledge from other areas technological capabilities. We therefore refine the focus to identify especially strong linkages between different individual classes. Here the analysis included all 3,234 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" that systematically appear in citing-cited pairs in the Norwegian patent citations. These clans are sets of classes that 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 four inter-linking member-classes using the network program, UCINET. Using this method, two major constellations were identified. The first is a relatively homogeneous area involving pharmaceuticals and the second is a more heterogeneous area involving mechanical engineering.

The pharmaceuticals constellation includes three clans with a common center at US class 424; "drug, bio-affecting and body treating compositions". These clans demonstrate first and foremost the strong intra-area ties found above in the Chemicals and Pharmaceuticals Technical Area. They also involve a number of patent-classes in which Norwegians specialize. Five of the nine classes (424, 426, 514, 436 and 536) of these three clans are classes in which Norwegian demonstrate a revealed technological advantage.

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 spillover. In relation to 424, Class 435 is used in the production of 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 2 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 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.

The second constellation involves a more heterogeneous set of technical areas and sub-areas, with a materials-engineering core. There is a total of seven classes that overlap in the three clans. Three of these (52, 75 and 264) are technological capabilities in which Norwegians specialize according to the RTA test.

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

Table 3
"Clans" of patents involving medical technologies

Pharmaceuticals and Instruments			
Clan 1			
424	Drug, bioaffecting and body treating compositions	III. Chemistry: pharmaceuticals	11. Pharmaceutics, cosmetics
425	Plastic article or earthen ware 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

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 integrates 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. 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 4
"Clans" of patents involving Engineering technologies

Mechanical and Process Engineering			
US-Class	US Class title	Technical Area	Technical Sub-areas
Clan 1			
52	Static structures (e.g., buildings)	VI. Consumer goods, civil engineering	30. civil engineering, building, mining
75	Specialized metallurgical processes,	III. Chemistry: pharmaceutics	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

Technology-science linkages

The final stage of our excursion brings us to patent-bibliometrics proper as we look for evidence in Non-patent-literature (NPL)-citations of science-technology linkages. 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 (e.g., trade literature, conference proceedings) a total of 716 times. Reviewing the caveats about the use of NPL literature[10] it is clear that not all of these citations represent direct knowledge linkages between scientific and technical knowledge areas but that, in general NPL, "can be taken as representative for the scientific bases of the citing patents."[10]

Table 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.

ISIC NAME	Journals	Conf. Proceed. etc.	Books	Hand-books	Trade lit.	Other	Total	Citation/ /patent (average)
Pharmacy	166	12	26	7	6	5	222	**4.4**
Paper, printing and publishing	0	0	0	1	20	0	21	**3.5**
Instruments	153	21	18	8	14	5	219	**2.4**
Non-ferrous basic metals	8	0	5	0	0	0	13	**1.4**
Chemistry, except pharmacy	15	4	5	3	2	16	45	**1.3**
Computers & office machines	14	3	8	1	9	11	46	**1.2**
Electric mach., ex. Electronics	3	0	5	3	7	2	20	**1.1**
Other industrial products	2	1	3	1	5	5	17	**0.8**
Not identified	7	0	3	1	8	0	19	**0.6**
Electronics	4	2	1	0	0	1	8	**0.5**
Metal products, ex. Machines	12	3	1	0	5	2	23	**0.4**
Other machinery	7	2	16	3	6	10	44	**0.4**
Ferrous basic metals	1	1	0	0	1	1	4	**0.3**
Food, beverages, tobacco	1	0	0	0	0	1	2	**0.3**
Shipbuilding	2	1	0	0	3	1	7	**0.2**
Motor vehicles	0	0	0	0	0	1	1	**0.1**
Stone, clay and glass products	0	0	0	0	1	0	1	**0.1**
Building and construction	0	1	0	0	0	0	1	**0.0**
TOTAL # of references	**395**	**51**	**91**	**28**	**87**	**61**	**713**	**1.1**

In Table 5, patents that cite NPL are broken down according to the ISIC classification (again using the Merit correspondence key) of the citing class and according to the type of NPL based on manual categorization of "journals", "conference proceedings", etc. Table 5 presents the raw numbers of citations from each category of patent for each category of NPL. In addition, the final column of the Table indicates the average number of citations to NPL calculated on the basis of all patents in each category.

The 603 patents of the population make an average of 1.1 citations to NPL, although fully two-thirds of the patents make no such reference. If we normalize for the industrial sector of the patent-population, the six industries that are listed first in the Table cite NPL more than average. Of these, however, it is especially the Pharmacy, the Paper, Printing and Publishing and the Instruments sectors that distinguish themselves, with over double the average rate of NPL citations.

In the case of Paper, Printing and Publishing, we observe that there are only a few patents that cite almost exclusively Trade-Literature. Pharmacy and Instruments, on the contrary, combine both relatively large numbers of patents with large numbers of citations, especially to journals. This robust relation makes them most relevant to a discussion to technology-science links.

Pharmacy (222 citations or an average of 4.4 citations per patent) and Instruments (219 or an average of 2.4 citations per patent) are the two industries that dominate as recipients of spillovers from non-patent literature. Together they claim over 60% of such citations, dominating especially those to 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. 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 they do cite some. Particularly the broad field of Other Machinery (44) is remarkable here.

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.

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.

Table 6
Norwegian patent citation to journals: Classified according to SCI correspondence between journals and scientific field

Field		# of ref.
	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:

1. Chemical sciences and their applications: Chemistry and its application in industrial chemicals, such as bulk chemicals. Biochemistry: Theory and its application essentially to drugs and instruments.
2. 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.
3. 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.
4. 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 (e.g., 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.

Conclusion

This excursion into the patent-bibliometrics of Norwegian patents has revealed a number of interesting links that tie Norwegian technological capabilities to other knowledge-bases. In the "technometrics" analysis, the paper identified five significant interrelationships that involve different types of technical knowledge. The technical area that was shown to be most central to technology-technology interactions was Machinery and Mechanical Engineering. It generated significant knowledge-spillovers both to Process-Engineering and to Instruments and it was on the receiving end of significant spillovers from Civil Engineering. The relationship between Chemicals & Pharmaceuticals and Process-Engineering, however, was the strongest, owing to its high level of mutual citations. It was demonstrated that each knowledge-area contributed significant spillovers to the other. The findings of the matrix-analysis was supported by the disaggregated identification of "clans" of patent-classes which cited and were cited by each other. Here too, chemicals and engineering figured centrally.

In the bibliometric analysis, the paper's study of citations between patents and scientific journals emphasized linkages to Instruments and to Pharmaceuticals. These two technical areas were far and away the most-citing of non-patent-literature and tended to indicate a close tie to science-based knowledge bases. Three types of scientific-knowledge were shown to be important to both these and other technical areas, 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.

This excursion into patent bibliometrics also emphasized the limitations and conditions that are intrinsic to this type of analysis. The findings of the paper should therefore be read with these in mind. On the background of this excursion, further analysis should be made into the nature of the linkages. One approach to technology-technology links would be to look at the relationship between primary and secondary classes of the patent population: the profile of this relationship could be compared with the relationship between cited and citing patents to see if their results were similar. Further, it would be interesting to study the population of cited patents more closely, in order to find other more direct signs of spillovers between cited and citing patents. A deeper analysis could also look at Norwegian domestic patenting. Domestic patenting might give better evidence of actual flows of spillovers in the economy. In turn, deeper analysis of patent-bibliometrics could be combined with other types of analysis, for example industrial sector studies.

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