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# **Patenting activity in biotechnology and pharmaceuticals: a comparative analysis of the Nordic Countries**

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## **Abstract**

The main aim of this paper is to study innovative activity, as measured by patent indicators, in pharmaceutical and biotechnological sectors in the Nordic Countries. The biotech sector in general and pharmaceutical in particular is one of the areas selected for strategic investments in every Nordic country. In terms of patents granted by country of inventors Denmark plays a leading role followed by Sweden, while patenting activity in Finland and Norway is lower. A concentration of patents towards a relative small number of assignees (mainly large biotech and pharmaceutical companies based in Denmark and Sweden) is also observed. Norwegian patents, as measured by patent citations indices, are more “important” than those of the other countries, as well as in terms of relative size of innovations. Although there are other contributing factors, our data suggest that geographical proximity to large pharmaceutical companies plays a role in determining the relative success of national policies, and also that new investment policies in countries where large biotech or pharmaceutical companies are not established can yield positive returns in terms of innovation growth.

**Keywords: Patent data, Innovation, Biotechnology, Pharmaceutical industry, Patent citations, Nordic Countries**

**JEL classification: O31, O34, L65, C20**

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## 1. Introduction

Biotechnology is considered to be one of the most important generic technologies to have emerged in the last decades of the 20<sup>th</sup> century. The biotech revolution is also expected to yield significant benefits to the pharmaceutical sector through improvements in productivity in drug discovery and development (Enriquez and Goldberg, 2000; Lawrence, 2006; Lawrence 2007; Walsh 2003). These much touted benefits by among others the consultancy industry has led to an upsurge in interest from national policymakers who are keen to promote science based innovation as a part of national policies for the economic renewal of flagging OECD economies. The Nordic countries are noted for having on average a high level R&D expenditure and in keeping with this, these countries have for the last two decades been active promoters of science based innovation. In this regard, the biotech sector in general and pharmaceutical in particular is one of the areas selected for strategic investments in every Nordic country. This has meant that biotech based pharmaceutical firms accounts for a significant percentage of national and regional investments. One of the key challenges of innovation policy is to monitor and evaluate to what extent strategic areas such as biotech based pharmaceutical firms are sites of significant innovative activity. Thus, there is a policy need for descriptions and data that could help to construct a picture of the degree of innovative activity taking place in the biotech based pharmaceutical sector. One of the established ways of measuring innovative activity is to use patent data as a proxy indicator. Reasoning from this, the central objective of this paper is to study innovative activity as measured by patent indicators. We focus on the pharmaceutical and biotechnological sectors in the Nordic countries in the time period 1977-2002. Using this data, we aim to capture the main pharmacological and biotechnological inventions that occurred within this period.

Health biotechnologies have attained a significant position among the strategic priorities of several European countries. Some studies of the biopharmaceutical industry include data on the Nordic Countries. As per the number and localization of European biotech enterprises, by gauging data on population and GDP (Allansdottir et al., 2002), Sweden ranks first, followed by Switzerland, Ireland, Finland and Denmark. The study by Allansdottir et al. focuses on the comparison among several countries, including the Nordic Countries, using the number of registered patents in a given country and the data on patent citations in the sector of reference as indicators. The analysis of these indicators

in the period from 1990-2000 leads to the following conclusions (Allansdottir et al, 2002): the United States has been and remains ahead in the biotech innovation activity, the figures on patent number and citations are significantly higher than European data; the United States is more specialised in biotech research than Europe and Japan, even though some small European countries (such as Denmark and other Scandinavian countries) are concentrated on the biotech sector; both public and private research can represent the means for new countries to undertake large-scale biotech research; the number of biotech patents that are registered in the United States and then are assigned to European organizations and companies is rather high, on the contrary, the percentage of European patents that are developed by US companies is much lower: this leads to think that the United States is an attraction point for biotech research conducted by European organizations. By looking at other indicators, like for instance the number of drugs in clinical trials in Europe (Lawrence, 2006) we observe that the four Nordic Countries are strongly present: Denmark ranks third with 50 trials ongoing, followed by Sweden ranking sixth with 25 trials, Finland and Norway follow with 7 and 5 trials respectively.

Other studies based on the geographical distribution of the biopharmaceutical industry in the Nordic Countries show different scenarios and evolution patterns of the firms, along with some common aspects. A study on Swedish biotechnology firms (Nilsson, 2000) reveals a strong connection with academic research as a key factor for their success, especially in turning research results into commercial technology; collaboration is thus an important element and the Swedish government has increased the responsibility of the academic environment to interact not only with firms, but also with society at large; the business model applied by the majority of Swedish biotech firms is based on networking and outsourcing. Another key factor for Swedish biotechnology-pharmaceutical sector is location of firms, as it is stated for instance by McKelvey et al. (2003): the authors claim that Swedish biotech-pharmaceutical sector had a different history from the other European countries, one which lies closer to the American phenomena. Strong clustering effects are observed in the so-called Medicon Valley, the area between southern Sweden and greater Copenhagen area in Denmark that has one of the highest density of companies per capita in Europe, being one of the most important biotechnology and pharmaceutical research and industry area (Frank, 2002). With respect to the other two countries, it has been observed that the Finnish biotechnology sector is very new, with more than half of

companies started after 1997. Most of the companies are very small, half of them are located close to the bio-centres of science parks. Collaboration most frequently takes place with domestic institutions. Finland has established numerous policies to support and facilitate the creation of a national innovation system, with biotechnology as one of the areas included (OECD, 2006). Norwegian biopharmaceutical industry is mainly made of small dedicated firms, university spin-offs, and few larger firms (OECD, 2006). Geographical distribution of biotechnology firms shows regional concentration, the major agglomeration being the Eastern part of the country and in particular Oslo area (Grønning, 2007).

The pharmaceutical R&D process is usually divided into several phases: drug discovery, first laboratory trials (pre-clinical), other non-human trials (long-run trials), clinical trials, approval procedure, marketing-product launch, pharmacovigilance. The highest part of R&D expense is devoted to clinical trials. Patent applications normally occur between drug discovery and first pre-clinical; patent grant procedure is also a very important phase in the innovative process, involving several different actors, and often we observe cases of patent narrowing or submission of new applications derived from the original filing. Patents are considered good output-based indicators of innovation and of technological change (Griliches, 1990), but as with other indicators, they have several disadvantages and their nature is heterogeneous, thus it is important to use them carefully in order to provide adequate measures of innovation (Archibugi, 1992). The use of patent data as indicators of technological activity is widely used and it offers important evidence of innovative activity, but still there are conceptual and methodological problems of measuring technology, in particular with the classification of the types of information which can be drawn from patent data (Archibugi and Pianta, 1996). Although the granting of a patent is not sufficient proof of innovation i.e. successful commercialisation, we argue that patents may still be regarded as relatively robust indicators of innovation in the pharmaceutical sector because the high cost of drug development and commercialisation makes patenting a precondition for assuming the costs. In order to evaluate the relative “importance” of the innovations we use patent citations, which are considered as better indicators than simple patent counts (Trajtenberg, 1990).

Data (taken from the NBER USPTO dataset) show that, in terms of patents granted by country of inventors Denmark plays a leading role followed by Sweden, while patenting activity in the biotech and pharmaceutical sectors in Finland and Norway is significantly lower than the other two countries. Data also display that growth in Denmark is mainly due to biotechnology patents, while in Sweden drug patents grow more rapidly. The analysis of patent assignees (i.e. the owners) by country confirms such trend: the vast majority of patents are granted to organizations based in Denmark and Sweden, and only to a smaller portion in Finland and Norway. Data exhibit also a concentration of patents towards a relative small number of assignees: the top 5 organizations hold about 50% of all patents (including those which are labelled as unassigned or assigned to individuals), and the first-ranking company owns one quarter of all patents. The top ranking assignees are represented by large/worldwide biotech-pharmaceutical companies, followed by medium-sized well established companies with strong presence in one country and in some cases subsidiaries in foreign countries. Data show also that, between the two most innovative Nordic countries, Denmark shows higher indices (in terms of both total simple patent indices and of total citations) in the biotechnology area, while Sweden is stronger in the drugs area. This suggests that each of the two countries has its own sub-specialization field, probably driven by the biggest companies: NovoNordisk in Denmark is mainly involved in biotech drugs R&D, Astra and Pharmacia in Sweden perform R&D mainly on small molecules. Concentration of the majority of patents in the hands of one or few assignees is also evident in Finland and in Norway. Overall concentration of ownership is counterbalanced by a high dispersion: more than 90% of assignees own only one or two patents.

Using patent citations indices, the relative technological and economic “importance” of patents in the four Nordic countries is assessed. Data show that although Norway produces relatively few patents, Norwegian patents are on average more “important” than those from the other countries, with high statistical significance. Sweden and Denmark, the main drivers for biopharmaceutical innovation in the Nordic countries, follow; Finnish patents are less important as measured by citations received. Patent claims data are used to measure the relative size of an innovation and to obtain further information about the technological performance at the country level in the biotechnological and pharmaceutical fields. Patent claims represent the core of the inventive activity as expressed by the patent

application, and they define the legal boundaries of the invention. The econometric analysis shows that the relative size of Norwegian patents is on average the highest among the group of four countries examined; while Swedish patents have the lowest relative size values, and Finland and Denmark are in between. Although there are several other contributing factors that no doubt play an important role, our data suggest that geographical proximity to large pharmaceutical firms is important in determining the relative success or failure of national policies to champion growth in a particular sector. This confirms results from previous studies which point to the role of path dependence in national competences.

This paper is organized as follows. Section 2 briefly analyzes the main strategic issues underlying the decision to file a patent and presents an overview of the main patent indicators, and in section 3 there is a brief presentation of the data used in the analysis. Section 4 presents the analysis of the innovative activity in the biotech and pharmaceuticals as measured by patent counts. Section 5 provides the analysis of patent assignees and in section 6 the relative importance of innovative activity is studied by using patent citation indices as well as the relative size of patents as measured by their claims. Section 7 concludes.

## **2. Patent strategies and patent indicators**

Biotechnological drugs are the most innovative pharmaceutical products in the last 25 years; some examples are insulin, erythropoietin, interferon, monoclonal antibodies among many others. In the pharmaceutical sector we observe a strong gap between the number of patent applications (and patents granted) and the number of drugs approved by regulatory authorities and marketed. The gap is both temporal (12-15 years on the average between drug discovery and marketing approval) and in the number of candidate products that have to pass severe tests. In the last years those gaps seem to increase, as approval times are gradually increasing and despite the biotech companies have increased the number of new drugs (Lawrence, 2006).

Several strategic decisions at the firms level are taken during the patent application phase, e.g. which therapeutic areas to focus on. The patent application to grant phase takes normally 1-3 years. Patent applications are filed at an early stage in a drug's lifecycle, and

the decision on when is the right time to file an application is a fundamental strategic choice by the applicant that is affected also by the different juridical systems (“first to file” vs. “first to invent”). In countries where the “first to file” system operates, such as in Europe, the problem is often solved by filing the application as early as possible, based on limited supporting data, and then to submit further experimental data during the review process; the validity of such strategy has been questioned by some recent decisions taken by the European Patent Office (White, 2007).

Patents in pharmaceutical and biotechnological sectors are usually product patents or process patents. A product patent allows rights (including exclusive manufacturing and marketing rights) relating to the object, while a process patent relates to a means. In the pharmaceutical sector a product patent normally protects one or more active principles, a process patent grants protection only to a specific process of synthesis of a certain molecule. As in the majority of cases there exist different alternatives of synthesizing the same active principle, in the drug industry product patents are more prevalent than process patents.

Product patents in pharmaceutical R&D can be further divided into “blocking patents” and “selection patents”. A blocking patent covers a family of compounds characterized by the same basic compound with similar therapeutic effects. A selection patent protects either a small family of compounds or a single molecule that is part of a more general family but it is also characterised by different or original therapeutic effects. Blocking patents are useful in presence of relevant innovations regarding a new family of molecules: in this case a simple selection patent could allow competitors to produce similar molecules, thus removing the competitive advantage of the innovating firm. Selection patents on the other hand are used to protect incremental or dependent innovations, e.g. the modification of an already known chemical compound, aimed at granting better pharmacokinetic profiles, higher tolerance, less side effects, or a different therapeutic application of the existing compound.

Biotech and pharmaceutical companies’ typical patenting strategy is often based on these two typologies of applications. Patent applications are filed containing a sort of “downfall” of claims, starting with a first broad claim that defines the main area of the

invention, then describing in detail the concrete application and the scope of the invention in further claims, whose content is fully or at least partly encompassed by the previous ones. This can help defining alternative strategies in case of rejection of one or more single claims. In several studies that employ patent indicators as measure of innovation the number of claims is used to approximately measure the extension and the coverage of a patent, and they may be indicative of the scope or width of invention (Lanjouw and Schankerman, 1999).

How many claims are included in the patent application is the result of a relevant strategic decision taken by the inventive firm. The content, extension and number of claims in a patent application represent the compromise reached between opposite goals: when a firm or an inventor decides to file a patent application typically faces several trade-off problems, one of which is related to the problem of finding the adequate levels of specification and protection of the invention, that is whether to ensure the broadest coverage of the invention (in order to establish a strong legal barrier against its competitors) or to clearly specify the content of the invention (in order to minimize the risks that the patent is not granted because of its excessive indefiniteness). Furthermore, filing patents with a greater number of claims might be a strategy employed by several applicants when their patenting strategy is strongly affected by its costs: instead of filing several specific patent applications only one application is done including as many claims as possible. It is argued (Nature Rev. Drug Disc. 6, 774; 2007) that the usual patenting strategies pursued by pharmaceutical and biotech firms will be deeply affected by the introduction of new rules at the United States Patent and Trademark Office that became effective from 1 November 2007; according to one of those new rules the number of claims that each patent can contain is limited to a maximum of 25, of which 5 at most can be independent. Another important rule that was introduced is the restriction to the maximum number of continuations of applications permitted. Although these new rules limitation will probably have an immediate negative impact on drug patenting activity, in the long run they will probably ensure more efficiency in the examination process and a reduction of time needed obtain the grant to the patent application.

An excess of patents in biomedical research (especially when dealing with basic science discoveries such as specific genes, receptors, transcription factors) might create a mass of

intersecting monopoly rights thus creating a situation where several different subjects have a right of mutual exclusion from the exploitation of the invention, this could therefore deter future research and development and technology transfer. To avoid the overlapping problem several options have been proposed, including patent pools, i.e. agreements to combine several patents together, and mandating arbitration arrangements (Kesselheim and Avorn, 2005). An analysis conducted on DNA-based patenting activity showed a time-lagged correlation between patent applications and patents issued, suggesting that the decrease in the number of applications might reflect a change in patenting strategies by firms in response to a changing environment (Mills and Tereskerz, 2007).

Patent data are often used as indicators of innovation in several technological areas, and although it may be argued that the simple granting of a patent does not give sufficient proof of commercialisation, patents may still be regarded as relatively robust indicators of innovation in the pharmaceutical and biotechnological sectors because of the high dependence of the commercialisation process on patenting. In order to evaluate the relative importance (or value) of the innovations patent citations are used, because they are considered as better indicators than simple patent counts, whose limit is that they do not take into account the heterogeneity of patent values; moreover patent citations can give useful information about several aspects of the innovation, such as: their originality, capability to link to scientific discoveries, connections between inventions, inventors, and assignees, spillover effects, and finally their relative importance (Hall, Jaffe and Trajtenberg, 2005). Following this trend, other measures based on combined use of patent counts, citations and other measures are proposed to determine the value of innovation, such as patent renewal data, patent family, nationality, number of claims, litigations (see for instance Tong and Frame, 1994; Lanjouw and Schenkerman, 1999; and Park and Park, 2006). Other than being an adequate measure of the value of innovation, patent citations on the other hand can have a negative impact on patent renewal applications, as they might indicate the presence of negative spillover effects by competing innovations that cause the cited patent to be obsolete (Maurseth, 2005).

In this paper the patents in biotechnology and pharmaceutical industry are analysed, by making comparisons among the main Nordic Countries. The analysis is based both on

patent applications and on patents granted during the reference period, including the assignees (owners) of patents. Other indicators than simple patent counts are used: patent citations and claims. Patent citations and claims indices are employed to measure the relative importance and the relative size of biopharmaceutical innovations in each country. Albeit with some limitations, the indicators based on patent data still represent a good measure of the innovative strategies in the pharmaceutical and biotechnological fields.

### **3. Data**

The NBER United States Patents and Trademark Office (USPTO) dataset (Hall, Jaffe, and Trajtenberg, 2001) is the main source. The dataset resumes all patents granted by the USPTO, grouping them into six main technological classes. Among those classes the category number 3, called “Drugs and medicals”, is selected and all patents granted in two subcategories defined as “Drugs” and “Biotechnology” are extracted; the latter could be interpreted more as “biotechnologies for health” rather than overall biotechnologies. The dataset consist of 3028 patents granted from 1977 to 2002. In order to reduce the risk of including patents that are not directly related to pharmaceuticals, two other subcategories are excluded: one is “Surgery and Medical Instruments” (about 1800 patents in the period covered by this study), that included several heterogeneous fields that are not directly related with (bio-)pharmaceuticals, or at least they show a weak connection with them. In order to verify this, since indicating more than one class is common practice in patent filing, a control through the whole USPTO database during the reference period is done by checking how many patents in the classes “Drugs” and “Biotechnology” included also classes that are part of the subcategory “Surgery and Medical Devices”, finding that only less than 2% of the drug and biotechnology patents were also classified as surgery and medical devices (and the same value is observed on the opposite case); the overlap between subcategories is then very limited. The other subcategory that has been excluded is the “Miscellaneous – Drugs and Medicals” subcategory, that accounts for a very small amount of patents (some more than 300); this subcategory includes the USPTO classes of dentistry, testing tools for optics, and prothesis, thus including innovations in fields that have low correlation with pharmacological research and development.

Some comparisons are made using the CRENOS dataset for European Patent Office (EPO) data (<http://www.crenos.it>). Cross-patent systems comparisons are quite difficult to run,

because of differences in the classification methodologies; however the purpose of the inclusion of a short paragraph devoted to EPO is done exclusively to assess whether general trends observed in USPTO are confirmed also by European patents during the same period of application. Appendix 1 shows the main technological categories used in the analysis, extracted from NBER and from CRENOS datasets, as well with a tentative matching of the different classes between them. Other sources used to verify some data are: the USPTO database (<http://patft.uspto.gov>), this is also the main source for NBER dataset; the European Patent Office database available at Espacenet (<http://ep.espacenet.com>). Population and R&D data are taken by statistical offices of each of the country included in the analysis.

The analysis covers the four main Nordic countries, i.e. Denmark, Finland, Norway and Sweden<sup>1</sup>. In order to establish the origin of the innovation, patents are classified by inventors country of residence. Data include also information on assignee names, and application and grant years. Patent data from NBER-USPTO database are summarized in table 1, where DK is Denmark, FI Finland, NO Norway, and SE Sweden.

Table 1. Patents granted in US by country of applicant (inventor), absolute values

| Years     | Grant year |     |    |     | Application year |     |    |     |
|-----------|------------|-----|----|-----|------------------|-----|----|-----|
|           | DK         | FI  | NO | SE  | DK               | FI  | NO | SE  |
| 1977-1982 | 59         | 11  | 12 | 137 | 71               | 18  | 15 | 131 |
| 1983-1987 | 71         | 34  | 18 | 88  | 87               | 40  | 21 | 123 |
| 1988-1992 | 145        | 47  | 33 | 151 | 195              | 63  | 44 | 161 |
| 1993-1997 | 285        | 99  | 63 | 270 | 526              | 164 | 92 | 478 |
| 1998-2002 | 673        | 171 | 98 | 563 | 332              | 74  | 47 | 270 |

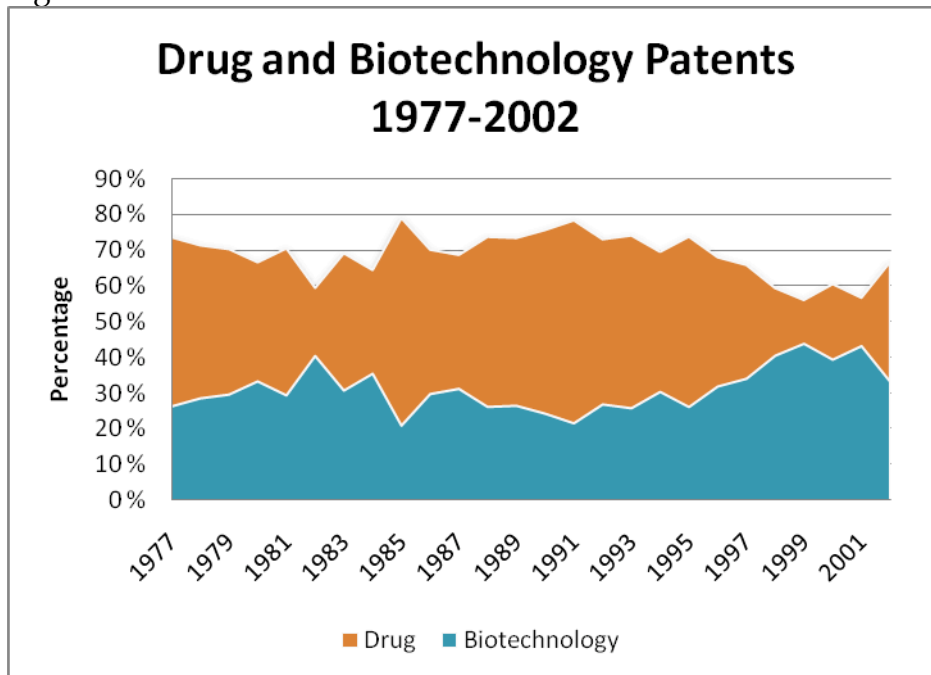
Table 1 summarizes data by intervals of years and also the two subcategories are summed together; the reduction in the “application year” last row is due to truncation (some, probably many, of patents issued to applications during the period 1998-2002 have been granted from 2003 onwards). The complete lists of all patents granted by each year and by each subcategory are reported in Appendix 2, that includes tables that show the number of

<sup>1</sup> Data do not include Iceland, whose contribution to the dataset was limited to only 14 patents in the period considered, thus lacking of statistical significance, and the associated territories (Faroe Islands, Greenland and Aaland) with no patents issued in the fields considered.

patents granted as well as the number of applications per year, for each country in each of the two subcategories; other tables in the appendix contain patent citations data.

Patent data are given in absolute values in the dataset; in order to allow comparisons across the four countries patent counts are divided by the population of each country, taken from national statistics offices. The measure, defined as patents per capita, is more accurate than absolute values to determine the inventive activity across nations. Another good way to do that is to divide the number of patents by the amount of R&D expense in each country in one year (eventually with lags), or to account for the number of employees in R&D; such measures however can be deeply influenced by several external factors, like different way of classifying those data as well as different accounting policies across countries. Moreover, since this paper deals with subsectoral data, it would be quite difficult to obtain accurate and fully comparable statistics on R&D expense and number of employees in the pharmaceutical and biotechnological sectors. Data are grouped by years in two different ways: by grant year, that is the year when the patent has been issued, and by year of application. Both classifications are useful, because grant year returns the exact moment the patent obtains juridical protection, thus being an economically valuable invention and a barrier to competitors, while application date determines a crucial moment in the innovation process, i.e. the decision to disclose (usually after a grace period) its knowledge to the public. A three years lag in analysis of application year is used, because of truncation problems, that is it takes some time from application to grant (more than two years on the average in the dataset). Figure 1 shows the evolution over time of each of the two subcategories to the total stock of patents issued.

Figure 1.

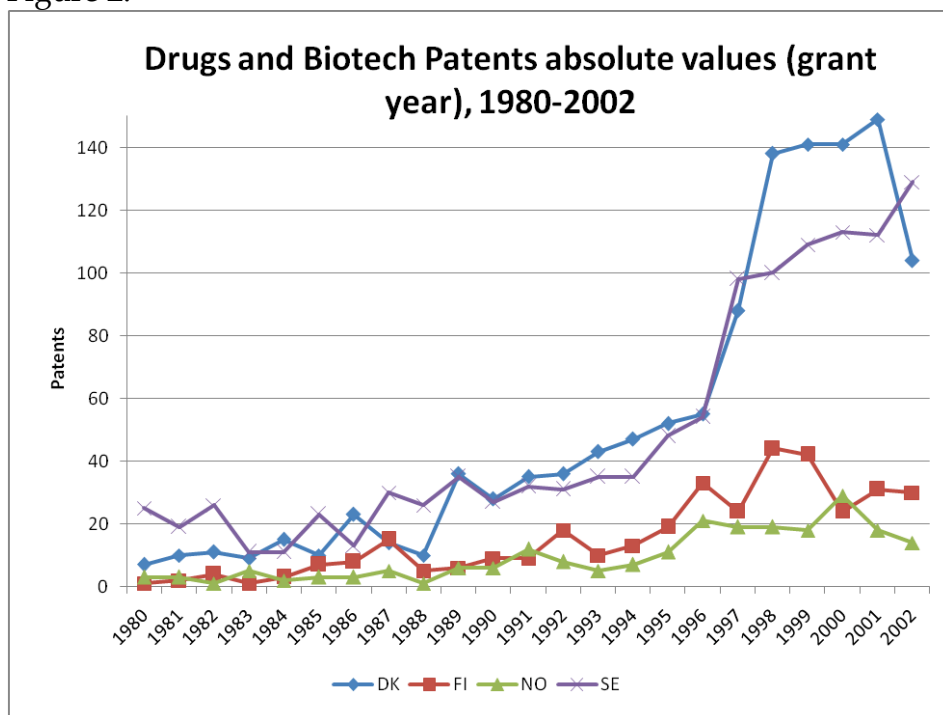


#### 4. Patenting activity in biotechnology and pharmaceutical sectors

This section offers a descriptive analysis of patent application and grants in the Nordic countries. It starts with a general analysis of patents issued in the fields of drug and biotechnology together, followed by a short review of the data for each of the two subcategories. Using the NBER USPTO patent dataset a comparative analysis of patents issued in categories “drugs and biotechnology” is done. Before going deeper into the data, it is useful to provide here a brief analysis of overall trends in drugs and biotechnology patents. Focusing of grant year from 1980 to 2002 there is little or no growth during 80s, with all four countries showing similar values. They experience some growth during 1990-95, with Denmark assuming a leading role followed by Sweden (at least in absolute values, while per capita indices reduce its relevance), while Finland and Norway follow. 1996-2001 saw a big leap in Denmark and Sweden (data suggest that growth in Denmark during this period is due to biotechnology, while in Sweden drug patents grow more rapidly); there are signs of growth also in Finland, mainly driven by biotechnological patents, and in Norway from 1994, but Norway’s growth stopped quite soon and from 1998 onwards there is no significant growth. It is interesting to note that something similar happens in Denmark: after a big jump in 1998-99, the number of patents in that country does not increase significantly, moreover in 2002 the number of patents granted in that country is dramatically reduced. Figure 2 shows the number of patents granted every year

from 1980 to 2002 by country of inventor. Denmark and Sweden show a clearly increasing trend, while Norway and Finland show significantly lower growth rates. A considerable increase is observed around mid '90s, probably due to the biotech boom.

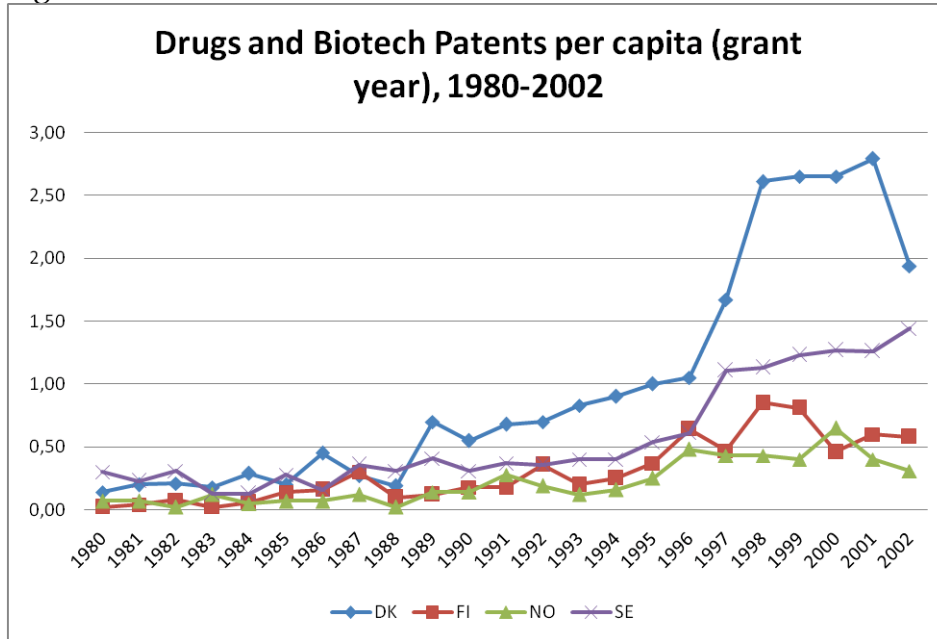
Figure 2.



Absolute patent values are not regarded as affordable measures of innovations, especially in making comparison among different countries. More affordable measures are given by relative patent indicators, where the number of patents is divided by standardizing measure such as the R&D expenditure or population. Since adequate and really comparable measures of national R&D expenditure in the fields of pharmaceuticals and biotechnological industries are not available, the patents per capita index is used here, still it is considered a measure of innovation that can be used to make comparison between countries, especially among those that have similar social and economic structure.

Patents per capita are showed in figure 3: the graph shows the number of patents granted by 100,000 inhabitants every year in each of the four countries.

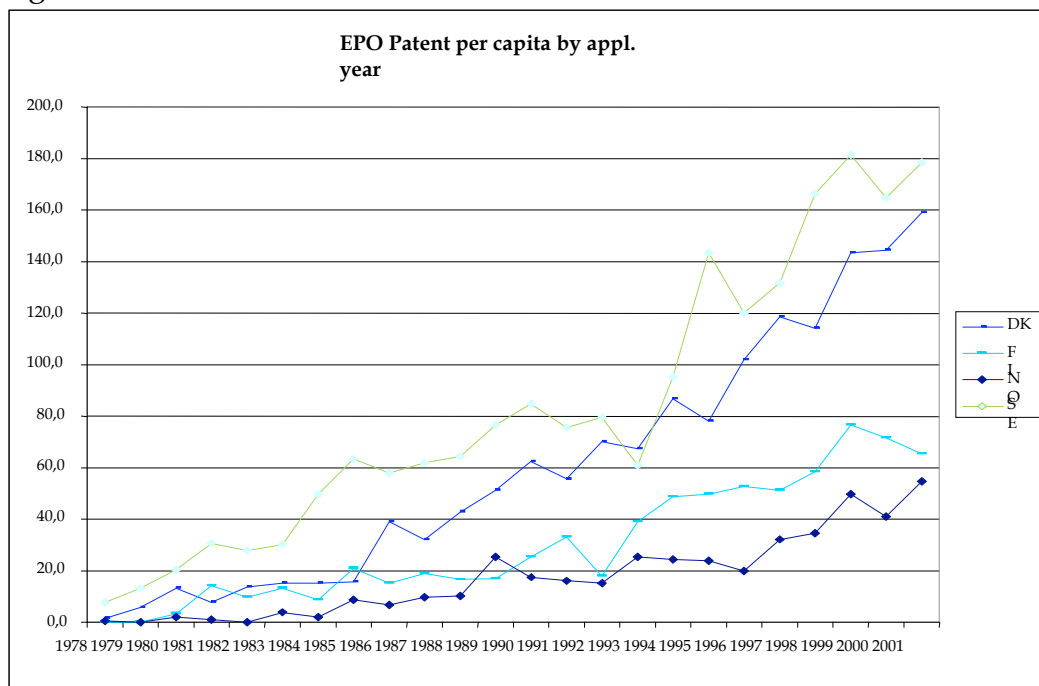
Figure 3.



It is clear that the standardized measure reduces the (relative) number of Swedish patents and its growth over time, putting their numbers closer to those of Finland and Norway. Denmark's growth is more accentuated, again showing the mid '90s boost, then reaching a plateau around 2001 and showing a strong fall in patents granted in 2002: this is probably not related with economic, financial or industrial crisis that happened in 2001-2, because almost 80% of patents granted in 2002 were applied for before 2001.

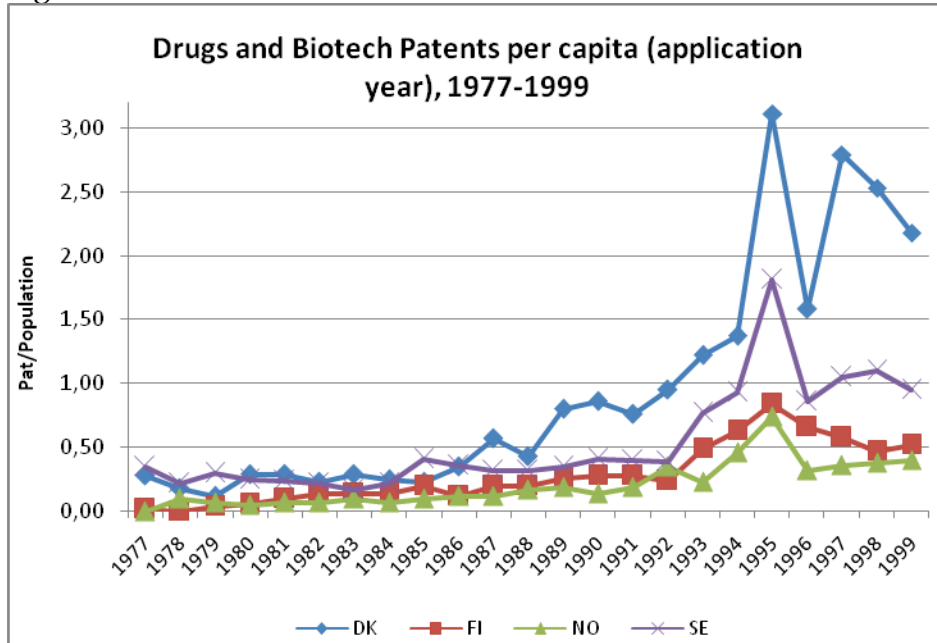
In order to allow international comparisons, figure 4 presents patents granted by the European Patent Office (EPO), using Crenos dataset (see Appendix 1). It shows the number of patents per capita (by 100,000 inhabitants) by grant year in each of the four countries, for similar classification codes as those included in the USPTO dataset. Trends in patenting in Europe are similar as in the US, with Denmark being one leader, the other one being Sweden that shows higher growth than in the US, and Finland and Norway as followers, but with two interesting distinctions: their growth is considerably higher in EU than in the US, and with Norway showing from 1996 growth rates comparable to those of the two the leaders, thus tending to reach the number of Finland in 2001.

Figure 4.



The analysis of patents per capita sorted by application year reveals something more, as it can be seen in figure 5: until 1994 we observe a slow constant growth, and in 1995 there is a peak of the number application for patents that received approval from USPTO. It is interesting to note that the peak is reached that year in each country, then followed by a constant decrease (Norway), a return to the values of the previous years without further decline (Finland and Sweden), and high oscillations (Denmark). Reasons of this isolated peak can be several, and maybe they are related to an increase in investments and R&D efforts in the past years, probably driven by a strong competition among the main pharmaceutical and biotechnological companies; it must also be kept in mind that during the early '90s a huge wave of mergers and acquisitions took place, thus leading to bigger player only by summing up the efforts of two or more companies that were accounted as separate during the previous period.

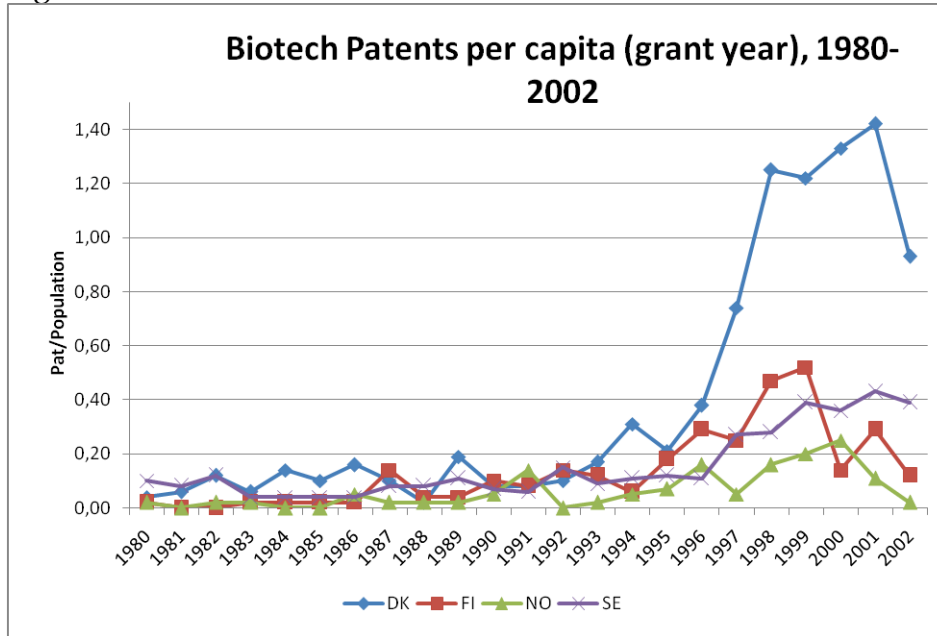
Figure 5.



By looking at each subcategory of the dataset, i.e. drugs and biotechnology, it is possible to derive some further information on innovative activity in the Nordic countries in those fields. In the drugs subcategory (values per capita), we observe similar trends as the subcategories taken together. For Denmark the increase is mainly due to drugs patents until 1996. Incidence of drugs patents to overall growth is greater in Sweden, especially during the big growth in 1998-2002: during those years the incidence of Swedish drugs patents reaches 75%. Norway and Finland show trends similar to those observed for both categories together, whereas Finland's drug patents growth from '90s is more erratic.

Among patents issued in subcategory biotechnology, starting from the data sorted by grant year in figure 6, the main difference is Denmark's peak of 1998-2001: it is more evident and bigger than in the other countries, while the decrease in 2002 seems due both to biotechnology and drugs patents, with no subcategory prevailing.

Figure 6.



Sweden shows lower values in biotech patents compared to the data on drugs, furthermore biotechnology has lower incidence on the growth over time. In some years Sweden's patents per capita are passed over by Finland, whose specialization on biotechnology is evident, especially from 1996 to 1999, then showing contradictory signs. Norway data have a rather variable trend, with a good performance during 1998-2000 followed by decline. Denmark can be considered then the leader country in biotechnology, at least from mid '90s. The emerging role of biotechnology in favouring the growth of patent indices is more relevant in Finland than in Sweden, while Norway shows variable results.

## 5. Analysis of patent assignees

Data shown on previous section do not tell us enough about the ownership and exploitation of those patents; we can suppose that the vast majority of patents are owned by corporations, but an analysis of assignees by name and type is necessary in order to better understanding the role of the actors involved in the innovation process. Following the subdivision of patent assignees in the USPTO dataset, table 2 shows the number of patents from 1977 to 2002 (grant year) by assignee type, in each of the two sub-categories and the four countries, and overall.

Table 2. Patents granted

| Assignee type        | No. of patents granted 1977-2002 |             |             |            |            |             |             |
|----------------------|----------------------------------|-------------|-------------|------------|------------|-------------|-------------|
|                      | Bio                              | Drug        | DK          | FI         | NO         | SE          | Overall     |
| Unassigned           | 127                              | 151         | 60          | 54         | 21         | 144         | 279         |
| US non gov. org.     | 74                               | 86          | 27          | 14         | 15         | 103         | 159         |
| Non-US non gov. org. | 830                              | 1720        | 1138        | 285        | 187        | 940         | 2550        |
| Non-US indiv.        | 17                               | 22          | 8           | 8          | 1          | 22          | 39          |
| US Fed. Gov.         | 1                                | 0           | 0           | 1          | 0          | 0           | 1           |
| <b>Tot</b>           | <b>1049</b>                      | <b>1979</b> | <b>1233</b> | <b>362</b> | <b>224</b> | <b>1209</b> | <b>3028</b> |

Over the total amount of patent in the dataset we observe that a vast majority is owned by non-US nongovernmental organizations; this category is quite completely dominated by firms. According to the database, universities and research centres own only a small portion of those patents (around 2%, including firms and organizations that are strictly related to universities and public bodies, such as Alko, Finnish state-owned company that has the monopoly of sale of alcoholics in Finland, that holds 17 patents). US nongovernmental organizations account for around 5% of all patents, and private companies own the majority of them (nearly 80%); through a deeper analysis of the assignee names in this category, it has been found that many assignees included in the dataset that are marked as US firms, seem to be branches of corporations whose ownership is not in the US. Other institutions, such as universities, research centres, hospitals, etc. own 20%, thus showing a more patent-oriented attitude of those actors in the US than in the Nordic countries (although this can be biased by the fact that the dataset refers to US patents, so probably many non-entrepreneurial organizations tend to patent less outside their own countries. A further analysis of national and EU patents should then be required to give more statistical robustness to the statement). Individuals, as it is usually expected in pharmaceutical and biotechnological sectors, do not account for a relevant number of patents owned (less than 1% of the total dataset). Finally, there are more patents included in the drug class than in the biotechnological class. In relative terms biotechnology shows less prevalence of firms and of non-US based organizations than drugs.

Figure 7.

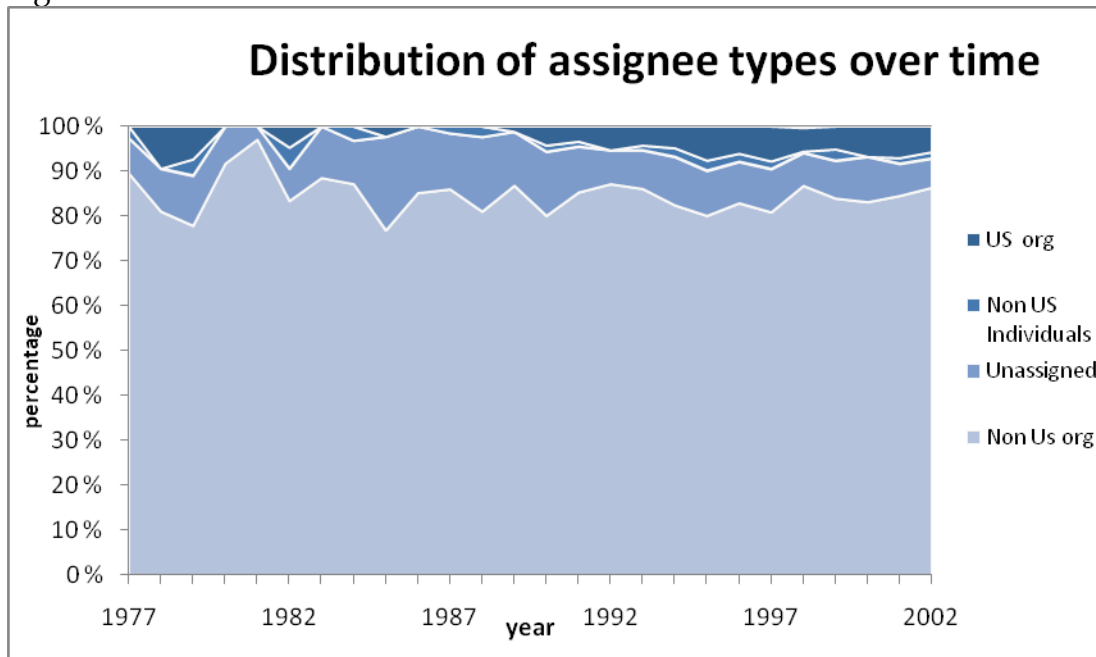


Figure 7 shows the distribution of assignee types over time. The simple assignee classification thus tells us not much about the ownership of patents. As expected, the vast majority of patents are granted to non-US nongovernmental organizations. Moreover, analysis based only on assignee names does not tell much about the effective participation to invention, for instance a number of inventions patented by firms could have originated from academia or other organizations that were not involved for several reasons into the patenting process or they sold their research outcomes during the initial phases. Although there are some limitations, assignee classification is helpful to determine what are the main trends in patenting by firms.

From a country perspective, the vast majority of patents are granted to organizations based in Denmark and Sweden, and only a smaller portion in Finland and Norway. The reasons can be several, some possible explanations are suggested. First, in Denmark and in Sweden there are more R&D clusters and centres of excellence from academia that are strictly connected to pharmaceutical and biotechnological enterprises (probably due to the existence of national systems of innovation that support the biopharmaceutical research in those two countries). Second, during the period covered by the dataset there are at least four big (bio-)pharmaceutical companies settled in those countries: NovoNordisk and Lundbeck in Denmark, and Astra and Pharmacia in Sweden; together they own a

substantial part of the patents issued in the period considered. Third, Finland shows a higher overall patenting activity than the other countries; Finnish patents are concentrated in some technological fields other than pharmaceuticals and biotechnology (like ICT for example). This suggests that in Finland there is a stronger innovation-driven activity than in other Nordic countries, and there are different technological specialization during the period considered (a search through all Finnish patents in the NBER dataset from 1977 to 2002 reveals that the main technological areas by number of patents granted are: telecommunications, material processing and paper making). Finally, if we look at Norway data, it can be confirmed that it has lower patenting indices than the other three countries; a concentration of drug and biotech patents into the hands of few assignees can probably be explained by factors that are similar to those we observe in the other countries: one or few companies playing a leading role, potential presence of technology clusters and concentration of investments in the biotechnological and pharmaceutical fields. Some of those hypotheses are tested through the analysis of assignee name and type for each patent granted in each country between 1977 and 2002. Table 3 shows the first twenty assignees (excluding individuals and unassigned) by name.

Table 3. First twenty assignees by number of patents granted

| <i>Assignee name</i>                                         | <i>Patents</i> |
|--------------------------------------------------------------|----------------|
| NOVO NORDISK A/S                                             | 565            |
| AKTIEBOLAGET ASTRA                                           | 146            |
| NYCOMED IMAGING AS                                           | 102            |
| LEO PHARMACEUTICAL PRODUCTS LTD. A/S (LOVENS KEMISKE FABRIK) | 66             |
| PHARMACIA AKTIEBOLAG                                         | 62             |
| NOVOZYMES A/S                                                | 57             |
| NOVO INDUSTRI A/S                                            | 56             |
| ORION YHTYMA OY. ORION PHARMACEUTICAL CO.                    | 55             |
| ASTRAZENECA AB                                               | 53             |
| H. LUNDBECK A/S                                              | 50             |
| NEUROSEARCH A/S                                              | 46             |
| PHARMACIA & UPJOHN AB                                        | 46             |
| AKTIEBOLAGET HASSLE                                          | 42             |
| ASTRA LAKEMEDEL AKTIEBOLAG                                   | 40             |
| A/S FERROSAN                                                 | 36             |
| SYMBICOM AKTIEBOLAG                                          | 22             |
| LEIRAS OY                                                    | 21             |
| ORION CORPORATION                                            | 21             |
| AKTIEBOLAGET DRACO                                           | 19             |

The first twenty assignees own more than half of the total patents issued (individuals and unassigned excluded). Concentration of ownership is counterbalanced by a high dispersion, with 307 assignees (over a total of 541, always excluding individuals and unassigned) owning only one patent, and 182 assignees owning only two patents. An accurate search in the dataset of assignees revealed that many of them filed patent applications under different names, and also that several patents are issued to companies being part of groups. The main assignees are then grouped by checking company connections through the full list of names. Table 4 below gives a brief overview of the ten main assignees among companies, in terms of number of patents granted.

Table 4. First ten assignee (companies)

| Assignee                             | No. of patents | % of total |
|--------------------------------------|----------------|------------|
|                                      | owned          | patents    |
| Novo Nordisk                         | 739            | 24,45%     |
| Astra (until 1999, then AstraZeneca) | 329            | 10,89%     |
| Pharmacia Upjohn                     | 183            | 6,06%      |
| Nycomed                              | 136            | 4,60%      |
| Orion Yhtymä                         | 107            | 3,54%      |
| Lowens Kemiske Fabrik / Leo Pharma   | 80             | 2,65%      |
| Lundbeck                             | 51             | 1,69%      |
| Neurosearch                          | 46             | 1,52%      |
| Ferring                              | 24             | 0,79%      |
| Norsk Hydro                          | 23             | 0,76%      |

Data show a concentration of patents towards a relative small number of assignees: the first 5 hold round 50% of all patents (including those who are labelled as unassigned or individuals), with the sole Novo Nordisk owning one quarter of all patents (the most part is developed by Danish inventors). The top ranked assignees are represented by large/worldwide biotech-pharmaceutical companies, then followed by medium-sized well established companies with strong presence in one country and in some cases subsidiaries and/or sales representatives in foreign countries.

These findings suggest that the composition and the geographical concentration of the biopharmaceutical firms and institutions play an important role in innovative activities

within the sector. This is in line with several other studies. For instance Allansdottir et al. (2002) show that biotechnological enterprises are usually concentrated in some geographic areas in which a strong interrelation among the various organizations localized inside clusters, the main reasons for this concentration being personal contacts, imitation and frequent interaction, the excludability of discoveries, the necessity to reach a certain critical mass of people, infrastructures and financial resources. According to many others there is a growing tendency towards concentration in the biotechnological and pharmaceutical industry (Achilladelis and Antonakis, 2001; Danzon et al., 2004). Geographical concentration is common in many other industries, and it has deep impact on the R&D process (Audretsch and Feldman, 1996). Concentration and clustering in the Nordic countries is also observed in many sectors that are different from the biopharmaceuticals (Asheim and Coenen, 2005), suggesting that they are common processes to different countries and different industries.

Data show also that, between the two most innovative countries in the selected fields, Denmark shows higher indices (patents counts, but also citations) in the biotechnology area, while Sweden is stronger in the drugs area. This suggests some further considerations: each country shows a sub-specialization field; these sub-specialization can be probably driven by the big companies of each country, NovoNordisk being more involved in biotech drugs R&D, and Astra (that in 1999 merged with the UK-based company Zeneca, becoming AstraZeneca, one of the largest pharmaceutical group worldwide) performing R&D mainly on small molecules. Finland shows a similar concentration of patents issued to one company, Orion Yhtymä, that owns more than one quarter of Finnish patents, and overall is one of the companies that has the highest numbers (more than 100 patents issued), suggesting that even in a country where propensity to invent in the drugs and biotech fields is smaller than Denmark and Sweden we observe similar concentration trends; data show also that many biotech patents are granted to Finland.

Norwegian biopharmaceutical industry is mainly made of small dedicated firms, university spin-offs, and few larger firms (OECD, 2006). Geographical distribution of biotechnology firms shows regional concentration, the major agglomeration being the Eastern part of the country and in particular Oslo area (Grønning, 2007). In Norway we

observe concentration effects similar to those of the other countries: about one half of the patents granted to Norwegian inventors are assigned to one company/group, i.e. Nycomed; among 135 Patents granted to Nycomed, 102 of them (all in the drug subcategory) belong to the subsidiary Nycomed Imaging, that in late 1997 merged with Amersham Healthcare (and in fact it became owned by the British company Amersham). Nevertheless, the fact that only 21 of Nycomed Imaging patents were applied for from 1998 onwards, and that all of the 102 are based on research conducted by inventors residing in Norway, means that Nycomed's R&D process was mainly designed and done in that country.

Furthermore, the observed cross-country and cross-firms specialization could mean that the subdivision of the patent dataset into the two subcategories is quite correct, at least in terms of determining the source of new therapeutic compounds: either small molecules or biopharmaceuticals. An analysis of the pipelines and product portfolios of the two above mentioned companies could help verifying such hypothesis.

## **6. Measuring relative importance and size of the innovations in the Nordic countries**

### **6.1 Relative importance**

The relative importance of patents in the four countries is evaluated by using patent citations indices taken from the NBER dataset. Patent citations are considered as better indicators of technological and economic importance of innovations than simple patent counts (Trajtenberg, 1990). Through a cross-country and cross-technology comparative analysis of relative importance of patents, the number of citations received by each patent is regressed on some control variables, i.e. dummies for each of the four Nordic countries and for each technological subcategory (drugs and biotech). In order to account for fixed-effects and truncation problems (Jaffe and Trajtenberg, 2004), the fixed-effect regression is done using mean patent citations for each year in the field "Medicals" from USPTO data (table 5).

Table 5. Number of citations in the category “Medicals”

| year | Obs    | Mean     | Std.Dev. | Min | Max  |
|------|--------|----------|----------|-----|------|
| 1977 | 361710 | 0,94305  | 16,00334 | 0   | 185  |
| 1978 | 332010 | 0,09488  | 14,58806 | 0   | 196  |
| 1979 | 279310 | 0,93448  | 17,30699 | 0   | 319  |
| 1980 | 397211 | 0,16088  | 16,51141 | 0   | 246  |
| 1981 | 415410 | 0,99278  | 15,0606  | 0   | 168  |
| 1982 | 376312 | 0,1924   | 18,76882 | 0   | 347  |
| 1983 | 350312 | 0,46846  | 19,15465 | 0   | 304  |
| 1984 | 427412 | 0,58985  | 18,20094 | 0   | 275  |
| 1985 | 458312 | 0,85621  | 20,30447 | 0   | 388  |
| 1986 | 500714 | 0,05333  | 20,93869 | 0   | 374  |
| 1987 | 604815 | 0,18965  | 29,26192 | 0   | 1069 |
| 1988 | 584414 | 0,02841  | 23,45502 | 0   | 647  |
| 1989 | 796813 | 0,42018  | 20,51024 | 0   | 347  |
| 1990 | 770113 | 0,2066   | 20,31167 | 0   | 384  |
| 1991 | 846312 | 0,88574  | 19,92851 | 0   | 311  |
| 1992 | 879912 | 0,33879  | 19,14171 | 0   | 280  |
| 1993 | 938811 | 0,08394  | 16,49769 | 0   | 245  |
| 1994 | 976110 | 0,60578  | 15,90839 | 0   | 235  |
| 1995 | 102788 | 0,890154 | 14,21148 | 0   | 227  |
| 1996 | 117357 | 0,164295 | 11,772   | 0   | 195  |
| 1997 | 144605 | 0,083956 | 8,769947 | 0   | 158  |
| 1998 | 185703 | 0,436941 | 5,972267 | 0   | 96   |
| 1999 | 187552 | 0,028846 | 3,781867 | 0   | 56   |
| 2000 | 180181 | 0,033633 | 2,182184 | 0   | 43   |
| 2001 | 19123  | 0,36124  | 0,945004 | 0   | 27   |
| 2002 | 18688  | 0,022849 | 0,17484  | 0   | 7    |

The regression was run on data from 1977 to 1999 (grant year); data from 2000 to 2002 were not included to reduce the impact of truncation of forward citations. However a test on data from 1977 to 2002 yielded the same results in terms of sign, magnitude and significance.

Table 6. Regression results

|             | Both Subcategories |          |           |          |
|-------------|--------------------|----------|-----------|----------|
|             | DK                 | FI       | NO        | SE       |
| DK          | -                  | 0.538    | -2.879*** | -0.812*  |
| FI          | -0.538             | -        | -3.417*** | -1.350** |
| NO          | 2.879***           | 3.417*** | -         | 2.067*** |
| SE          | 0.812*             | 1.350**  | -2.067*** | -        |
| <b>cons</b> | 5.051***           | 4.512*** | 7.929***  | 5.862*** |

Significance: \*\*\* at least at a 1% confidence; \*\* at least at a 5% confidence; \* at least at a 10% confidence

The results are shown in table 6. The sign and magnitude of those coefficients tells if and how much a country receives more or less citations on average than the other three countries. Data show that Norwegian patents received more citations on average than the other countries (by dividing the coefficients by the constant term of 7.929, we see that they are about 50% better than Finland, 35% more than Denmark, and almost 25% than Sweden), with high statistical significance; in other words, considering that patent citations are considered as a good proxy for the technological and economic importance, patents held by Norwegian assignees are more important than the other countries . Sweden and Denmark follow, and Finnish patents are on average the least important as measured by citations received, and some of their data are not statistically significant.

By running the regression on each of the two technological categories separately (table 7), we observe similar results; the main difference between them stands in lack of statistical significance of biotechnology subcategory, while drugs class proves to be more robust. The reason maybe stands on the fact that there are more drug patents in the dataset than biotechnology patents (1979 to 1049), and also because of the number of citations received is higher in the drugs group.

Table 7. regression results by subcategory

|      | Drug     |          |           |           | Biotech  |          |          |          |
|------|----------|----------|-----------|-----------|----------|----------|----------|----------|
|      | DK       | FI       | NO        | SE        | DK       | FI       | NO       | SE       |
| DK   | -        | 1.655*   | -3.456*** | -0.911*   | -        | 0.771    | -1.652   | -0.291   |
| FI   | -1.655*  | -        | -5.111*** | -2.567*** | -0.771   | -        | -0.881   | 0.480    |
| NO   | 3.456**  | 5.111*** | -         | 2.544***  | 1.652    | 0.881    | -        | 1.362    |
| SE   | 0.911*   | 2.566*** | -2.544*** | -         | 0.291    | -0.480   | -1.365   | -        |
| cons | 5.329*** | 3.675*** | 8.785***  | 6.241***  | 4.539*** | 5.310*** | 6.191*** | 4.830*** |

Significance: \*\*\* at least at a 1% confidence; \*\* at least at a 5% confidence; \* at least at a 10% confidence

The dataset has been also divided into two different categories by country type. Data from those countries that already established infrastructures to support the biopharmaceutical industry (i.e. Denmark and Sweden) are evaluated separately from the Nordic countries that tried to establish such infrastructures in recent years (i.e. Finland, that started its policy of supporting biopharmaceutical industry from the end of the 1990's, and Norway that started some years later). In order to test if there are differences in patent importance indices between the two subgroups and within them, the regression is run as above over the number of citations received by each patent, using dummies for country subgroups and technological subcategories. Table 8 shows the results.

Table 8. regression results by country groups

|                                        | Drugs & Biotech | Drugs only | Biotech only |
|----------------------------------------|-----------------|------------|--------------|
| 1) DK & SE vs. FI & NO:<br>coefficient | -0.749*         | -0.429     | -1.415*      |
| constant                               | 4.347***        | 4.492***   | 4.113***     |
| 2) DK vs. SE:<br>coefficient           | -1.061***       | -0.711*    | -1.280***    |
| constant                               | 4.142***        | 4.392***   | 3.478***     |
| 3) FI vs NO:<br>coefficient            | -2.576***       | -3.551***  | -0.699       |
| constant                               | 5.945***        | 6.497***   | 4.609***     |

Significance: \*\*\* at least at a 1% confidence; \*\* at least at a 5% confidence; \* at least at a 10% confidence. All data obtained by robust linear regression.

The comparison between countries with well-established bio-pharmaceutical clusters (Denmark and Sweden) and countries that are trying to establish them (Finland and Norway), shows that patents from the former group are on average less important, in terms of citations received, by about 15% (given by the coefficient of -0.749 divided by the constant term of 4.347); the difference is more evident in the biotech patents group. Within the two most advanced countries in terms of infrastructures we observe that Danish patents are less cited than Swedish patents by about 25%, again the biotech area shows a greater difference than the drugs area. Finally, the comparison between Finland and Norway shows that the quality of Norwegian patents is higher by more than 40%; in this case drugs patents show a broader difference (about 55% in favour of Norway), while the comparison of patent citations in biotech does not show significant results.

## **6.2 Size of innovation**

Patent claims data can reveal further information about the technological performance at the country level in the biotechnological and pharmaceutical fields. Each patent contains one or more claims: they represent the core of the inventive activity as expressed by the patent application, and they define the legal boundaries of the invention, as the assignee can only demand protection for the aspects of the invention that are included in its claims. In the drug discovery field patent applications are normally filed at an early stage in a drug's lifecycle. A typical patenting strategy pursued by biotech and pharmaceutical companies is to define a sort of "downfall" of claims, starting with a first broad claim that defines the main area of the invention, then narrowing the domain and the scope of the invention in the following claims, whose content is fully or at least partly encompassed by the previous ones (to which they often explicitly refer to). Thus the number of claims approximately measures the extension and the coverage of a patent, and they may be indicative of the scope or width of invention (Lanjouw and Schankerman, 1999). How many claims are included in the patent application is the result of a relevant strategic decision done by the inventive firm. When a firm or an inventor decides to file a patent application typically faces a trade-off problem, that is whether to ensure the broadest coverage of the invention (in order to ensure the highest legal barrier against its competitors) or to clearly specify the content of the invention (in order to minimize the risks that the patent is not granted because of its excessive indefiniteness). The number of claims can show the compromise reached between these two opposite goals. Furthermore,

a greater number (and content) of claims is a strategy employed by several applicants if their patenting strategy is strongly affected by its costs: instead of filing several specific patent applications only one application is done including as many claims as possible. This strategy will be negatively conditioned with the introduction of new rules at the US Patent and Trademark Office, which limit the number of claims that each patent can contain to a maximum of 25, of which 5 at most can be independent; on the other hand, the new rules will probably ensure more efficiency in the examination process and a reduction of time needed to grant the patent. Since the new rules came into force from 1 November 2007, they do not affect the investigation done in the present paper.

Patent claims are used to measure the relative size of an innovation and they can provide better indicators of the national technological capacity than simple patent counts (Tong and Frame, 1994). A simple econometric model for count data is employed here, using the Poisson distribution regression of the number of claims (dependent variable) over country and technology dummies; where the basic assumptions of the Poisson methodology seemed to be violated the negative binomial is used to test the validity of the estimates, finding that the estimated coefficients have the same values (compared to the Poisson regression the negative binomial standard errors are greater and the statistical significance is slightly lower). Such types of models are widely used to analyze patent indicators (see for instance Hausman et al., 1984). Tables 9 and 10 show the results of the regression of number of claims over country and subcategories dummies, by grant year between 1977 and 2002.

Table 9. Patent claims regression

|             | Both Subcategories |           |           |          |
|-------------|--------------------|-----------|-----------|----------|
|             | DK                 | FI        | NO        | SE       |
| DK          | -                  | 0.058***  | -0.025*   | 0.115*** |
| FI          | -0.058***          | -         | -0.084*** | 0.056*** |
| NO          | 0.025*             | 0.084***  | -         | 0.141*** |
| SE          | -0.115***          | -0.056*** | -0.141*** | -        |
| <b>cons</b> | 2.721***           | 2.662***  | 2.746***  | 2.606*** |

Significance: \*\*\* at least at a 1% confidence; \*\* at least at a 5% confidence; \* at least at a 10% confidence

The results of the separate regression by each technological subcategory are almost the same as those above in sign, magnitude and significance<sup>2</sup>. The cross country comparison proves that the relative size of Norwegian patents, as measured by number of claims, is on average the highest among the group of four countries examined, Swedish patents have the lowest relative size, and Finland and Denmark are in between. As for the patent citations, further cross-country comparison were done with claims by dividing the dataset between the more advanced countries in the field (Denmark and Sweden) and the other two Nordic countries (Finland and Norway), and making comparative analysis of the two countries subgroups and within them.

Table 10. Patent citations regression by country groups

|                         | Drugs & Biotech |
|-------------------------|-----------------|
| 1) DK & SE vs. FI & NO: |                 |
| coefficient             | -0.698          |
| constant                | 14.927***       |
| 2) DK vs. SE:           |                 |
| coefficient             | 1.726***        |
| constant                | 13.110***       |
| 3) FI vs NO:            |                 |
| coefficient             | -1.354          |
| constant                | 15.638***       |

Significance: \*\*\* at least at a 1% confidence; \*\* at least at a 5% confidence; \* at least at a 10% confidence

The main finding is that, if we run the comparison between the two “advanced” countries, Danish patents size is on average broader than Swedish patents<sup>3</sup>. As expected, relative size of innovations is higher in Norway than in Finland, however the result lacks of statistical significance.

## 7. Conclusions

<sup>2</sup> The main differences observed are: Norway’s coefficients are bigger in the biotechnology field than in the drug subcategory, and coefficients for Sweden are slightly better in the drug field than in biotechnology; these differences seem to confirm the technological specialization observed with the simple patent counts and the citation indices analysis.

<sup>3</sup> Data not shown in the table show also that the difference is higher in the biotech subcategory, but the result is not statistically significant; in the drugs field the coefficient is 1.37 in favour of Denmark (significant at a 5% confidence).

The Nordic countries are noted for having on average a high level R&D expenditure and have for the last two decades been active promoters of science based innovation, in which biotech based pharmaceutical industry accounts for a significant percentage of national and regional investments. The vast majority of patents are granted to organizations based in Denmark and Sweden, and only a smaller portion in Finland and Norway, this is probably due to the presence of large biotech and pharmaceutical companies and to path dependence effects. A concentration of patents towards a relative small number of assignees (mainly large biotech and pharmaceutical companies) is also observed. Patent strategies and relevance of innovations can be at least partially captured by some patent-based indicators, i.e. citations and claims. The analysis showed that, despite being the Nordic Country with the lowest simple patent counts indices, Norway has the highest indices of relative importance and size of innovations in the fields of drug and biotech USPTO patents.

Closer examination of the individual Nordic countries investments and performance in biotech pharma yields some interesting comparisons. Norway for instance shows a significant increase in the number of overall patent applications during the 1990s. This increase is an indication of the increasing policy commitment to invest in highly innovative activities, even though the Norwegian industrial system is dominated by more traditional economic activities connected to its dependence on oil. Denmark and Sweden are the two Nordic countries with the most established infrastructure and have strong clusters in the biotech and pharmaceutical sectors. Denmark patents more than Sweden, but Swedish patents are more “important” than Danish patents (as measured by citation indices), while the relative size of innovations in Denmark is higher than in Sweden. These differences can be explained by different patenting strategies among the market leaders and key players. For instance, Danish firms patent more frequently than their Swedish counterparts and include on average more claims in their applications, while Swedish biotech and pharmaceutical companies tend to patent less frequently and to concentrate the invention in less claims, but their patents are more “important” than Danish patents as they receive on average more citations). Thus the results of the estimates suggest there might be notable differences in different technological sectors of innovation in each of the four Nordic Countries.

Although the above data and analysis is only a partial picture, we may nevertheless glean from it some insight into the workings of innovation policies in the respective Nordic countries. The patent indicators examined in this work suggest that other things being equal, geographical proximity to large pharmaceutical companies plays a role in determining the relative success of national policies, as in the case of Denmark and Sweden. Further, despite the strong predictive effect of path dependencies, the Norwegian case shows that new investment policies in countries where large biotech or pharmaceutical companies are not established can yield positive returns in terms of innovation growth. There is need for further study to ascertain what are the variables at work here and how they can be extrapolated to other sites.

Future developments of this study could then be conducted on broader datasets, including an extension of the time interval to more recent years, different technological sectors, and more disaggregated data. Other patent-related indicators can be included, for example citations made (or backward citations), that show how much patents depend on the previous state of the art of their technology; they are also considered as a measure of originality, and they can also be useful to investigate the presence of spillover effects. The analysis of claims could give more precise results in terms of measure of relative size and scope of an invention if there were more detailed information about the number of independent and dependent claim in each patent. Finally, an extension of this working paper should include a deeper analysis of innovation policies of the Nordic Countries in the biotechnological and pharmaceutical sectors.

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## APPENDIX 1 - Selecting patent grants and applications to USPTO and EPO in the fields of drugs and biotechnology

The main problem is to match classification in order to provide EPO data that are comparable to those of the USPTO. In US classification (made by Hall et al. 2001) two of the subcategories from category 3 “Drugs and Medicals” were selected.

TABLE A1. USPTO Classification

| Sub Cat                            | USPTO Classes                          | Description                                                                       |
|------------------------------------|----------------------------------------|-----------------------------------------------------------------------------------|
| <b>31 Drugs</b>                    | <b>424</b>                             | DRUG, BIO-AFFECTING AND BODY TREATING COMPOSITIONS                                |
|                                    | <b>514</b>                             | DRUG, BIO-AFFECTING AND BODY TREATING COMPOSITIONS                                |
| 32 Surgery and medical instruments | 128, 600, 601, 602, 603, 604, 606, 607 |                                                                                   |
| <b>33 Biotechnology</b>            | <b>435</b>                             | CHEMISTRY: MOLECULAR BIOLOGY AND MICROBIOLOGY                                     |
|                                    | <b>800</b>                             | MULTICELLULAR LIVING ORGANISMS AND UNMODIFIED PARTS THEREOF AND RELATED PROCESSES |
| 39 Miscellaneous                   | 351, 433, 623                          |                                                                                   |

The subcategory “Drugs” is made of two USPTO classes: Class 514 is considered to be an integral part of Class 424. This Class retains all pertinent definitions and class lines of Class 424. The subcategory “Biotechnology” is made of two other classes: Class 435 and Class 800.

The EPO Dataset provided by CRENOS sums up per-capita patents granted by application year, for the following ipc4 categories summarized in table A2.

Table A2. EPO classification

| Class | Description                                                                                                                                           |
|-------|-------------------------------------------------------------------------------------------------------------------------------------------------------|
| A61K  | Preparations for medical, dental or toilet purposes                                                                                                   |
| C07H  | Sugars; derivatives thereof                                                                                                                           |
| C07K  | Peptides                                                                                                                                              |
| C12N  | Micro-organisms or enzymes; compositions thereof                                                                                                      |
| C12P  | Fermentation or enzyme-using processes to synthesize a desired chemical compound or composition or to separate optical isomers from a racemic mixture |
| C12Q  | Measuring or testing processes involving enzymes or micro-organisms                                                                                   |
| G01N  | Investigating or analyzing materials by determining their chemical or physical properties                                                             |

In order to match the two different classifications it has been tested if and how many patents share the USPTO and the IPC classes; USPTO includes the IPC classification in its files.

## Appendix 2 - Patent data tables

Table A3. Patents granted in the US by country of applicant (inventor), absolute values.  
Subcategory "Drugs"

| Year  | Grant year |     |     |     |      | Application year |     |     |     |      |
|-------|------------|-----|-----|-----|------|------------------|-----|-----|-----|------|
|       | DK         | FI  | NO  | SE  | Tot  | DK               | FI  | NO  | SE  | Tot  |
| 1977  | 10         | 1   | 0   | 17  | 28   | 7                | 1   | 0   | 20  | 28   |
| 1978  | 6          | 0   | 1   | 23  | 30   | 8                | 0   | 4   | 11  | 23   |
| 1979  | 6          | 1   | 1   | 11  | 19   | 3                | 1   | 2   | 16  | 22   |
| 1980  | 5          | 0   | 2   | 17  | 24   | 8                | 3   | 1   | 15  | 27   |
| 1981  | 7          | 2   | 3   | 12  | 24   | 8                | 4   | 3   | 15  | 30   |
| 1982  | 5          | 4   | 0   | 16  | 25   | 5                | 5   | 1   | 13  | 24   |
| 1983  | 6          | 0   | 4   | 8   | 18   | 10               | 4   | 4   | 10  | 28   |
| 1984  | 8          | 2   | 2   | 8   | 20   | 7                | 3   | 2   | 12  | 24   |
| 1985  | 5          | 6   | 3   | 20  | 34   | 8                | 7   | 4   | 30  | 49   |
| 1986  | 15         | 7   | 1   | 10  | 33   | 12               | 5   | 4   | 22  | 43   |
| 1987  | 9          | 8   | 4   | 23  | 44   | 23               | 3   | 2   | 18  | 46   |
| 1988  | 9          | 3   | 0   | 19  | 31   | 18               | 7   | 5   | 23  | 53   |
| 1989  | 26         | 4   | 5   | 26  | 61   | 36               | 5   | 4   | 22  | 67   |
| 1990  | 24         | 4   | 4   | 21  | 53   | 32               | 9   | 5   | 22  | 68   |
| 1991  | 31         | 5   | 6   | 27  | 69   | 35               | 8   | 7   | 27  | 77   |
| 1992  | 31         | 11  | 8   | 18  | 68   | 33               | 7   | 11  | 23  | 74   |
| 1993  | 34         | 4   | 4   | 27  | 69   | 42               | 13  | 7   | 54  | 116  |
| 1994  | 31         | 10  | 5   | 25  | 71   | 41               | 13  | 13  | 59  | 126  |
| 1995  | 41         | 10  | 8   | 37  | 96   | 95               | 20  | 22  | 117 | 254  |
| 1996  | 35         | 18  | 14  | 44  | 111  | 38               | 15  | 9   | 60  | 122  |
| 1997  | 49         | 11  | 17  | 74  | 151  | 77               | 14  | 11  | 65  | 167  |
| 1998  | 72         | 20  | 12  | 75  | 179  | 65               | 16  | 12  | 67  | 160  |
| 1999  | 76         | 15  | 9   | 74  | 174  | 67               | 18  | 12  | 54  | 151  |
| 2000  | 70         | 17  | 18  | 81  | 186  | 25               | 15  | 7   | 49  | 96   |
| 2001  | 73         | 16  | 13  | 74  | 176  | 17               | 6   | 4   | 20  | 47   |
| 2002  | 54         | 24  | 13  | 94  | 185  | 0                | 0   | 0   | 1   | 1    |
| Total | 738        | 203 | 157 | 881 | 1979 | 720              | 202 | 156 | 845 | 1923 |

Table A4. Patents granted in the US by country of applicant (inventor), absolute values. Subcategory "Biotechnology"

| Year  | Grant year |     |    |     |      | Application year |     |    |     |      |
|-------|------------|-----|----|-----|------|------------------|-----|----|-----|------|
|       | DK         | FI  | NO | SE  | Tot  | DK               | FI  | NO | SE  | Tot  |
| 1977  | 3          | 1   | 2  | 4   | 10   | 7                | 0   | 0  | 9   | 16   |
| 1978  | 6          | 1   | 0  | 5   | 12   | 1                | 0   | 0  | 7   | 8    |
| 1979  | 0          | 0   | 1  | 7   | 8    | 3                | 1   | 1  | 9   | 14   |
| 1980  | 2          | 1   | 1  | 8   | 12   | 7                | 0   | 1  | 6   | 14   |
| 1981  | 3          | 0   | 0  | 7   | 10   | 7                | 1   | 0  | 5   | 13   |
| 1982  | 6          | 0   | 1  | 10  | 17   | 7                | 2   | 2  | 5   | 16   |
| 1983  | 3          | 1   | 1  | 3   | 8    | 5                | 3   | 0  | 4   | 12   |
| 1984  | 7          | 1   | 0  | 3   | 11   | 6                | 4   | 1  | 6   | 17   |
| 1985  | 5          | 1   | 0  | 3   | 9    | 4                | 3   | 0  | 4   | 11   |
| 1986  | 8          | 1   | 2  | 3   | 14   | 6                | 1   | 1  | 8   | 16   |
| 1987  | 5          | 7   | 1  | 7   | 20   | 6                | 7   | 3  | 9   | 25   |
| 1988  | 1          | 2   | 1  | 7   | 11   | 4                | 3   | 2  | 4   | 13   |
| 1989  | 10         | 2   | 1  | 9   | 22   | 5                | 8   | 4  | 8   | 25   |
| 1990  | 4          | 5   | 2  | 6   | 17   | 12               | 5   | 1  | 13  | 31   |
| 1991  | 4          | 4   | 6  | 5   | 19   | 4                | 6   | 1  | 8   | 19   |
| 1992  | 5          | 7   | 0  | 13  | 25   | 16               | 5   | 4  | 11  | 36   |
| 1993  | 9          | 6   | 1  | 8   | 24   | 21               | 12  | 3  | 13  | 49   |
| 1994  | 16         | 3   | 2  | 10  | 31   | 30               | 19  | 7  | 23  | 79   |
| 1995  | 11         | 9   | 3  | 11  | 34   | 67               | 23  | 10 | 43  | 143  |
| 1996  | 20         | 15  | 7  | 10  | 52   | 45               | 19  | 5  | 16  | 85   |
| 1997  | 39         | 13  | 2  | 24  | 78   | 70               | 16  | 5  | 28  | 119  |
| 1998  | 66         | 24  | 7  | 25  | 122  | 69               | 8   | 5  | 30  | 112  |
| 1999  | 65         | 27  | 9  | 35  | 136  | 49               | 9   | 6  | 30  | 94   |
| 2000  | 71         | 7   | 11 | 32  | 121  | 35               | 2   | 1  | 17  | 55   |
| 2001  | 76         | 15  | 5  | 38  | 134  | 4                | 0   | 0  | 2   | 6    |
| 2002  | 50         | 6   | 1  | 35  | 92   | 1                | 0   | 0  | 0   | 1    |
| Total | 495        | 159 | 67 | 328 | 1049 | 491              | 157 | 63 | 318 | 1029 |

Table A5. Patents granted in US by country of applicant (inventor), drugs and biotech, absolute values.

|      | Grant year |    |    |     | Application year |    |    |     |
|------|------------|----|----|-----|------------------|----|----|-----|
|      | DK         | FI | NO | SE  | DK               | FI | NO | SE  |
| 1963 | 2          | 0  | 0  | 8   | 2                | 0  | 0  | 1   |
| 1964 | 3          | 0  | 0  | 2   | 5                | 0  | 2  | 5   |
| 1965 | 2          | 0  | 1  | 6   | 3                | 0  | 0  | 7   |
| 1966 | 2          | 0  | 1  | 7   | 3                | 0  | 0  | 6   |
| 1967 | 10         | 0  | 2  | 7   | 0                | 0  | 0  | 6   |
| 1968 | 1          | 0  | 0  | 5   | 5                | 0  | 0  | 8   |
| 1969 | 1          | 0  | 0  | 6   | 6                | 0  | 1  | 14  |
| 1970 | 0          | 0  | 0  | 5   | 5                | 0  | 1  | 12  |
| 1971 | 6          | 0  | 0  | 10  | 1                | 0  | 1  | 16  |
| 1972 | 7          | 0  | 1  | 20  | 2                | 1  | 0  | 8   |
| 1973 | 2          | 0  | 0  | 13  | 5                | 0  | 1  | 22  |
| 1974 | 3          | 0  | 2  | 17  | 6                | 0  | 3  | 26  |
| 1975 | 5          | 1  | 2  | 21  | 10               | 1  | 2  | 29  |
| 1976 | 9          | 0  | 2  | 36  | 12               | 2  | 3  | 24  |
| 1977 | 13         | 2  | 2  | 21  | 14               | 1  | 0  | 29  |
| 1978 | 12         | 1  | 1  | 28  | 9                | 0  | 4  | 18  |
| 1979 | 6          | 1  | 2  | 18  | 6                | 2  | 3  | 25  |
| 1980 | 7          | 1  | 3  | 25  | 15               | 3  | 2  | 21  |
| 1981 | 10         | 2  | 3  | 19  | 15               | 5  | 3  | 20  |
| 1982 | 11         | 4  | 1  | 26  | 12               | 7  | 3  | 18  |
| 1983 | 9          | 1  | 5  | 11  | 15               | 7  | 4  | 14  |
| 1984 | 15         | 3  | 2  | 11  | 13               | 7  | 3  | 18  |
| 1985 | 10         | 7  | 3  | 23  | 12               | 10 | 4  | 34  |
| 1986 | 23         | 8  | 3  | 13  | 18               | 6  | 5  | 30  |
| 1987 | 14         | 15 | 5  | 30  | 29               | 10 | 5  | 27  |
| 1988 | 10         | 5  | 1  | 26  | 22               | 10 | 7  | 27  |
| 1989 | 36         | 6  | 6  | 35  | 41               | 13 | 8  | 30  |
| 1990 | 28         | 9  | 6  | 27  | 44               | 14 | 6  | 35  |
| 1991 | 35         | 9  | 12 | 32  | 39               | 14 | 8  | 35  |
| 1992 | 36         | 18 | 8  | 31  | 49               | 12 | 15 | 34  |
| 1993 | 43         | 10 | 5  | 35  | 63               | 25 | 10 | 67  |
| 1994 | 47         | 13 | 7  | 35  | 71               | 32 | 20 | 82  |
| 1995 | 52         | 19 | 11 | 48  | 162              | 43 | 32 | 160 |
| 1996 | 55         | 33 | 21 | 54  | 83               | 34 | 14 | 76  |
| 1997 | 88         | 24 | 19 | 98  | 147              | 30 | 16 | 93  |
| 1998 | 138        | 44 | 19 | 100 | 134              | 24 | 17 | 97  |
| 1999 | 141        | 42 | 18 | 109 | 116              | 27 | 18 | 84  |
| 2000 | 141        | 24 | 29 | 113 | 60               | 17 | 8  | 66  |
| 2001 | 149        | 31 | 18 | 112 | 21               | 6  | 4  | 22  |
| 2002 | 104        | 30 | 14 | 129 | 1                | 0  | 0  | 1   |

Table A6. Patent citation indices.

|      | Patents citation index (absolute values) |     |     |     | Patents citation index (average per patent) |       |       |       |
|------|------------------------------------------|-----|-----|-----|---------------------------------------------|-------|-------|-------|
|      | Grant year                               |     |     |     | Grant year                                  |       |       |       |
|      | DK                                       | FI  | NO  | SE  | DK                                          | FI    | NO    | SE    |
| 1977 | 92                                       | 3   | 17  | 182 | 6,08                                        | 0,5   | 7,5   | 7,67  |
| 1978 | 175                                      | 10  | 5   | 357 | 13,58                                       | 9     | 4     | 11,75 |
| 1979 | 51                                       | 4   | 17  | 269 | 7,5                                         | 3     | 7,5   | 13,94 |
| 1980 | 74                                       | 4   | 19  | 229 | 9,57                                        | 3     | 5,33  | 8,16  |
| 1981 | 75                                       | 13  | 17  | 313 | 6,5                                         | 5,5   | 4,67  | 15,47 |
| 1982 | 94                                       | 51  | 22  | 277 | 7,55                                        | 11,75 | 21    | 9,65  |
| 1983 | 64                                       | 2   | 51  | 127 | 6,11                                        | 1     | 9,2   | 10,55 |
| 1984 | 147                                      | 38  | 12  | 82  | 8,8                                         | 11,67 | 5     | 6,45  |
| 1985 | 108                                      | 28  | 18  | 388 | 9,8                                         | 3     | 5     | 15,87 |
| 1986 | 290                                      | 174 | 16  | 134 | 11,61                                       | 20,75 | 4,33  | 9,31  |
| 1987 | 192                                      | 163 | 59  | 379 | 12,71                                       | 9,87  | 10,8  | 11,63 |
| 1988 | 79                                       | 73  | 1   | 312 | 6,9                                         | 13,6  | 0     | 11    |
| 1989 | 318                                      | 39  | 79  | 426 | 7,83                                        | 5,5   | 12,17 | 11,17 |
| 1990 | 274                                      | 102 | 86  | 228 | 8,79                                        | 10,33 | 13,33 | 7,44  |
| 1991 | 366                                      | 52  | 143 | 206 | 9,46                                        | 4,78  | 10,92 | 5,44  |
| 1992 | 231                                      | 131 | 69  | 208 | 5,42                                        | 6,28  | 7,63  | 5,71  |
| 1993 | 392                                      | 35  | 64  | 300 | 8,12                                        | 2,5   | 11,8  | 7,57  |
| 1994 | 311                                      | 63  | 96  | 195 | 5,62                                        | 3,85  | 12,71 | 4,57  |
| 1995 | 303                                      | 71  | 56  | 271 | 4,83                                        | 2,74  | 4,09  | 4,65  |
| 1996 | 210                                      | 181 | 400 | 292 | 2,82                                        | 4,48  | 18,05 | 4,41  |
| 1997 | 218                                      | 59  | 133 | 480 | 1,48                                        | 1,46  | 6     | 3,9   |
| 1998 | 396                                      | 100 | 56  | 349 | 1,87                                        | 1,27  | 1,95  | 2,49  |
| 1999 | 281                                      | 71  | 31  | 247 | 0,99                                        | 0,69  | 0,72  | 1,27  |
| 2000 | 200                                      | 47  | 58  | 174 | 0,42                                        | 0,96  | 1     | 0,54  |
| 2001 | 177                                      | 37  | 21  | 124 | 0,19                                        | 0,19  | 0,17  | 0,11  |
| 2002 | 105                                      | 30  | 14  | 131 | 0,01                                        | 0     | 0     | 0,02  |