Patents and publications as sources of novel and inventive knowledge

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Abstract:

This paper briefly reviews the knowledge-generation process and explores to what degree technical and scientific knowledge from prior art anticipates novelty or the inventive step of an invention. Inventions are novel if they have not been described (in the public) before, and they are inventive if the technical solution was non-obvious to a skilled person in the field. We employ a novel approach of patent citation analysis to investigate this phenomenon. Since in this context common approaches of such citation analysis are biased (usually, citations are neither exhaustive nor relevant in their entirety), we focus on examination reports of European patent applications and the references given therein. Our findings reveal that particularly technical knowledge comprised in patents serves as a source of novelty, while scientific knowledge frequently stems from multiple scientific papers and accounts for the inventive step. In addition, it is found that in many cases scientific knowledge is of commercial relevance and therefore constitutes more than general background information that aids the technical knowledge generation process.

Keywords: Patent citation analysis, Examination reports, Novelty and inventive step, Technological search; Swanson-type discovery

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1. Introduction

This paper contributes to the literature of technical knowledge generation. There are different scientific communities doing research in this field. Our approach presents a step to combine findings from management and information science. We first illustrate major aspects of these two research domains that altogether describe the knowledge creation process as a new combination of established knowledge domains that itself may be similar or distant in nature. In our analysis we subsequently focus on the generation of technical knowledge through inventors, as it is contained in patents. Peculiarities in the patent system allow us to conduct a more fine-grained analysis on which sources, of technical or scientific kind, help creating novel ideas and establishing an inventive step. Our analytical approach comprises the analysis of references, not given in patents but in examination reports of rejected European patents. These reports provide the necessary information to assess if a source of prior art relates to either novelty or the inventive step. We also compare the amount and nature of the references provided in such examination reports with references given in the full-text or search reports of patents. Here, we find that they only partially overlap, which also means that our approach of studying examination reports should provide better insights than the data commonly used for citation analyses. In a next step, we closer examine the results of our citation analysis, and finally draw conclusions on how new technical knowledge stems from sources that help creating novel and inventive ideas, and where knowledge discovery systems may successfully be employed. The outline of our paper can also be found in Figure 1.

{insert Figure 1 about here}

2. Theory on knowledge creation

2.1 Management Science and knowledge generation

The related management science literature focuses mainly on the management process of how newly generated scientific or technical knowledge can be turned into successful products. Nevertheless, there are few attempts to describe how such knowledge is actually generated within a firm. The term 'within a firm' means that the explanations are not necessarily limited to scientific or technical knowledge, even though these fields frequently serve as the basis for the explanations. NONAKA ET AL. (2000) developed a framework for such knowledge generation processes as a combination of socialization, where tacit knowledge is transferred between individuals; externalization, where tacit knowledge is made explicit; the combination of various pieces of explicit knowledge; and internalization, where explicit knowledge becomes tacit. The terminology 'tacit' and 'explicit' goes back to POLANYI (1966).

Other scholars in the management science area focus on the combination of previously known technical concepts (SCHUMPETER, 1952; NELSON & WINTER, 1982). FLEMING (2001) and FLEMING & SORENSON (2004) build on this concept of new combinations and further investigate it with respect to technical knowledge (defined as being patented) and scientific knowledge (defined as being published in the scientific literature). Their focus is the invention process where inventors have the possibility to search for and then combine different types of knowledge, a procedure they label "technological

search". The authors differentiate between local and distant search. Local search relates to changes of single, similar components of a more complex concept, or their substitution by another. Distant search, in contrast, is defined as the established combination of new technical components, or a new combination of established components, or even the new combination of new components. FLEMING (2001) finds that new technical knowledge created via distant search is less useful on average than technical knowledge created by local search, but it increases the likelihood of creating particularly useful technical knowledge. Possessing a broad technological knowledge base stimulates firms to conduct distant search (QUINTANA-GARCÍA & BENAVIDES-VELASCO, 2008). Furthermore, FLEMING & SORENSON (2004) reveal that searching scientific sources in the invention process is particularly helpful for local search: scientific discoveries and theories help the inventor by providing guidance which combinations would not lead to success, and by doing so, science helps to increase the technological search efficiency. They could show that scientific background knowledge for distant search, in contrast, hardly provides useful answers for inventors. In conclusion, the authors could show that scientific knowledge is a useful aid for creating technical knowledge.

2.2 Information science and knowledge generation

In information science, knowledge generation is frequently linked to retrieving knowledge from searchable documents, but this topic is hardly discussed on the basis of actually creating new knowledge. However, in the 1980s Don R. Swanson published some work on this topic, and his findings

have led to a stream of succeeding publications. Studying a wide range of literature, SWANSON (1986, 1987) found two bibliographically distant medical research fields that where logically connected. More specifically, he found papers on the effect of fish oil on regulating blood pressure in the human body, and papers on the effect of blood pressure on Raynaud's disease, a medical disorder. The two different areas of literature where neither connected via citation links, nor could one link them based on bibliographic coupling (KESSLER, 1963) or co-citation analysis (SMALL, 1973; MARSHAKOVA, 1973). Swanson describes the situation as bibliographic isolation of "complementary but noninteractive literatures" (SWANSON & SMALHEISER, 1997, p. 201) where there is only a logically connection leading to the hypothesis that fish oil is likely to have an effect on Raynaud's disease. He finally was able to establish the logical link between the bibliographically disparate areas by searching for keywords and terms extracted from titles and abstracts in the Medline database. Ever since, his findings could be confirmed by other scholars (GORDON & LINDSAY, 1996) and extended to other medical areas (SWANSON & SMALHEISER, 1997). In addition, various methodologies have been proposed to improve such knowledge discovery processes, for instance by structured keywords (KAJIKAWA ET AL., 2006) or natural language processing (NLP) (WEEBER ET AL., 2001). The reason why these approaches deliver useful results in comparison to citation-based methodologies is that there are substantial differences among semantic and citation-based similarities. The latter tend to describe knowledge flows that not necessarily need to be connected with similar contents (HARTER ET AL., 1993, STERNITZKE & BERGMANN, 2009).

Some scholars even envision the emerge of advanced text-mining tools that, one day, will enable scientists to come up with new discoveries and create new knowledge out of publicly available databases (GORDON & LINDSAY, 1996).

Independently from Swanson-type knowledge discovery, the fundamental principal of knowledge generation is basically the same as in management science: "Combining the retrieved information [from searches in literature databases] with his own experiments and observations, the scientist creates new scientific knowledge" (WEEBER ET AL., 2001, p. 548).

Combining the views from both management science and information science literature, one can conclude that distant search as described by FLEMING (2001) and FLEMING & SORENSON (2004) may, in a few cases, also occur as a Swanson-type discovery of isolated knowledge domains, even though the probability of finding such links is quite low with current bibliographic search tools.

2.3 From technological search to knowledge sources

Above, we have discussed the knowledge generation process from a technological search perspective. Both literatures from information and management science see new knowledge as something that was created out of existing knowledge pieces. From an information science standpoint it is interesting to investigate where such knowledge stems from. Therefore, the focus of our study lies on technical knowledge generation that finally leads to patented inventions. More exactly, we aim to investigate knowledge sources and their contribution to creating *novel* and *inventive* knowledge by

investigating the role of technical prior art (as expressed in cited patent documents) and scientific prior art (as expressed in cited scientific publications) for generating novelty and an inventive step. The results will help us understand – from a management and information science perspective – where to search for information that will enable inventors to (a) create knowledge more easily and (b) fulfill the criteria of patentability.

3. Methodology

3.1 Defining novelty and inventive step

Patents are an important source of technical knowledge (for a review, see ERNST, 1996). Inventors file patents, and patents frequently contain citations to relevant prior art, indicating the sources where the newly combined knowledge stems from. Patents are also legal documents that allow their holders to exclude others from practicing the invention described in the patent, granting the inventor a temporary monopoly on the market in order to reward the inventive effort and help amortize the past research and development efforts. The criteria for obtaining such a right are relatively high. Article 52 of the European Patent Convention (EPC), for instance, defines the criteria of patentability as follows: a patent shall be granted for inventions that are "new, involve an inventive step and are susceptible of industrial application". † The terms "new", "inventive step"‡ and "industrial application" are more clearly defined in the subsequent articles: "an invention shall be considered to be new if it does not form part of the state

† Since patent law is harmonized to a certain degree through the TRIPS agreements, these core criteria are basically the same in most countries worldwide.

‡ In the United States, the term „nonobviousness" is used alternatively for "inventive step".

of the art", whereas "the state of the art shall be held to comprise everything made available to the public by means of a written or oral description, by use, or in any other way, before the date of filing […] the […] patent application" (Art. 54 (1, 2) EPC). "An invention shall be considered as involving an inventive step if, having regard to the state of the art, it is not obvious to a person skilled in the art" (Art 56 (1) EPC). And, last but not least, "an invention shall be considered as susceptible of industrial application if it can be made or used in any kind of industry, including agriculture" (Art. 57 EPC).

In practice, the latter criterion is the easiest to fulfill, while the two former are the key points in patent examination, and both can help us in better understanding the generation of new knowledge. Hence, this differentiation into novelty and inventive step allows us to have a closer look at the technical knowledge generation process.

3.2 Examination reports as sources for relevant citations

As mentioned above, we employ citation analysis in order to answer our research question. Citations or references contained in patents have two sources: on the one hand they originate from the inventor or the person drafting the patent application, e.g. a patent attorney. As one would expect, the sources mentioned in this case should not describe something that will conflict the granting of the patent, i.e. anticipates novelty or inventive step of the application. On the other hand, references are added by the examiner. The former are contained in the full-text of the patent document, whereas the latter can be found in search reports or the references cited-section of the

patent documents. Frequently, patent examiners use references provided by the inventor and add some from own searches. So the lists in search reports or references cited-sections of granted patents comprise both. About 41 percent of the citations contained in the references cited-section in US patents originate from the examiners (SAMPAT, 2004; THOMPSON, 2004). This number is also somewhat reflected in the findings from JAFFE ET AL. (2000) who found that, when submitting the patent application, inventors knew about 70 percent of all references contained on the front page of US patents. In general, patent examiners tend to cite sources that are quite descriptive in nature (SCHMOCH & ET AL., 1988, p. 72; SCHMOCH, 1993, p. 195). US patent examiners, in particular, cite many sources that *might* be relevant (MEYER, 2000).

This paper chooses a different approach. We aim to investigate references that can be related to novelty and/or the inventive step and that are particularly relevant. The former goal can be achieved by studying examination reports of patent documents since examiners check novelty and inventive step of the claims by linking them to references found. This can be done manually by reading the argumentation of the patent examiners and assess if the references cited by them relate to novelty, the inventive step, or both. To our knowledge, examination reports have not been a data source in patent citation analysis so far. To assure relevancy of the references – our second goal – we focus solely on examination reports of patent documents that were *not* granted since the references contained therein disclose the invention already. In this case, patent examiners show a higher propensity to provide the necessary information regarding novelty and inventive step by

necessarily citing prior art that anticipates these aspects. The geographic focus of the study is Europe, with the European Patent Office (EPO) as the focal authority. The EPO and the World Intellectual Property Organization (WIPO) employ a coding procedure providing information if the reference alone is relevant, or the reference is relevant together with other sources. The former references are coded with X, the latter with Y. This data was included into our analysis as well. This information helps us to understand how relevant knowledge is, in fact, distributed across various sources, i.e. publications.

4. The dataset

All patent documents studied were so-called WO patent applications filed via the Patent Cooperation Treaty (PCT) and aiming at a variety of offices, among them, the EPO. The fields of study are organic fine chemicals, macromolecular chemistry, polymers, pharmaceuticals, cosmetics, and biotechnology, as defined via classes of the International Patent Classification (IPC) by DTI/OST. As mentioned before, all had failed in the examination procedure, whereas failure means that an official rejection of the patent application by the office could have occurred, or the application was withdrawn by the applicant, which in practice frequently occurs when the patent office had communicated severe objections against patentability. The sample was drawn from a set of PCT patent applications investigated in an earlier publication (see STERNITZKE, 2008) consisting of all PCT applications with priority dates between December 1-15, 1996. Excluding other technology fields and cases with incomplete data yielded in a dataset

of 79 patent applications. In many of these applications, malicious prior art was not the only reason for failure.

Search and examination reports were retrieved from EPOLINE, the European patent register. Patent family and classification information was retrieved from the Derwent World Patents Index (WPINDEX) database.

5. Results and Discussion

5.1 Methodology test

Before presenting our results related to our main research theme we will compare the results from our newly introduced citation analysis methodology and compare the results from studying patent examination reports with analyses based on examiner and full-text citations.

We therefore linked the references regarded as “malicious” in the examination report (i.e. anticipating novelty or the inventive step of the invention) to those mentioned in the International Search Report, a document prepared by an international search authority for all WO applications. In total, 70 percent of all patent references that were later considered to be “malicious” prior art had been mentioned in this report, and 57 percent of all nonpatent references. This means that relying on citation data from e.g. search reports, as is frequently contained in patent databases such as Derwent’s Patent Citation Index (DPCI), would (a) include many references that are not “malicious” regarding novelty or the inventive step, and (b) it would only include a subset of all relevant references.

A closer look at our dataset reveals that 20 patent applications out of the 79 documents identified had failed in the examination procedure even though

no “malicious” prior art was mentioned. The remaining 59 WO patent applications contained both patent as well as nonpatent references from the applicant, and only a subset was regarded to be “malicious” by the examiner.

5.2 Generating novelty and inventive step

In total, 125 patent references and 86 nonpatent references were found in the examination reports, indicating that a substantial amount of novel and inventive knowledge is contained in other sources than patents. We did not track the nature of nonpatent references as was done by e.g. HICKS ET AL. (2001) or CALLAERT ET AL. (2006), but they related to scientific articles/publications, in many cases from prestigious journals, but also conference proceedings, databases with genetic sequences, or books. Hence, contrary to what one would maybe expect, nonpatent sources are not just relevant for describing the general background of the invention (as one might conclude from the work of FLEMING & SORENSON (2004)), they, in fact, contain relevant knowledge that also seems to be commercially relevant.

So what will the more fine-grained structure of novelty and inventive step tell us about knowledge creation? Table 1 and 2 illustrate our findings. About two thirds of all patent references are novelty-related alone, signifying that these documents contain prior art that anticipated novelty in at least one claim of the patent application. About half of the patent references refer to the inventive step, alone or in combination with others. In contrast, nonpatent references are less relevant for rendering novelty of

claims obsolete; they seem to anticipate more the inventive step. We checked the significance of the findings by means of a chi-square test. It is found that patents contain significantly more novelty-related knowledge than nonpatent (scientific) publications, but the latter comprise significantly more knowledge relating to an inventive step that is dispersed over various sources.

{insert Tables 1 and 2 about here}

Coming back to the technological search process, especially the latter findings are in line with what has been found before: distant search may bring together ideas that may not be novel itself, but which, through combination, may represent an inventive step. Nevertheless, the fact that the scientific knowledge is distributed across various publications supports the picture given by FLEMING & SORENSON (2004), i.e. that scientific knowledge serves as a "map" where theories describe several paths, dead ends, etc. in the technological search process. Such as distribution across various sources underpins the necessity of individuals to possess the *capabilities for understanding* such dispersed knowledge and subsequently *combine* it in order to generate new knowledge.

The application of knowledge discovery tools, with the capabilities of performing Swanson-type discoveries, seems to be particularly fruitful in the scientific domain because relevant knowledge is distributed across various publications here, while fewer patents comprise relevant information.

6. Conclusions

Our analysis could show that the main source of new technical knowledge is knowledge stemming from patent documents. The latter generally disclose a substantial part of new knowledge, while scientific (nonpatent) sources frequently refer to *dispersed* pieces of knowledge that relate to the inventive step. Inventors therefore can improve their invention processes by searching relevant knowledge domains in order to create patentable inventions. Nevertheless, the fact that science both delivers novel and inventive knowledge raises doubts about the argumentation of FLEMING & SORENSON (2004) that scientific knowledge is only relevant for background information. Knowledge discovery systems with the capability of identifying logically connected but bibliographically distant research domains seem to be particularly useful when searching the landscape of scientific research where knowledge is highly distributed.

The analyses in this paper encounter several limitations. First, our focus lies solely on certain technology fields. The situation may be different in mechanical or electrical engineering than in chemicals or pharmaceuticals. But even among the latter areas there may be heterogeneity. Second, to demonstrate that prior art anticipates some claims, European patent examiners need to make references only to a minimum number of sources EPO (2005). This means that only a subset of references cited in search reports may be mentioned as being relevant in the examination report, even though more documents from the search report are relevant as well. Third, patent examiners tend to search primarily patent sources. If they already

find some relevant sources, they certainly won't continue their search in the nonpatent literature. This means that the effect of nonpatent literature may be underestimated. Fourth, some patent examiners tended to not assess the inventive step when novelty of a claim, a characteristic that is certainly easier to assess than the inventive step, was already rejected (e.g. see examination report for WO 9825944). This seems to be intuitive because it is sufficient to prevent a patent claim from being granted if one of the patentability requirements is not fulfilled. Other examiners did not follow this policy (e.g. see examination report for WO 9825961) and examined both novelty and inventive step. This might have led to an overestimation of the impact of novelty within prior art documents. Fifth, relevant prior art should also be available in a number of examination reports of patent applications that were subsequently granted. It is common during the examination process to modify or delete certain claims due to objections of the examiner that are rooted in "malicious" prior art. So the vast amount of examination reports relating to patents that were finally granted may also comprise relevant prior art references that could be included into future investigations.

Future research should not only expand the analysis to other technological fields, it should also question inventors on how different sources of knowledge are combined. Finally, it would also be interesting to explore to what extend (important) patents link bibliographically distant knowledge domains as described by SWANSON (1986, 1987).

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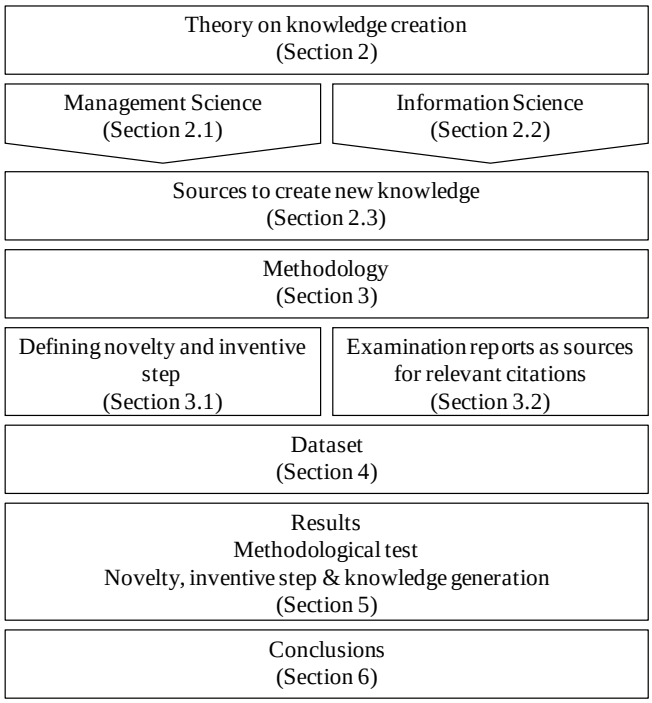

Figure 1: Framework of the paper.

Table 1: Distribution of references' purpose:

Type of reference	Patent references[§]	Nonpatent references[§]
Total	125 (100%)	86 (100%)
Novelty-related alone	80 (64.0%)	39 (45.3%)
Novelty-related together with others	2 (1.6%)	2 (2.3%)
Inventive step-related alone	35 (28.0%)	26 (30.2%)
Inventive step-related together with others	29 (23.2%)	32 (37.2%)

[§] more than one entry per reference possible.

Table 2: Chi-square test of the distribution of references' purpose

Type of reference	Number of references	Patent references[§]	Nonpatent references[§]
Novelty-related (single reference)	Observed	80	39
	Expected	70.9	48.1
Novelty-related (multiple references)	Observed	2	2
	Expected	2.4	1.6
Inventive step-related (single reference)	Observed	35	26
	Expected	36.4	24.6
Inventive step-related (multiple references)	Observed	29	32
	Expected	36.4	24.6
Total		125	86

[§] more than one entry per reference possible. p=0.077