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Abstract

The objective of the paper is to develop a method through which we can identify the actors (industrial, institutional and individual) who are active in technology development in the same or similar knowledge fields. The paper is, thus, aimed to make a methodological contribution to the literature, which has emerged on the systemic nature of innovation. The method involves broadening out from a starting point in a specific patent class, which corresponds as closely as possibly to the technological area of interest, to a set of related patent classes by using co-classifications and citations. After close scrutiny of both patent classes and patents, the actors in the new classes, as well as in the original class, are then identified. We try out the method on radio wave antennas for communication technology in Sweden. We find a range of firms and other actors in a whole set of industries, which bear little relation to one another in an input-output sense. Although we can not ascertain the extent of linkages or relations between these actors, our hypothesis is that they constitute a cluster around radio wave antenna technology in Sweden.

Keywords

knowledge-based clusters, indicators, patents, similar and complementary technologies, horisontal linkages, knowledge spillovers, actors

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Contents

Introduction

There is a growing consensus among scholars in economics of innovation (e.g. Freeman, 1987), management of technology (e.g. Håkansson 1987), history of technology (e.g. Hughes, 1983) that a useful unit of analysis of both business strategy and industrial policy is an innovation system, or cluster, of some kind. It is argued that firms are tied together not only by market transactions but also by network relations which may give rise to significant positive externalities in the form of knowledge spill-over. A great deal of work has been undertaken to ascertain the existence and extent of knowledge spill-overs (e.g. Håkansson 1987, Jaffe et. al. 1993) as well as to identify clusters in a range of countries, the latter in particular following in the wake of Porter's book (1990).

This paper introduces a complementary method of identifying clusters to the conventional one used which is largely based on input-output links. The objective of the paper is to explore a method through which we can identify firms, institutions and individuals who are active in developing similar technologies, independently of the character of the final output of the firms. It does not, however, claim to be able to identify network relations between these actors. By identifying a set of actors, the method can help both firms and policy-makers to delimit a knowledge based cluster, thus delineating an area for both strategic and policy actions.

We try out the method on radio wave antenna technology in Sweden. Using the method, we identify a range of firms and other actors in a whole set of industries which bear little relation to one another in an input-output sense but which share a knowledge base in this technological field.

The paper is set out as follows. In section 2, we review some of the literature on clusters and innovation systems and the methods employed to identify clusters. We outline the method we have used to identify actors in the particular knowledge field of radiowave antenna technology in section 3. Section 4 contains the empirical result of our exploratory study whereas in section 5 we present our main conclusions.

2. Methods used to identify clusters in the 'systemic' innovation literature

Since the publication of Freeman's book (1987) on the Japanese system of innovation and Hughes' book (1983) on large technical systems, we have seen a number of studies and approaches which share a 'systemic' view of the innovation process. Some focus on *national* innovation systems (e.g. Lundvall 1992), whereas others study *sectoral* (Breschi and Malerba 1995), *technological* (Carlsson and Stankiewicz 1991) or *regional* systems (e.g. Saxenian 1994).[1] Whereas most of the studies have been carried out within the broader area of economics of innovation, scholars in management have incorporated firm strategy issues into a systemic view on innovation (Enright 1995, Håkansson 1987, Porter 1990, Utterback and Afuah 1996).

The basic proposition in this literature is that it is not sufficient to study the process of innovation by analysing a single firm; this firm's relations to other firms and organisations, as well as the institutional context around the firm must be incorporated. From this it follows that a unit of analysis which is larger than the single firm needs to be studied. Such a unit is labelled in a variety of ways in the literature, for instance: 'cluster', innovation system and network.

In the literature, firms are seen as being tied together by various types of Marshallian externalities, in particular by knowledge spill-overs. These may take place within user-supplier relations, between horizontally related firms through, for instance, their joint participation in a bridging institution (Carlsson and Jacobsson 1991) or between competitors, for example by imitation or by the transfer of personnel.

These spill-overs, and other externalities, are central to the argument for including a *spatial* dimension when the process of innovation is studied. Regionally or nationally clustered actors are argued to benefit disproportionately from spill-overs due to the tacit nature of knowledge, the local nature of labour markets and to the evolution of specific local infrastructure and institutions.

[1] See Edquist (1997) for a review of innovation systems approaches.

A fair number of studies have been undertaken to identify, and sometimes explain, the source and evolution of such local clusters (e.g. Carlsson 1995 and 1996, Braunerhielm and Carlsson 1996, Enright 1995, Maskell 1996, Porter 1990, Ylä-Anttila 1994).

Knowledge spill-overs are seen to take place within and between industries. These industries are either identified through trade statistics where some relative specialisation is calculated and tested for ‘stickiness’ (e.g. Dalum 1996) or, if several industries are linked, by tracing *vertical* relationships between industries using trade and production data (Porter 1990) or input-output tables (Braunerhielm and Carlsson 1996). A case in point would be the forest cluster in Finland which consists of key products such as paper and pulp and up and downstream industries such as paper machines and printing plants (Ylä-Anttila 1994).

Hence, the methods employed do not start with how knowledge is shared and technology transferred between actors which then form a cluster, but rather the opposite; individual industries, or industries which are linked by input-output relations are first identified, and their (co-) evolution is, in part at least, explained by locally constrained spill-overs.[2]

We do not doubt the importance of the mechanisms mentioned above, especially user-supplier relationships, for the shaping of clusters. It is serious, however, that when the theoretical basis for cluster formation largely lies in knowledge externalities, the methods employed to delineate clusters are based not on a classes of knowledge but product or industry classes. It is particularly serious that horizontal relationships between related industries are difficult to capture using a method which is input-output based. This is a weakness as technical change is breaking down the barriers between industries (Porter 1985), or, to use the terminology of Rosenberg (1976), technological convergence is clearly seen between many industries. Although Håkansson (1987) argues that most relationships are vertical, a convergence opens up for the possibility that the method used may *wrongly delineate knowledge-based clusters* by neglecting to include firms and other actors which are (horizontally) related by an overlapping knowledge base but which are not linked by producing similar products or by exhibiting any input-output relationships. Clearly such firms can draw upon Marshallian externalities just as vertically linked firms do.

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[2] In the ‘network’ school in Uppsala, the methods employed are different, relying more on interview data. Still, much of their work takes an industry as a point of departure.

An alternative, or rather complementary, method would be to do the opposite; begin with identifying knowledge overlaps and then delineate a cluster, or innovation system, based on a particular technology or knowledge field and not primarily on a set of industries. This is, in principle, the approach of 'technological systems' (see e.g. Carlsson 1995 and 1997). The empirical work undertaken by the team working on technological systems has not, however, always departed much from the product or industry approach to delineate a system[3], with the exception of Granberg (1995,1997) [4]. Starting from a 'core' technology, Granberg maps the set of actors, and their relationships, which are involved in developing and applying that technology to a varied set of products (and in that process he adds technologies complementary to the core technology). The actors include both firms and academic organisations.

This way of delineating a cluster, or technological system, is clearly knowledge based, as opposed to product or industry based, and we would expect that the cluster of actors identified by way of this approach would contain a different set of actors than a product based one. For instance, ceramic materials are applied to such a diverse set of products as cutting tools, engines and ball bearings. Clearly, this suggests that there are knowledge overlaps between, for example, the three Swedish firms Sandvik, Volvo and SKF who all apply ceramic technology to their respective products. Of course, there would also be those firms which develop the materials technology, independent of the application, and perhaps suppliers of machinery to produce ceramics material who need to understand the properties of ceramics.

Granberg's method of identifying the appropriate set of actors involves using both patent, bibliometric and interview data. We depart from Granberg's method in this paper in that we use patent data more extensively and in a more complete manner. The identification of the actors who either develop or apply a technology was done by broadening out from a starting point in a specific patent class to a set of related patent classes by using co-classifications and citations. In this paper, we use methods developed by others but for different purposes and we

[3] We have benefited from discussions with Annika Rickne on this point.

[4] A similar approach was used by Lundgren (1991) who works within the framework of the network school originated at the University of Uppsala in Sweden. Other work within that school take as a starting point either an industry, such as paper and pulp or medical instruments, individual firms or whole value chains, for instance from the tree to a newspaper.

combine the individual methods in a special way. In the following section we describe the method.

3. A method for capturing knowledge based clusters

In this section we outline a method based on patents for identifying actors in a technological system, or a knowledge based cluster. The method draws heavily on the work of others but our understanding is that we combine and apply established "tools of the trade" in a new manner.

Patents are used in this method since they are in most cases the best available indicator of *technological* development activities, excluding software.[5] Technology is here defined and interpreted as *technical knowledge*, which excludes artefacts. In other words, this interpretation reflects our focus on knowledge-based clusters.

A particularly attractive feature of patents for the method is that they contain standardised means to *relate* inventions to earlier inventions (through patent citations) and technological areas to other technological areas (through co-classifications of patents). Since this technical information is almost exclusively inserted into the patent files by patent officials (experts) and not by the inventors or the applicants themselves, the information should be reliable. Another reason for using patents is that they disclose technical information which can be used to assess the precise character of the inventions.

A patented invention is often not just classified in one patent class but covers several patent classes;[6] it is co-classified simply because it contains technical features which are reflected in several patent classes. An example of this is "integrated radiating and coupling device for duplex communications" (US pat. no. 5603098). The invention transmits and receives electromagnetic waves in the air and directs those waves into a larger technical system. Such an invention is first classified as a radio wave antenna technology (US patent class 343) but it is also classified as a waveguide[7] technology (US patent class 333) since this technology is

[5] The degree of software embedded in the granted rights of patents is increasing (Olsson, 1996) which, potentially at least, may decrease this problem.
[6] In the U.S: patent classification system, there are approximately 100,000 classes.
[7] In fact the invention contains a stripline which may function as a waveguide or as a filter.

developed in the invention.[8] The device is also classified in “telecommunication” (US patent class 455) since it is used to transmit information in two directions.

So, co-classifications between different patent classes indicate a relatedness of a technological nature. Presumably the more frequent the links are between two or more classes, as revealed by the frequency of co-classifications, the more certain we can be of a close technological relationship. This assumption has been used by, for instance, Grupp (1996) who has used co-classifications to measure the closeness between various broad technological fields.

The granted rights of a patent does not include technical features publicly known before the application date but the patent must name these in order to disclose the nature of the patented invention. This is done by referring to earlier patents (citations) or other types of references, e.g. to scientific articles. In the example above illustrating the procedure of co-classification, the citations in the patent referred to, for instance, a microwave circulator patent as well as a scientific article[9] dealing with wide-band operation of microstrip circulators.

In other words, “ … a citation of Patent X by Patent Y means that X represents a piece of previously existing knowledge upon which Y builds” (Jaffe et.al. 1993, p.580). Citations therefore, by pointing out its technological (and scientific) antecedents, indicate a technological relatedness. This feature of citations has been used to study the frequency of locally constrained spill-overs by studying the geographical co-location of actors granted a patent and actors citing these patents (e.g. Jaffe et.al. 1993).[10]

Using co-classifications and citations, we have developed a method for tracing actors which are related in a technological sense, i.e. the actors have developed inventions with a technological overlap and, thus, have revealed a common understanding of a specific knowledge field. The method consists of six steps, see Figure 1.

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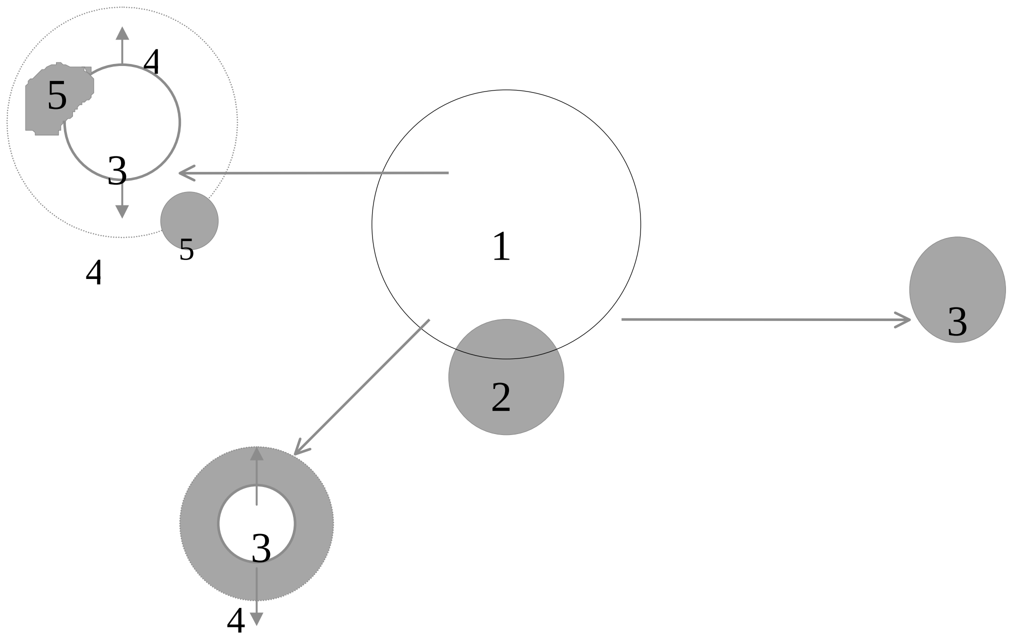
[8] It is often impossible without expert knowledge to decide whether the stripline technology which is part of the invention actually has some technological newness or if it is just the combination with other technologies that is new.

[9] Thus, indicating some scientific relation.

[10] This means that the literature does not measure spill-overs directly.

Fig 1. Identification of actors in similar technologies



1. Identify Point of Departure (Original Patent Classes)
2. Classify Patents as Qualifying/Non-qualifying
3. Identify Qualifying New Patent Classes (by Co-classifications or Citations)
4. Search for, and Select Related Patent Classes
5. Classify Patents as Qualifying/Non-qualifying
6. Identify Actors - not shown here

N.B. the shaded areas on the diagram denote the patents and patent classes classified by us as non-qualifying.

In the first step, we identify one or several patent classes, which we take as our point of departure.[11] For instance, in our empirical part (see section 4), we chose U.S. Patent Office class 343 (Communications: radio-wave antennas) as this corresponds most closely to our

[11] Prior to this stage, we need of course define the technological area of interest.

technical area of interest which is radio wave antenna technology. We could, of course suggest that the actors patenting within this class could be seen as constituting a cluster. This would, however, not be correct for two reasons.

First of all, not all the patents in the original class qualify in terms of reflecting a development of the technology in question. The second step is, therefore, to eliminate some of the patents in the original class. The elimination is done by evaluating the precise nature of the inventions described in the individual patents. This can be done by experts or by the researchers but it is not possible to do without an understanding of the technology. This scrutiny results in a division of the original patents into two groups; one with qualifying and the other one with non-qualifying patents. In Figure 1, circle 1 represents the original class, while the shaded area (2) represents the eliminated - non-qualifying patents.

Secondly, our earlier discussion on co-classifications and citations indicate that there may be actors who patent in other classes who are technologically closely related to the actors in the original class (US patent class 343) and, thus, ought to be included in the cluster. The third step consists, therefore, of identifying patent classes, which are related to the qualifying patents in the original class either via co-classification or via citations.[12] Some of these classes are included (light areas 3) whereas others are not (shaded areas 3) since their relationship with the original class is judged to be spurious. The exclusion of some seemingly related classes is done after a close scrutiny of the patent classes and inspection of individual patents in those classes.

The fourth step consists of moving from the identified (sub-) classes into their immediate vicinity in search of other qualifying patent classes. This is done since the identified classes in step 3 are at the most detailed level in the patent classification system and we would therefore expect to be able to find related patents in their close vicinity. The search is done by closely studying the names and definitions of sub-classes in the vicinity of the identified classes and aggregating those which appear to be related (the shaded area (4) denotes an unsuccessful attempt to identify related sub-classes). The fifth step consists of reading all the patents to

[12] Citations here means both the patents cited by the original patents, and the patents the original patent is cited by. Hence, both antecedent and subsequent patent classes are included. Only the main class for cited patent was used as a new patent class.

eliminate any “noise” that the aggregation of the classes has introduced (the shaded areas (5) denote an exclusion of non-qualifying patents). The final step is to identify all the *actors* who have been granted patents which have been judged to contain a development of our specific knowledge field. These actors are seen as forming, at least potentially, a knowledge based cluster or technological system.

4. An empirical exploration of radio wave antenna technology in Sweden

The purpose of this section is to illustrate the method, in an exploratory fashion, by identifying actors which may form a knowledge based cluster around radio wave antenna technology. We will first discuss the process whereby the relevant patents and patent classes were identified and then proceed to give our results in terms of the number and characteristics of the associated actors. Already here we would like to emphasize that the procedure involve many judgements and that we have been deliberately very cautious in these judgements so as not to exaggerate the empirical findings.

4.1 Identification of relevant patents and patent classes

As mentioned above, the original patent class was 343 in the US Patent Office (Communications: Radio wave antennas). It was identified in the first step of the method. The second step involved a close scrutiny of the patents in the original class. In this scrutiny, we categorised the patents into two groups; a qualifying and a non qualifying group. The key dimension in this categorisation was our judgement of the extent to which the development of radio wave antenna technology was a part of the patent. It is important to make this distinction as we are interested in delimiting a knowledge based cluster around radio wave antenna technology.

In some cases, we found that radio wave antenna technology was developed or applied in such a manner which involved a modification/adaptation of the technology. In these instances, we categorised the patents as qualifying. In other cases, however, the radio wave antenna technology was only a component, which was included without any modification in the technology. These patents were classified as non-qualifying. It may be surprising that a patent allocated to the original class might not involve any development of the radio wave antenna technology but as patents are often classified in several classes (they are co-classified), the most relevant class may not have been ‘our’ class at all.

An example of a qualifying case is when microwave antennas are applied to a base station (used in mobile telephone systems) together with radio channel generating circuits (US pat. no. 5,548,813). This invention is used for sending a large number of individual radio channel signals to a set of coverage areas through phased array antennas. The antennas are operated so that they only transmit one radio channel at a time. The particular design of each antenna and how they are combined allows for selective power adjustment, which has the benefit of reducing interference in the communication with the mobile units. Thus, the invention applies radio wave antenna technology to a telecommunication system.

A case of a non-qualifying patent is an invention which consists of an adjustable parabolic aerial mounting structure (US pat. no. 4980697). This invention does not develop radio wave antenna technology but deals with how to physically support a structure and was therefore judged to be unqualified. A second non-qualifying case (US pat. no. 4333402) concerns a projectile for spreading materials for disturbing electromagnetic waves (radar). The invention concerned the means for spreading the materials (by means of explosives and was therefore co-classified in a class covering ammunitions and explosives) and not radio wave technology.

In the third step, we added a number of patent classes identified using co-classifications and citations of the qualifying patents in the original class. [13, 14] This procedure resulted in an expansion of the original patent class with 45 new classes at a three digit level (step 2). However, only one or a few of the many sub-classes contained within each 3 digit class were identified as qualifying through our procedure.

Upon close inspection, we found that as many as 39 of the classes had to be excluded even though the patent identifying them was judged to involve a development/modification of radio

[13] The earliest patent application was made in 1973 and the latest in 1995. The database therefore covers a fair number of years. This could be seen as problematic if we aim to give an accurate picture of the cluster at a given point in time.

[14] The choice of how to expand the original class was made to reflect the technological relations of the Swedish actors as represented by *their* patents and not by *all* the relations that can be found in patents from the original patent class had we used *all* the patents in the class in USPTO. This implies that the number of related classes may be underestimated.

wave antenna technology. In some instances, the patent class was judged to be so heterogeneous that we strongly suspected that other patents classified in the particular class had nothing to do with radio wave antenna technology. A case in point is a patent (US pat. no. 4743725) which dries materials around pre-formed holes by emitting microwaves. This patent is co-classified in class 166 (Wells), sub class 166/248, which contains patents covering the passing of electric currents through the earth. As this is technologically related to the original area in only a very distant way, we excluded the class.

Having excluded all but six new classes, we proceeded, in step 4, to search in their vicinity for classes that may contain qualifying patents. In some cases, a limit to incorporating new sub-classes was easily ascertained since the US patent classification is sometimes functional in character. In one case, the particular 3-digit class was class 219 (Electric heating). Due to the functional character of the class, only the sub-classes directly related to “Microwave heating” (219/678 - 219/763) were judged to be potentially relevant whereas other classes, e.g. “Metal Heating” (219/50 - 219/162) were seen as irrelevant since they seem to have no connection to the original technology. A second example where the functional character of the patent system helped us is a patent, which applies radio wave antenna technology in a detection apparatus. Detection can be done by various means, however, so the sub-class included was very specific (340/572). Had we chosen a broader class, we would have included a whole set of heterogeneous sub-classes with no technological relatedness to the original class.[15]

The search and scrutiny led to the incorporation of the entire 3 digit classes 333[16] (Wave transmission lines and networks), 342 (Communications: Directive radio wave systems and devices, e.g. radar, radio navigation) and 455[17, 18] (Telecommunications). A fourth class, 219 (Electric Heating) was only aggregated up to the functional level involving microwave heating. For the remaining two classes, 340 (Communications: Electrical) and 204

[15] By applying a very critical eye, we may have excluded some relevant classes.

[16] This could be compared to the total co-classification pattern in the USPTO. 6.6% (536 out of 8097) of all the granted patents in class 333 in the USPTO (1976-01-01 to 1997-05-01) were co-classified with class 343. For class 342 the figures are 5.8% (258 out of 4415).

[17] It is important not to confuse the name of the patent class 455, “Telecommunication” with the wide range of technologies occurring in the industry of telecommunications. The definition of the class is according to the USPTO ”[t]he patent class is the generic class, not elsewhere classifiable, for all types of communication systems in which electric or electromagnetic signals are used to transmit a modulated carrier wave. ”

[18] 3.8% (440 out of 11430) of the patents in the USPTO in class 455 were co-classified in 343 between 1976-01-01 to 1997-05-01.

(Chemistry: Electrical and Wave Energy), we judged that the three digit level was too heterogeneous to be included and that only the sub-classes identified in step 3 were judged to be sufficiently related to the original class to be included.

The fifth step involved the study of all the patent abstracts and patent claims.[19] The inclusion of these classes in their entirety was based on our judgement of the appropriateness of aggregation by scrutinising the names and definitions of the patent classes in the selected classes at various levels of aggregation. This was seen as necessary since, in spite of the scrutiny of the patent classes, a fair amount of uncertainty still remained. Without a scrutiny of the patents, we would clearly include actors who were not involved in the development of the original technology. For example, the inclusion of the entire class of 455 did provide a number of new actors after step 4 but after the scrutiny of the patents[20] in the class, these actors were excluded.[21] All in all, some 200 patents in the six new patent classes were disposed of in step 5. Finally, the last step was to identify the actors (Swedish firms, other organisations and inventors) which had been granted a patent.

4.2 The empirical results

The original class (343) had 51 qualifying patents granted by the USPTO to 10 actors.[22] At the end of step 6, we had included 111 patents granted to 35 actors, see table 1.[23] A considerable increase took place, therefore, both in terms of the number of patents and the number of actors.[24]

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[19] The patent claims seem to provide the most reliable information since the patent abstracts often do not reveal the precise nature of the invention.

[20] Since the focus is on horisontal links, almost all the patents classified in class 455 but not co-classified in 343, 342 or 333, were excluded because the inventions deal with e.g. communication systems and not antenna related technologies. Of course, in a cluster discussion around the much broader concept of telecommunication, these inventions with their actors would be included. The exclusion is done since the relatedness *as shown in the patents* does not indicate that the actors have the capability to develop antenna technology.

[21] Some 90 patents from 4 actors that were classified in class 455 were not included.

[22] The number of patents was 56 but 5 were excluded for various reasons.

[23] The foreign firms in the table are included since the search was made for both Swedish inventors and/or applicants. This was done to find some key inventors and to eliminate the risk of missing links due to centralised patenting behaviour to the home country of the firms.

[24] Within the three seemingly "most related" classes 343, 342 and 333 (at the three digit level), the number of actors was 26. The broadening of the actor and patent base therefore also holds if we had defined these three patent classes as our point of departure.

The full range of actors included 27 firms[25] and 8 individual inventors. The firms were classified in as many as 11 three digit industries (SNI 92)[26] where an ‘industry’ is broadly equivalent to the four digit level in ISIC, e.g. 35.1 ‘building and repair of ships and boats’.[27] Only four of the actors were classified in industry classes 322 (Manufacturing of radio and TV transmitters, and apparatus for wired telephony and telegraphy) or 323 (Manufacturing of radio and TV receivers, and apparatus for reproduction of audio and video signals) which pertain to telecommunications, although these firms account for about 40 per cent of the patents.

Table 1

Some basic data on the cluster

Actor[a]	**Industry classification**[b, c]	**Number of patents**[d]	**Patent in original patent class**
ABB	**73102**, 74150	1	No
AGA AB	**74150**	1	No
Alfastar AB (SE).	**29530**	1	No
Allgon	**32200**, 32300, 71330,74140	2	Yes
Besam AB	**31620**	1	No
Bofors AB	29600, **73102**	3	No
Centre de Recherches en Physique des Plasma, Schweiz	Foreign research institution	1	No
Enander, B., Fuks, P., Larsson, G.	INV	1	No
Esselte Meto International, Germany	21250, **51659**	1	No
Flintab AB	29240, 31620, 72201, **29720**	1	No
Gunnarsson, S.	INV	2	No

[25] With a ‘firm’ we mean either an independent firm or a larger multi-divisional firm. Ericsson is regarded as one firm, as is SAAB, both of which have many divisions.

[26] For eight of the firms, an industry classification was not available, which means that 10 industries is probably an underestimation.

[27] When a firm was classified in more than one class, we only counted one class and we chose the one which was most likely to reflect the patent. Again, we chose to select only one class as we wish to make a conservative estimate.

Hellsten; H.	INV	3	No
Henoch; B.	INV	2	No
Hornfeldt, S., Gafvert, K.	INV	1	No
Husqvarna Aktiebolag	29320, **29401**	1	No
Ingenjörsfirma N.D.C. Netzler & Dahlgren	**29220**, 30020	1	Yes
Ingenjörsfirman Nils Weibull AB	**29569**, 28110, 34300, 28759	1	No
Institutet for Mikrovågsteknik	Research Institution	12	Yes
Intermodulation and Safety System AB	NF	2	Yes
Klostermark; B.	INV	1	No
Luxor AB	**70202**	1	No
NobelTech Electronics AB	**74150**	1	No
P.O.R Microtrans	**74202**	1	No
P.S. Paging System, A.B.	NF	1	No
Q&Q Retreading System AB	**51659**	1	No
SAAB (SAAB Automobile AB, SAAB Missiles, SAAB Marine Electronics, Saab-Scania, Saab-Scania Combitech Aktiebolag)	32100, 74202, **33200**, 33300	5	Yes
Sivers IMA AB	**32300**, 32100, 31200	1	No
Skandinavisk Torkteknik AB	NF	1	Yes
Sparbanken Syd	NF	1	Yes
Stone-Elander, S., Elander, N.	INV	1	No
Telefonaktiebolaget L M Ericsson	31620, 32100, **32200**, 32300, 51653, 73102, 74112	44[e]	Yes

Telia AB; Televerket	**32200,** 64201, 51653	2	Yes
Torby, A	INV	1	No
U.S. Philips Corp.	**32200**, 32300, 51431 52720	10	Yes
Whirlpool	**29719**	2	No

Source*:* Svenska Aktiebolagsregistret, 1996

[a] Foreign firms were identified through Swedish inventors. This identification means one of three things; due to centralised patenting the international headquarters was wrongly identified since the inventive activities occurred in Sweden, the Swedish inventor lets a foreign firm apply for his patent, or a Swede working abroad provides a 'false' link to a foreign firm. For the former, the corporations were classified as Swedish.

[b] The industries are classified by SE-SIC 92. The abbreviations means the following: INV is equal to "inventor" and NF to "not found".

[c] Bold numbers indicate that we used that industry group when we counted the number of industries found among our actors. Note that this may not indicate the proper classification for the applicant but the classification was limited to only one class so as not to overestimate the number of industries.

[d] The number covers the patents in the patent classes, 343, 342, 333, 455, 219/678 - 219/763, 340/551, 340/571-340/572, 204/284, 89/1.5-89/1.6.

[e] The number includes 6 patents from Ericsson GE Mobile Communications, Inc. USA

Among the actors we encounter Swedish firms who are involved in mobile telephony (Ericsson, Telia and Allgon) and military equipment, e.g. robot guidance systems (Bofors, NobelTech, SAAB[28] and Ericsson). These were all expected to show some activity in the radiowave antenna technology and were found despite the quite narrow original class. Also as expected, we found a research institute, which is well known for its work in this field (Institutet för Mikrovågsteknik). However, we also found a range of other firms (not to speak of individual inventors) which we had not expected to find. Among these, we can mention security systems (Intermodulation and Safety Systems), garage doors (Besam) and automated guided vehicles (N. D. C.). There is also a connection to microwave heating and in particular microwave ovens (Whirlpool, Philips and Alfastar), which has a significant technological overlap with the radiowave antenna technology.

[28] Interestingly, military work in SAAB has been developed into the promising application of traffic billing (road customs duty tariff)

Hence, we can conclude that the method allows us to identify a range of actors and industries in which technological activities have occurred within our technological field of enquiry. It is these actors which we hypothesise make up a knowledge based cluster, or technological system, in radio wave antenna technology.

In order to go some way towards a validation of the method, we carried out 20 interviews with representatives from large and small firms, universities and individual inventors.[29] The interviews had two objectives. The first, and chief, objective was to compare the perception of the interviewees with respect to which actors are knowledgeable in our field with our own results.

The interviews confirmed that our method had allowed us to identify the core of the actors involved in this technological field. It should be noted, however, that a respondent spontaneously mentioned an actor who was not found in the USPTO database but who had patented in PRV (the Swedish patent office). The choice of database may therefore be problematic but a comparison of these two databases revealed that almost all of the discrepancy between PRV and the USPTO consisted of individual patentees and not firms.

We also discovered that our method allowed us to identify actors which the interviewees were unaware of. This applied to, for example, the firm Netzler and Dahlgren as well as a number of individual inventors.

The second objective was to find out whether or not the interviewees shared our perception as to which patents could be labelled as qualifying or not qualifying. In other words, we were concerned with the risk that we had exaggerated the number of actors, in spite of our very cautious approach to the data. The interviewees confirmed, however, that our evaluation was reasonable and no objections were given to our assessments, in fact they confirmed that we had been quite cautious. In the discussion we naturally dwelled a great deal on how to delimit our technological field. The discussion focused in particular on whether or not the exclusion of optical as well as radio frequency (RF) technologies and microwave related components was correct.

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[29] For practical reasons, our interviews covered most of the actors in the region of Western Sweden and not all Swedish actors.

With regard to the relation between optical and microwave technologies it was argued that electrical engineers are able to participate in both of these fields as soon as they ‘learn each others language’ even though their efficiency/proficiency initially decreases after a change in the area of work. However, it was agreed that there is a much larger technological distance between these technological fields than within them. A similar conclusion was reached for the RF field.

In relationship to microwave related components such as magnetrons, lasers or gyrotrons, it was suggested that a microwave engineer may need to understand such components (to use or sometimes develop it) but that the fields of knowledge are distinct. In other words, given the present purpose, the exclusion of these areas was correct.

5. Concluding remarks

The objective of this paper was to explore a method through which we can identify actors who are active in technology development in similar knowledge fields but may be independent in terms of the character of the final output. That is, we identified a need for a method whereby actors included in a knowledge-based cluster or a technological system can be identified. We understood that this is of importance given the belief that there is a partial mismatch between the theory behind cluster formation and the empirical methods used to delineate clusters.

Although our point of departure (patent class 343) was very narrow, we had no problems in finding a large number of related patent classes using co-classifications and citations. Obviously the key part in our method is the exclusion of less relevant patents and classes. To do this, which is very difficult, knowledge in the technical field of inquiry is necessary and is, in fact, central to the application of the method. The method can, therefore, not be used without a prior, or brought in, competence in the field of inquiry. In applying that competence, personal judgement can not be avoided. We have deliberately used a very conservative approach in our judgement so as to minimise the risk of exaggerating the size of the cluster. A set of interviews with experts in the field confirmed not only our judgements but also that these had been cautious.

As was clearly seen in the empirical section, we saw a considerable expansion in the number of patent classes, patents, actors and industries when our method was applied to the case of radio wave antenna technology, as approximated initially by patent class 343. This may be viewed as a trivial finding but we believe it was not self-evident, in particular when the expansion from the original patent class was made in such a cautious manner. Again, interviews with experts suggested that we had managed to find most of the actors involved in developing our technological field. Indeed, we even found some which these experts did not know.

Our results clearly indicate the problems involved in only using trade or industry data as the basis for delineating a cluster. Had we, for instance, used production data to identify the actors involved, we would presumably have gone for industry classes 322 (Manufacturing of radio and TV transmitters, and apparatus for wired telephony and telegraphy) and, possibly, 323 (Manufacturing of radio and TV receivers, and apparatus for reproduction of audio and video signals). Within these, we would have found, as was mentioned above, only four actors with qualifying patents, including one downstream actor (Telia). From the perspective of those two industry classes, most actors are therefore horizontally related, which presumably reflects a technological convergence among many industries. We therefore suggest that we have developed a method, which can complement[30] conventional methods for identifying a cluster, in particular such clusters which are believed to be strongly knowledge-based.

Of course, the method can say nothing about real knowledge links between actors but can provide hypotheses of such relations. It can also serve as a tool for policy makers who desire to influence the character of the networks and knowledge links in the economy, i.e. the method can help policy makers to delineate an area for policy action. This may be particularly interesting in early phases of the diffusion of a new technology where the method may capture the technological activities in a new field by a diverse set of otherwise unrelated actors which later may turn into a cluster with close network relations.[31]

[30] Of course, given the drawbacks of patents as technology indicator, the method needs to be completed with other work, such as interviews.

[31] The method can also be used to trace the evolution of a technological system and in that process, identify relations which may have been of historical importance or, possibly, relations which will be of future importance.

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The Research Programme

The DRUID-research programme is organised in 3 different research themes:

- The firm as a learning organisation

- Competence building and inter-firm dynamics

- The learning economy and the competitiveness of systems of innovation

In each of the three areas there is one strategic theoretical and one central empirical and policy oriented orientation.

Theme A: The firm as a learning organisation

The theoretical perspective confronts and combines the ressource-based view (Penrose, 1959) with recent approaches where the focus is on learning and the dynamic capabilities of the firm (Dosi, Teece and Winter, 1992). The aim of this theoretical work is to develop an analytical understanding of the firm as a learning organisation.

The empirical and policy issues relate to the nexus technology, productivity, organisational change and human ressources. More insight in the dynamic interplay between these factors at the level of the firm is crucial to understand international differences in performance at the macro level in terms of economic growth and employment.

Theme B: Competence building and inter-firm dynamics

The theoretical perspective relates to the dynamics of the inter-firm division of labour and the formation of network relationships between firms. An attempt will be made to develop evolutionary models with Schumpeterian innovations as the motor driving a Marshallian evolution of the division of labour.

The empirical and policy issues relate the formation of knowledge-intensive regional and sectoral networks of firms to competitiveness and structural change. Data on the structure of production will be combined with indicators of knowledge and learning. IO-matrixes which include flows of knowledge and new technologies will be developed and supplemented by data from case-studies and questionnaires.

Theme C: The learning economy and the competitiveness of systems of innovation.

The third theme aims at a stronger conceptual and theoretical base for new concepts such as 'systems of innovation' and 'the learning economy' and to link these concepts to the ecological dimension. The focus is on the interaction between institutional and technical change in a specified geographical space. An attempt will be made to synthesise theories of economic development emphasising the role of science based-sectors with those emphasising learning-by-producing and the growing knowledge-intensity of all economic activities.

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