Innovation Systems as Patent Networks

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**** This is a draft paper; the argument and analysis need further development. Any comments are very welcom. Please, however, do not quote without consent from the authors. ****

The National Innovation Systems – NIS – literature (Edquist 1997, Nelson 1993, Lundvall 1992) has become bogged down into case studies of how specific institutions affect innovation in a specific country. As Balzat & Hanusch (2004) argue: there is a need for NIS studies to develop complementary and also quantitative methods in order to generate new insights that are comparable across national borders.

In this paper we use data for patents granted by the World Intellectual Property Organization (WIPO), a UN organization, to map national innovation systems. Applying for a patent at the WIPO is relatively easy and allows the applicant to both apply in relevant markets afterwards, or establish their position vis-à-vis competitors.

Rather than analyzing in which fields, or sectors, patents are granted, which would meet with all the drawbacks that patents have as an indicator for innovation (cf. Kleinknecht *et al*., 2002), we use different information that can be drawn from patents. Patents are grouped into a primary class and secondary classes. Co-classification of a patent in two classes signifies a relation between these classes that is significant from the point of view of knowledge development and thus for a knowledge-based innovation system. Using social

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network analysis, we can map these co-classification among classes and thus determine what characterizes a national innovation system.

The main contribution of this paper may be methodological – as it adds to the repertoire of methods NIS studies use, but also as a different kind of information on patents is used – but we also contribute empirically. Using social network analysis of the complete set of 3287 patents granted by the WIPO to Dutch firms and individuals, we find that biotech, pharmaceutical and chemical technology, with applications in food and medication may be overtaking the traditionally dominant position of electronics / computer technology. Given that these technological fields and their associated industries show high propensities to patent, the dependence of the Dutch NIS on patent law thus increases.

1. National Innovation Systems

In terms of both direction and success rate, innovation performance differs widely across firms grouped by regions, sectors or specifically nations. At these aggregated levels, a system's approach has been popular since at least the early 1990s (Lundvall, 1988; Nelson 1993). A National Innovation Systems approach assumes that differences among the innovation performance across countries are due to their specificities and idiosyncrasies that will not (simply) disappear due to market processes. An institutional perspective is often invoked, claiming that both informal and formal institutions can be persistently different among countries in a way that affects innovation patterns and outcomes. Actors and networks are also referred to in this respect (Carlsson & Stankiewicz 1991), their workings perhaps best understood in terms of institutions and what they legitimately allow or prescribe (cf. Dolfsma & Verburg 2008). In this respect, and contra Bergek *et al*. (2008), a system can be more than an analytical abstract: it remains an empirical question whether or not at the national level one can perceive coherence in the institutional structure with regard to innovation.[3] The outcomes of the largely unplanned workings of an innovation system may thus be difficult to predict precisely, but can be approached. The NIS approach is an attractive starting point because of its coherence and usefulness for policy.

Using the nation as units of analysis, authors often refer to its institutions that help create new knowledge, such as strong universities, an attractive climate for private research institutes, possibilities for migrant knowledge workers to enter a country and a patent system. Many such institutions, and certainly the latter, also play a role in knowledge diffusion. A well-functioning education system, people's attitude towards taking the risk of setting up a new firm, or a country's laws with regard to for instance bankruptcy are other institutions that play a role in knowledge diffusion.[4]

While a useful approach in many ways, the promise of comparability across countries has been largely unmet (Edquist 2004; Liu & White 2001). This may be due to the heterogenous nature of the concept of NIS or its constituent parts (Bergek *et al*. 2008), but may as well be due to the empirical and case-study based approach taken as is evident in history-friendly analyses as in Nelson (1993). Quite a few studies inspired by a national innovation system idea have focused on a limited number of institutions, or even a single one, to study their effect on innovation direction and performance. The advantage of the approach – an awareness of idiosyncrasies – may then become a drawback since from up close the differences between systems stand out more than the similarities. It can thus be quite difficult to argue what causes the differences or the similarities when comparing between countries.

[3] Using a different indicator, Leydesdorff & Fritsch (2006) find that Germany cannot be considered integrated nationally as an innovation system, while the Netherlands can (Leydesdorff, Dolfsma & Van der Panne 2006).
[4] The NIS literature may be focused too much on knowledge creation, while knowledge diffusion may be of greater importance to the knowledge economy (Leydesdorff et al. 2006).

The choice of institutions and the choice regarding the aggregation level for analysis can differ substantially between studies, resulting in a situation where some believe that the approach has come to be stranded due to the case study approach adopted.

We concur with Balzat & Hanusch (2004) that it is possible to salvage a NIS analysis by developing additional, complementary approaches to the study of national innovation patterns. These include, but may not be restricted to, quantitative methods. One may have to sacrifice to some extent the attractive feature of a rich – or, as anthropologist Clifford Geertz (1973) calls it, “thick” – description as one focuses less on the workings of a system rather than the outcome, but one potentially gains as comparability and rigor is enhanced.

We propose to use patent data in a particular way, to study the outcomes of a National Innovation System. As a result, due to the interplay among actors within the system, their behaviour determined by extant institutions, both the direction of technological development as well as the robustness of that pattern emerge. While analysis of a particular NIS or of a particular set of players within a NIS allows for detailed analysis of the dynamics of a NIS (Storz 2008), the approach we opt for also allows for comparison over time of the way in which elements and functions of a NIS (Bergek et al. 2008; Liu & White 2001) produce innovations. This holds, we would argue, for both an analysis of national innovation systems as well as for an analysis of a sectoral or technological innovation system (Malerba & Orsenigo 1997). In this contribution our main emphasis will be on NIS.

While patent data offers a quantitative measure, they are often used in a rather unimaginative way. Patents granted are aggregated to the level of firms, regions, sectors or countries to determine the respective aggregate’s (potential) (future) significance. While patent data is shaped by institutions, and reflects information about applications that is the result of institutional configurations, they are not defined by institutions a priori. Institutions themselves are embedded in knowledge infrastructures, providing the technological opportunities that have to be interfaced with market positions and expected demand that agents can act upon. From this perspective, patent data offer a vastly more informative source of information. We analyse patents granted as a sediment of substantive-technical efforts by actors to develop new knowledge or find (non-obvious) applications for existing knowledge. Classes of patent applications, and particularly co-classifications, thus may be taken as an important indicator of a mutual knowledge basis within the boundaries of a system (Breschi *et al*., 2003; Leydesdorff, 2008). The network of co-classifications for patents, drawing on a unified and harmonized database, thus indicates the workings of a NIS and its relevant institutions.

2. Data and Method

2006 WIPO patents. Patents have been a widely used type of data for innovation studies, in part because of their availability. Patents granted in the United States, for many sectors the most important single market, are easily downloadable from the USPTO website. Such US data may not be relevant for the characterization of, for instance, a European country (Criscuolo 2006; Leydesdorff 2004). Patent data as a measure of innovativeness of a country, of a sector or of a firm has more generally come under increased discussion. Patents as an output measure of innovation is problematic – many of them do not have any commercial value for firms (Kleinknecht *et al*. 2002). As a result, the propensity to patent differs widely across industries (Arundel 2001). Yet, of all patents granted in the US, 55-75 percent lapse through failure to pay maintenance fees; if litigation against a patent's validity is a sign of commercial value of that patent, the fact that only 1.5% of patents are litigated and only 0.1

percent litigated to trial does not bode well (Lemley & Shapiro 2005; Dolfsma 2006). Many patents thus are applied for only for strategic reasons (cf. Granstrand 2000).

Patent databases are a much richer source of information, however. One can do much more than count the number of patents for each country or firm. Each patent is given a classification indicating its technological field. In addition, patent officers give co-classifications as well. The classification and co-classification indicates actual or potential knowledge transfer between different technological fields (Verspagen 2006). Based on the patents granted to a particular entity (firm, country), it can be established how the knowledge base of the entity can be characterized empirically.

Patent law, of course, tries to find a balance between the public interest of stimulating development of new and the wide diffusion of existing knowledge, on the one hand, and the private interest of profit, on the other. Whether or not it is true remains an empirical issue (Dolfsma 2006), but innovation is believed to be stimulated if innovators have a legal right to exclusively exploit the results of innovative efforts. However, the balance is struck differently in different countries (cf. OECD 1997), and noticeable in different ways. An important characteristic of the US patent law, which makes it unique, concerns who is deemed to have the right in an invention: the one who first files or the one who first invents. In the US the administratively less tractable first-to-invent may claim the rights. It is an example of public interests outweighing the private interests by providing a degree of certainty to the innovator applying for a patent as she can browse the patents applied for or granted to determine whether the knowledge embodied in a patent is already legally protected. In the US inventors who had not applied for a patent may even challenge a patent granted if they can convincingly show that they had been earlier to invent. On the other hand, in the US applicant only needs to publish the information contained in a patent after the patent is granted, while publication is required in Europe when a patent is applied for. As a patent application can be rejected, the inventor thus runs the risk of diffusing her knowledge without receiving the legal right to exclusive commercial exploitation in return. This clause in European patent legislation favors the public interest more.

The World Intellectual Property Organization (WIPO; www.wipo.org), an organization residing under the United Nations based in Geneva, offers the possibility to easily and cheaply apply for a patent. WIPO staff assists in drafting the patent application, which means that expensive additional technical and legal services that might be required for a European or US application need not be hired. The application for a patent submitted at WIPO can subsequently be submitted in other countries or jurisdictions as well within a specific time frame if commercially attractive. The legal systems of other countries recognize WIPO applications technically and legally. In addition, WIPO patents are part of the 'prior art' that patent officers need to consult in case they receive an application from a different party on a related technical invention. Such an application may then have to be rejected, or can relatively easily and cheaply be challenged in court by the patentee of a WIPO patent.

WIPO patent protection is thus an accessible means to obtain legal protection for an invention that may have industrial applications. Especially for parties that lack financial means, this makes applying for a WIPO patent attractive. Relatively small firms and parties from developing or emerging economies may find applying for a WIPO patent particularly attractive. Such parties may also have defensive motives to apply for a patent. Smaller firms are known to shy away from R&D deployment in areas where larger firms already have a patent position for fear of being sued by these firms (Lanjouw & Schankermann 2004).

Litigation in patent law, specifically in the US, has grown increasingly rife, where especially large firms reserve substantial funds to legally defend their patent position even if technically their position might not seem particularly strong. Much patenting, again in the US in particular, is thus of a offensively strategic nature (cf. Lemley & Shapiro 2005). Needless to say, the number of patents applied for has increased substantially in recent years, at the USPTO as well as at WIPO where strategic patenting is less dominant. As a source of information about technological development and innovation WIPO data are more valuable.

Together with the European Patent Office (EPO), a.o.,[5] WIPO invests substantial resources in developing the International Patent Classification (IPC). Currently the eighth edition is in use. Because of the standardized nature of the data presented in the WIPO database, patents registered there are a good source for data on innovation. Comparison across countries, or an analysis of a specific sector across country boundaries is also possible using this data. Needless to say, patent data from WIPO are not perfect as an indicator. As was notified the propensity to patent, for example, is known to differ substantially across sectors. On average only 35% of product and 25% of process innovations are patented (Arundel & Kabla 1998). The propensity to patent product innovation ranges between 8 and 80 percent. Other means may be deployed, and be deemed more important, to protect a firm's intellectual property. Secrecy is one of these.

Network analysis. We use classifications and co-classifications for patents to analyze the Dutch Innovation System as a network of related technological classes. 3287 Patents were granted to Dutch applications by WIPO from a total of 138.751 patents granted in 2006. Social Network Analysis allows one to construct a figure for the National Innovation System

[5] Inpadoc in Vienna, Austria.

(De Nooy *et al*. 2005). We analyse at the 4-digit level using raw patent data.[6] Circles in these figures are patent classes. Lines between classes indicate co-classication, while thickness of lines indicates the number of co-classifications. 624 different patent classes are identified. The thicker the lines, thus, the more knowledge is actually or potentially exchanged between the classes by actors active there. To enhance readibility, weaker relations between classes can be excluded from a picture.

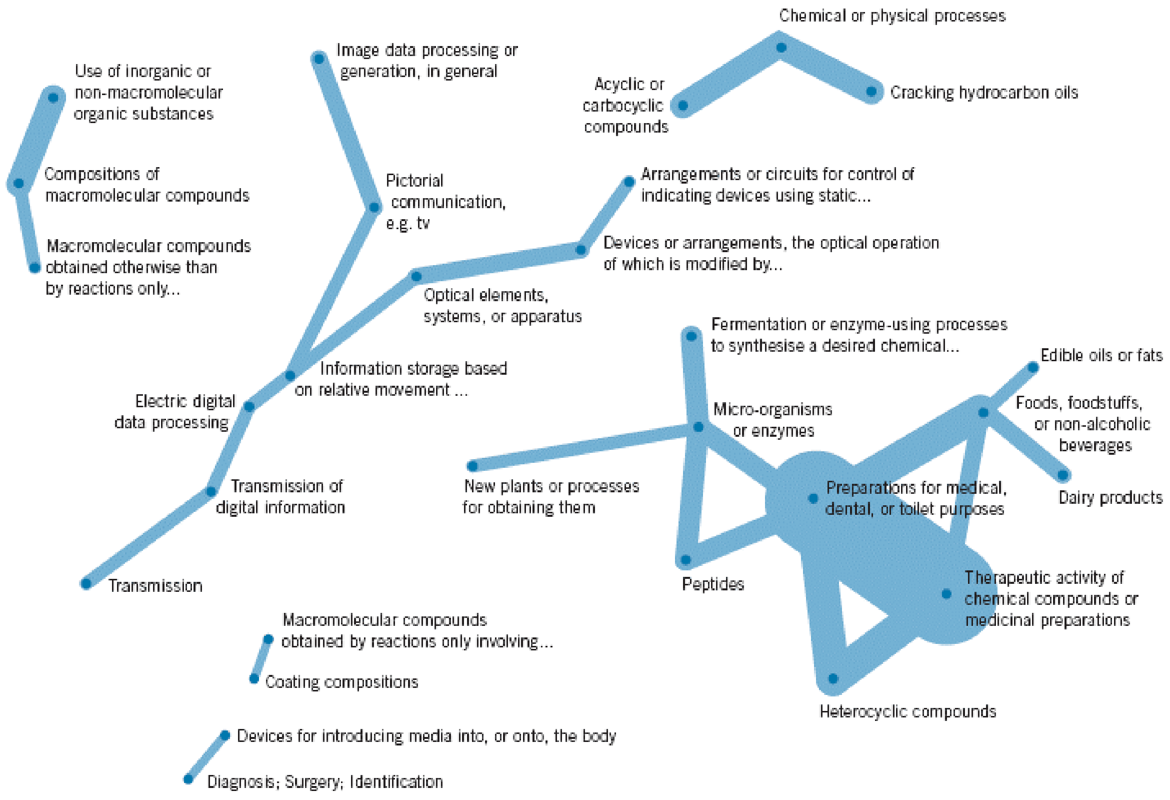


Figure 1: Patent classification categories and co-classification relations; core network for internationally registered Dutch patents, 2006. (N = 3287; raw data) Source: WIPO.

3. Results

[6] To deal with the indexer-effect since patent officers assign the additional classes for a patent, we use raw rather than normalized data. Pajek-input files containing normalised data for all countries are available at: http://www.leydesdorff.net/wipo06/index.htm

For any of the 132 countries where individuals or organizations are located that had been granted one of the 135,536 patents - showing a spread from 2 (Brunei Darussalam, Burundi, Cayman Islands, Côte D'Ivoire, Guatamala, San Marino, Seychelles, Tuvalu, Uzbekistan, Virgin Islands) to 48,190 (USA) - by the WIPO in 2006 a network analysis of the National Innovation Systems as a patent network can be provided. We would like to present two such analyses: one for an economically and technically developed country and one for an economically and technically emerging country. For purposes of interpretation of the results we take the Netherlands as a developed country and India as an emerging country.

The Dutch Innovation System. A factor analysis to find out if a cluster of patent classes among the 3287 patents granted to parties in the Netherlands can be determined based on the extent to which they co-classify (see Appendix I) provides little clues as to which patent classes may be combined to form factors that help explain variance in the data. The factor analysis is explored at the 3-digit aggregation level. Only a small fraction (11.82%) is explained clustering 9 factors. This indicates that the Dutch innovation system is quite dispersed, which may be a sign of its relative maturity.

Social Network Analysis offers as a highly attractive and informative possibility the option of visualization. Given the visualization of Figure 1, it is clear that the innovation complex around Eindhoven and the north of the Limburg province is strongly present. Some 50% of R&D formally spent by Dutch firms is spent in these two NUTS 3 regions. This is the electronics, computer and information processing technology, and optics cluster related to such firms as Philips, Océ, ASML, and supplying firms. A second large cluster is that of chemical technology, biotech, and pharmaceutical technology, especially with applications in medication and functional foods. Even though firms in these sectors are more likely to apply for patents in case of an innovation than firms in different sectors, the cluster is larger and more closely knit than expected. This domain is not generally recognized as important in the Dutch innovation cluster (REF), and is certainly a relatively younger cluster in terms of innovation focus. A new high-tech cluster seems to be developing.

In addition to these larger clusters of techno-economic activities, smaller clusters can be appreciated in the visualization. Chemical technology related to application in paints is visible in the network representation of the Dutch NIS despite the high threshold applied. DSM is active here. So is oil refining, with companies such as Royal Dutch/Shell, despite the focus on process innovation in this mature industry. Given the recent change in strategic emphasis of the Dutch industrial behemoth Philips, the cluster indicating medical diagnostic equipment may change too, and possibly move in the direction of the electronics / computing cluster. Packaging, for example of food stuffs, is on the verge of being included. It is a sector that develops new products that year-upon-year are perceived by experts to be highly innovative and valuable. Consumers have been impressed more by the functional food mostly by dairy industrialists such as Campina and Friesland food.

The National Innovation System in India. 936 Patents were granted in 2006 to parties located in India. Without throwing up a threshold of number of co-classifications any tie between two classes should have in order to enter the picture, the picture becomes quite difficult to read, let alone interprete (Fig. 2).

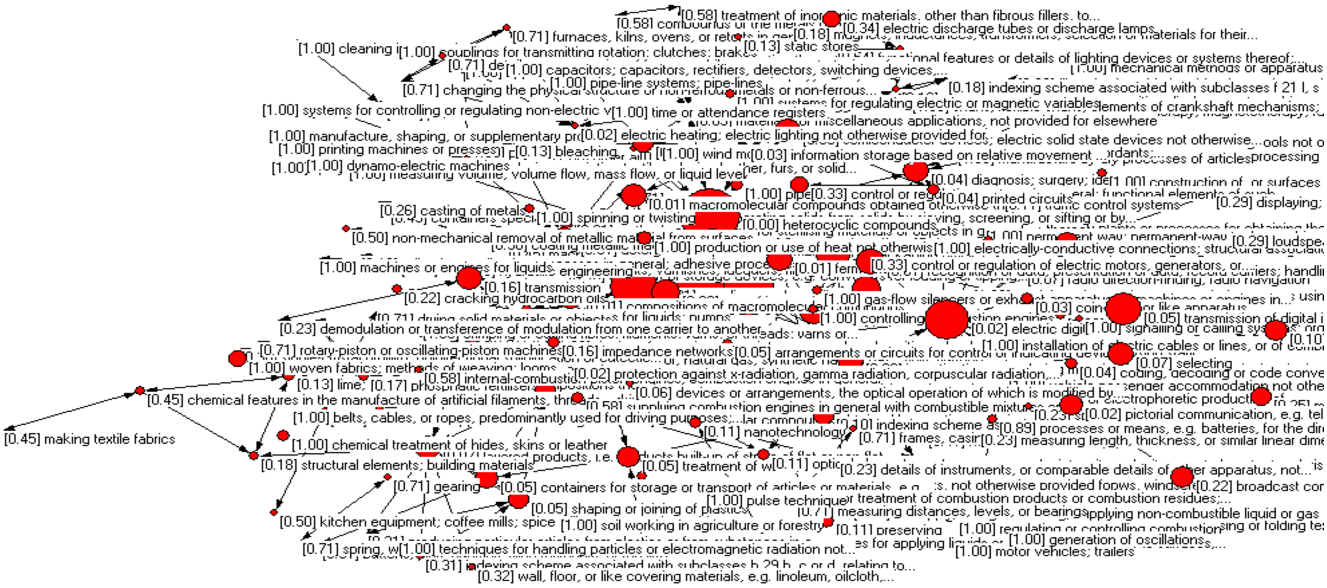


Figure 2: Patent classification categories and co-classification relations; full network for internationally registered Indian patents, 2006. ($N = 936$; cosine ≥ 0.05) Source: WIPO.

Throwing up such a threshold, for instance for a *k*-core of twelve, presents Figure 3. Here one finds that the Indian Innovation System's main strengths seem to be in chemistry. Medical applications seem important too, which may be where India's known strengths in production of generic medication shows. This set of companies is reported to move into the phase of developing medication themselves, rather than copying medical innovations developed elsewhere [REF]. The industry is known to show a high propensity to patent, and so India can be expected to see its presence enhanced in the coming years.

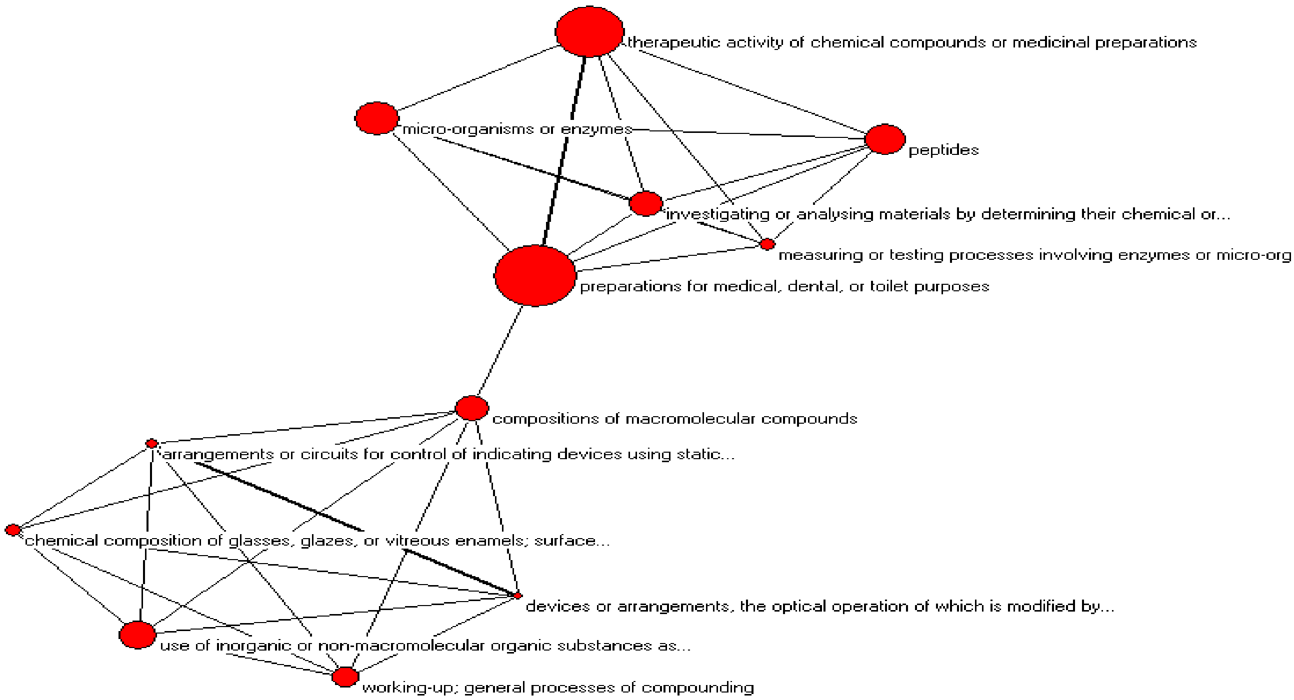


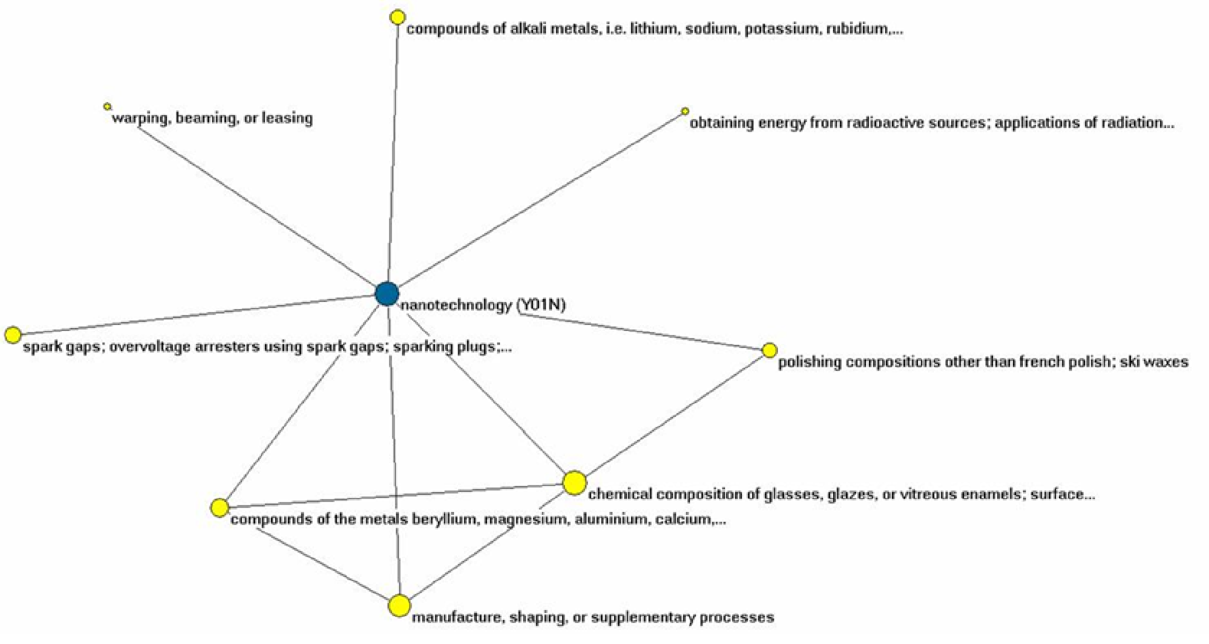
Figure 3: Patent classification categories and co-classification relations; k-core 12 network for internationally registered Indian patents, 2006. (N = 936; cosine ≥ 0.05) Source: WIPO.

What is striking is that another strong segment in the Indian economy, IT, is barely present. IT in India is mostly focused on services aspects, of course, and these tend to be excluded from possibilities for applying for patents in most countries except for the US.

Patents have been granted to parties in India in the field of Nanotechnology (WIPO patent clase Y01N), but these are filtered out very quickly when applying a threshold. This is no surprise for a number of reasons. As a separate class it is only recognized recently. Even globally, zooming in on the ties this one patent class maintains with others, it is observable that only a tie with one other patent class enters the picture ('Soil working in agriculture forestry etc.'). It appears that Nanotechnology is indeed a quite separate field of knowledge development, at least from the perspective of application.

Nanotechnology. Taking a sectoral innovation systems approach now, an approach that is conceptually close to the discussion of technological regimes (Dosi 1982), it is possible to determine which technological areas are close to nanotechnology. Figure 4 presents the picture. While the data used is normalized using cosine, no additional threshold is chosen. One can thus conclude that the area of Nanotechnology is rather loosely connected to other technological regimes or fields. The way in which the technology is related to others does not show any structurally specific shape. While this may change in the future, it thus does appear to constitute a separate regime.

Figure 4: Patent classes Nanotechnology (Y01N) co-classifies with globally (*k-core* = 1; *N* = 762; cosine ≥ 0.05).



4. Conclusions

Analyzing co-classification relations of patents opens up avenues for research in the area of National Systems of Innovation. This literature has a tendency to get bogged down in case studies of the effects of specific institutions for specific countries. Making use of patent data in a way that has not been done before in innovation studies we thus offer three distinct contributions in this paper. First of all, we offer a possible avenue for research in the area of innovation studies and the field of NIS in particular. Secondly, we show that widely available data on patents can be put to a different and broader use than has hitherto been done. This is a methodological advance of particular importance for innovation and industry studies. It is also a advance for the theoretical literature as it allows for an analysis and understanding of knowledge flows within a syste. Thirdly, drawing on this, we offer empirical insights into important aspects of particular national innovation systems, the Dutch and Indian innovation systems.

The picture that emerges for the Dutch innovation system is both familiar and somewhat surprising. What is to be expected is the strong presence of the electronics, computer, and optical cluster. Internationally well-recognized and established industrial firms such as electronics giant Philips, world leader in semi-conductor productions ASML, or producer of copy machines Océ feature in this corner of the innovation system. What is more surprising is the strongly intertwined chemical, biotechnical and pharmaceutical cluster, especially with application for (veterinary) medication and (functional) food. The presence of this element in the Dutch NIS is not generally recognized, and, given the high propensity to patent in the related industries (Arundel & Kabla 1998), would suggest that the Dutch innovation becomes increasingly dependent on intellectual property law. For India, the picture may be more surprising even. IT, which in India is known to be a strong sector, is noticeably absent. So is Nanotech. Chemistry and pharmacy are most strongly present. Looking at Nanotech, globally, taking a sectoral innovation systems approach, it appear that it is very much a technological regime in development, currently rather loosely connected to the broader set of technological fields as currently recognized.

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