Environmental Technology Strengths:

International Rankings Based on US Patent Data

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(Shortened version for heading: **Environmental Technology Strengths**)

Abstract

Patent information has been used by economists and researchers in the field of innovation to analyse current and forecast future technological directions. The recent surge in patenting activities in developed countries reaffirms the strong position of the patent system in a globalised world dominated by market mechanisms. This paper analyses the technological position of the top twelve foreign patenting countries in the USA, namely Australia, Canada, France, Germany, Italy, Japan, Korea, the Netherlands, Sweden, Switzerland, Taiwan and UK, using four technological strength indicators based on patent data. These are the technological specialisation index (for national technological priorities), patent share (for global impact), citation rate (for further knowledge development) and rate of assigned patents (for market potential). The technological strength indicators are calculated for patents relating to environmental technologies between 1975 and 2000. These technologies are expected to have a significant impact on society, the economy and the natural environment as they have the potential to reduce the effects of

global climate change. The empirical findings demonstrate that the expertise and strengths in environmental technologies are concentrated in a relatively small number of countries, namely Germany, Canada and Japan. Nevertheless, these countries show different priorities, being more successful in some aspects of technology strengths than in others.

KEY WORDS

Environmental patents, environmental technologies, international rankings, technological strengths, US patents.

The importance of technologies which are able to respond to global climate change threats has been emphasised and strongly encouraged at international sustainability forums, and also reflected in any resulting documents. Although the future of the Kyoto Protocol (under which most industrialised countries agreed to reduce greenhouse gases emissions by an average of 5.2% between 2008-2012 compared with 1990 levels) appears uncertain at present, the 2002 Sustainability Summit in Johannesburg voiced the need for further reductions. It is clear that the business-as-usual scenario is no longer a possibility in the presence of scientific evidence and international aspirations for safety and environmental sustainability. As the globalised world today is dominated by market mechanisms, sustainability will remain unachievable unless there is a change in this pillar of industrialisation.

The international reaction to climate change has been mixed. Some countries have been more responsible than others, having introduced a number of mechanisms, including financial and regulatory, to encourage the development of environmentally friendly technologies. Other

countries have taken a less pro-active stance by leaving the market and consumers to dictate their preferences. There is also the sustainability industry which has demonstrated a strong will to address environmental concerns and provide showcases of what can be done to alleviate these problems. Several important questions need to be addressed. (1) How has this translated into the process of development of new technologies? (2) Have some countries shown a greater commitment and achieved more than have others? (3) Who are the leaders in environmental technologies, particularly in the industrialsed world?

This paper discusses the achievements of the international community in terms of environmental technologies, as represented in foreign patenting activities in the USA, the world's largest and most technologically advanced market. Technological strength indicators, which are explained in the next section, form the basis of the analysis. The performance between 1975 and 2000 of the top twelve foreign patenting countries in the USA (namely Australia, Canada, France, Germany, Great Britain, Italy, Japan, the Netherlands, South Korea, Sweden, Switzerland and Taiwan) is analysed and compared. The last section draws conclusions about technological performance by individual countries and their global contribution to the development of this class of technologies.

Technological Strength Indicators

Since the mid-1970s, patenting has became a particularly powerful intellectual property protection mechanism, reflecting the beliefs of industrialists, economists, politicians and lawyers, among others, that patents are conductive to economic progress. Despite periodic criticisms, there has been a tendency to reaffirm and even expand the patent system (Arup 1993). The US patent system, in particular, has steadily attracted companies and individuals from around the world that

are interested in further developing technologies (Rosegger 1996). A number of studies have confirmed that patenting activities cause subsequent and immediate market changes (see, for example, Soete 1987, Griliches et al. 1991, and Ernst 1997).

The patent system also provides powerful information for measuring the innovative performances of countries and industries (Soete 1987, and Patel and Pavitt 1994). It is argued that patent data help to reveal early trends of technological change (Campbell 1983). According to Griliches (1990:1661), "(i)n this desert of data, patent statistics loom up as a mirage of wonderful plentitude and objectivity". Patents generally reflect new technological directions, and many technologies are often covered by series (families or clusters) of patents. Patent activities can easily be affected by changes in political priorities or strategies by countries or companies. For example, environmental technologies have been actively promoted by agencies such as the Global Environmental Facility of the World Bank and the United Nations Environmental Program (UNEP), as well as national governments. This is in response to concerns associated with the further deterioration of the natural environment, and in an attempt to abate already existing ecological problems associated with phenomena such as global warming, ozone layer depletion, land erosion, depletion of natural resources and acid rain. It is interesting to see how far the industrialised countries have advanced along this road.

Technological strength indicators based on patent statistics are used to describe national strengths and weaknesses in environmental technologies (for further explanation, see Marinova 1999, and Marinova and McAleer 2002b). These indicators, which are represented in Figure 1, are organised around the following four components of technological development: contribution of

patents to further knowledge development (or “knowledge”), potential economic benefits (or “market”), national priorities (or “local”), and international presence (or “global”). These components can be used to assess the technological strengths of a country, region, industry sector or company.

The local and global components in Figure 1 reflect the development of the technologies and patents themselves. Evidence from innovation studies stresses the importance of two co-existing trends in the development of technologies, namely globalisation and localisation (Pavitt, 1995). The locally developed skills and knowledge benefit from the interrelated global technological developments and globalised economy, while global technological trends also benefit from local creativity.

By their nature, patents represent both advancement of knowledge and potential tools for exploiting economic benefits. However, this does not happen automatically, and registered patents can remain unused for extended periods for a variety of reasons. If a patent (or a cluster of patents) is to provide technological strength, it will have to manifest its potential in an explicit way, namely through contribution to further knowledge development and/or commercialisation. The knowledge and market characteristics in Figure 1 are indicative of the potential power of patents.

At the country level, the four technological strength indicators are as follows:

• Local: The technological specialisation index is a measure of the local development of technologies. Paci et al. (1997) stress the informative value of the index as it takes into account the sectoral differences in patenting. In some industries or sectors, patenting is a preferred way of protecting market advantages; in others, these could be achieved through different means, such as brand names, trade secrets, first trader strategies, or economies of scale. The technological specialisation index is calculated by dividing the national share of patents in a particular area (e.g. Australian environmental technologies as a share of total Australian patents registered in the USA) by the overall share of patents in this area (e.g. environmental technologies as a share of total US patents). If the value is greater than one for a particular technology, the latter represents a technological strength at a national level. The higher is the value, the more prominent is this advantage.

• Global: An indicator for measuring the global impact of technologies is the national share (or percentage) of a particular technology in the overall number of patents in the same field (Patel and Pavitt 1991).

• Knowledge: The citation rate is a measure of the usefulness of a patent in subsequent patent documents, and hence in the creation of new knowledge. It gives the mean number of citations per patent from a particular country (i.e. the mean number of citations for a particular patent in subsequent US patents). The higher is the citation rate, the more frequently quoted are patents in subsequent patents applications.

- Market: The rate of assigned patents measures the proximity of patents to commercial exploitation in the market. When a patent is assigned to one or more companies or individuals, the legally protected prototype is closer to commercialisation, so that assigned patents are presumed to be closer to achieving commercial profitability (Firestone 1971). Although this does not mean that an unassigned patent cannot also be commercially exploited, assigning a patent indicates an explicit intention to use it for commercial purposes.

It is interesting to note that none of the indicators has a time dimension. The main justification for this is the fact that technological strengths can be established over an extended period (when patents are more or less evenly distributed), or alternatively in a relatively short period of time (when there is high concentration of patents). In both cases, the end result is the development of technological capabilities.

It is important to draw a distinction between technological and economic strengths, as the latter does not necessarily follow from the former. For example, a study by Narin et al. (1987) found that patent data are positively correlated with various measures of a company's technological strengths, but not with their financial performance. Whether a company will be in a position to exploit economic capabilities from an invention will depend on the appropriability of the technology, namely whether it will be able to extract all the commercial benefits, as other factors such as national system of innovation, government regulations, and social attitudes are also important.

The US market has always been attractive to foreign companies and individuals because of its advanced technological nature and large size. In absolute numbers, the US patent office receives by far largest number of foreign applications (Archibugi 1992), and close to 50% of all patents in the US are granted to foreigners (Griliches 1990). The second half of the 1980s and the 1990s witnessed an unprecedented surge in patenting activities in the USA by foreign countries. This trend was observed and analysed in a number of studies (e.g. Arundel and Kabla 1998, and Kortum and Lerner 1999). The remainder of the paper explores trends and international strengths in the area of environmental technologies. Before doing so, it is necessary to clarify what constitutes an environmental technology, and hence an environmental patent.

The source of the data used to calculate the technological strength indicators is the database of the US Patent and Trademark Office. At present the US patent classification system does not provide specific categories which cover environmental patents, and there is also no widely accepted agreement in the literature as to what constitutes an environmental (ecological or green, clean or cleaner) technology. The United Nations Environmental Programme uses the term "environmentally sound technologies", which "encompass technologies that have the potential for significantly improved environmental performance relative to other technologies" (UNEP 2002). Such technologies use fewer resources, are less polluting, protect and/or rehabilitate the natural environment, recycle materials and waste, and conserve energy and water.

Major parts of any patent are the description of the technical background and the summary of the invention. As a rule, the new technology is judged against the existing technological solutions, with the expectation that it will perform at a higher standard. When the technology is described in

terms of its superior environmental performance, such an invention can be considered to be an environmental patent. [Although ‘ecological’, ‘environmental’, ‘green’, ‘cleaner’, and related terms are considered synonymous when applied to patented technologies, the term ‘environmental patent’ is used in this paper).

The following approach was used to identify environmental patents: a patent is considered to be related to the ecological environment if its abstract or full text contains words such as "ecology", "ecological", "ecologically" or any other word beginning with "eco-", and "environmentally". It was not possible to incorporate in this definition of environmental patents a keyword search using "environment" or "environmental" because of their widespread use outside the area of the ecological environment, such as in the digital, physical or economic environments. The number of patents related to ecologically sustainable technology, which would not include one or more of the various definitional words given above, is likely to be limited.

Environmental Technology Patenting

Innovation is an evolutionary process (e.g. Saviotti 1996, and Tisdell 1995) and reflects other major trends within society, such as technological and socio-organisational paradigms. The development of green technologies is the currently emerging technological and socio-economic paradigm. However, the adoption of the ecologically sustainable paradigm is a slow process paved with difficulties, and it is interesting to see what the pace of development of the contributing technologies has been.

The annual trend in the total number of environmental patents in the USA is presented in Figure 2, while Figure 3 shows the annual shares of US environmental patents to total US patents between 1975 and 1998. These data refer to the application time of the patents, and not the issue time, which is considered to represent patenting activities more accurately (for further discussion, see Marinova and McAleer 2001, 2002a). The average time for patent applications to be processed is around two years (22.9 months in 1997, according to USPTO 1997). Therefore, the figures for 1999, 2000 and 2001 are not indicative of the actual number of patents that are expected to be approved, and hence have not been included. The annual trend in approved US environmental patents reached a peak of 3,565 in 1995, and a second peak of 3,300 in 1997. A comparison of the trends between the rates of growth of total US patents and total US environmental patents shows that the number of US environmental patents has been growing at a faster rate than total US patents, which is a positive development (Marinova and McAleer 2002a). This relationship indicates changes in the world economy that are leading to a greater interest in the natural environment. Technological innovators seem to have responded to community concerns in relation to the technologies used, as well as their impact on the environment.

Although they have been increasing, the annual share of patents which address ecological issues and their implications remains very small (see Figure 3). Since 1993 the annual share has been around only 2% of the total patents lodged in the USA, and the increasing trend has clearly disappeared. This may be a warning sign of a lack of commitment by industry and individuals to sustain improvement in environmental performance over the long term.

In general, environmental technologies can be of a highly disparate nature and come from all streams of science, research and development. Moreover, they are often designed to satisfy the requirements of a particular location or to resolve a particular problem, and hence will not necessarily be captured by international patenting. Patenting abroad, however, is always representative of the technologies which have the most potential. Therefore, the patent indicators discussed in the next section reveal strengths developed by particular foreign countries.

International Comparisons

Table 1 shows the number of environmental patents in the USA, the patent intensities (or number of patents per 1 million population), and four technological strength indicators for environmental technologies between January 1975 and December 2001, for the top twelve foreign patenting countries, namely Australia, Canada, France, Germany, Italy, Japan, Korea, the Netherlands, Sweden, Switzerland, Taiwan and UK. Germany has the most environmental patents with 4,067, followed by Canada and Japan, with significantly lower numbers of patents at 1,260 and 1,147 respectively. The contribution of these three countries is so dominating that each of the remaining nine countries is below the mean of 813 (see Table 1).

When the population size is taken into consideration, Switzerland is ranked first with 108 environmental patents per 1 million population (Table 1). Germany and Canada also demonstrate a high national commitment to this type of technology and are ranked second and third with patent intensities of 49 and 40, respectively. Japan, on the other hand drops to seventh place with a modest patent intensity of 9. Nevertheless, if interest is in assessing the impact of countries on

the global development of environmental technologies, the national patent intensity is not a very informative indicator. The four technological strength indicators are a more accurate indicator of such an impact.

Only five of the twelve countries have a technological specialisation index greater than 1, which indicates the local importance of environmental technologies. The country with the highest technological specialisation index is Australia at 1.40. Canada and Germany are equal second with 1.34, Switzerland is fourth with 1.29, and Great Britain is fifth with 1.05 (see Tables 1 and 2). The mean index is 0.80. It is interesting to note that Japan, which is by far the largest foreign patenting country in the USA (McAleer et al. 2002), has the lowest technological specialisation index of 0.15. This shows that the environment is not an important patenting activity in the USA for Japan.

The most influential foreign country on the US market is Germany, with an overwhelming 10.48% of total environmental patents (as represented by the patent share in Tables 1 and 2), followed by Canada in second place with 3.25% and Japan in third place with 2.95%. Switzerland's share is 2.01%, while all the remaining countries have modest shares below 2%.

Commercialisation appears to be a significant factor for Japanese inventors, as the ownership of the vast majority of their patents is assigned. The rate of assigned patents for Japanese environmental technologies is the highest at 0.88 (see Tables 1 and 2). Germany follows Japan closely with 0.83, while Australia is third with 0.77. The mean for the top twelve countries is 0.67. It is interesting to note the much lower rates of assigned patents for Taiwan (0.47), Canada

(0.54), Switzerland (0.55), France (0.57) and Great Britain (0.58). It would appear that close to one-half of the environmental patents from these five countries explore new opportunities without immediate marketing strategies.

The citation rate, which is an indication of the value of registered patents for further technological knowledge development, has the highest value of 5.29 (i.e. more than five citations per environmental patent, on average) for Japan (see Tables 1 and 2). Canada is second with a significantly lower value of 3.96, and France is third with 3.40. The mean citation per environmental patent is 2.85. However, the lower citation rate for some countries is affected by the fact that a large share of their environmental patents has been issued only recently, thereby leaving a much shorter time for future citations. This is the case, for example with Australia which ranks ninth with a citation rate of 1.93. As 48% of Australia's environmental patents have been lodged since 1998, with patents consequently issued in 1999 and 2000, this leaves a short period for patent citations. Notwithstanding this, countries like Australia are still able to make an impact on the global development of environmental technologies.

In addition to the specific rankings according to the four technological strength indicators, Table 2 shows the overall ranking of the twelve nations. The best performing country is Germany, Canada and Japan are equal second, and Australia is ranked fourth. The performance of Germany is particularly impressive, as this country ranks among the top two economies in three of the four indicators, and is fourth in another. Canada and Japan also rank among the top three in three of the four indicators, but drop toward the bottom of the list for the fourth (Canada to second last

position for the rate of assigned patents, and Japan to last place for the technological specialisation index).

Conclusion

Environmental technologies are expected to have a significant impact on society, the economy and the natural environment. The technological strength indicators proved to be a useful tool in assessing the potential of several leading countries in this field. Indicators based on patent statistics, as applied to the top twelve foreign patenting countries in the USA, revealed different emphases in the development of environmental technologies.

Germany is the best performing country, which has a technological specialisation index of 1.34 (second in the group of twelve countries), a patent share of 10.5% (first), a rate of assigned patents of 0.83 (second), and a citation rate of 3.18 (fourth). Canada and Japan ranked equal second, but demonstrated significant national differences in their environmental technologies. Although both countries have relatively high patent shares (3.25% for Canada and 2.95% for Japan, which ranked them second and third, respectively) and citation rates (3.96 for Canada and 5.29 for Japan, which ranked them second and first, respectively), their two remaining indicators were strikingly different. For Canada, environmental technologies are a national priority (as demonstrated by the high value of the technological specialisation index of 1.34, which ranked equal second), but patenting is not oriented towards speedy commercialisation as the rate of assigned patents of 0.54 is the second lowest. The reverse is true for Japan, with the rate of assigned patents at 0.83 being the highest, but the local importance of environmental

technologies being the lowest (with a technological specialisation index of 0.15). For Australia, environmental technologies appear to be a national priority as the country has the highest technological specialisation index of 1.40, and 3 of 4 registered patents are close to commercialisation (the rate of assigned patents being 0.77, which is ranked third). The values for the other two indicators, however, are in the middle range. Of the remaining countries, France is the only country with one of the indicators among the top three, with a citation rate of 3.40.

The empirical findings demonstrate that the expertise and strength in environmental technologies are concentrated in a relatively small number of countries, namely Germany, Canada and Japan, with Australia close behind the leaders. Nevertheless, these countries show different priorities, being more successful in some aspects of technological strengths than in others. All of them, however, are currently establishing the foundations for the future significant impact of this important group of technologies.

Technology strength indicators based on patent data are convenient and helpful tools in analysing current and future technological strengths. They do, however, have their limitations, and should be considered as indicative in representing the various technologies. It would be interesting to complement the qualitative analysis in this paper with quantitative information about trends in particular technological development and industries, as well as specific company and organisational strategies.

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Figure 1. Technological strength indicators based on patent statistics

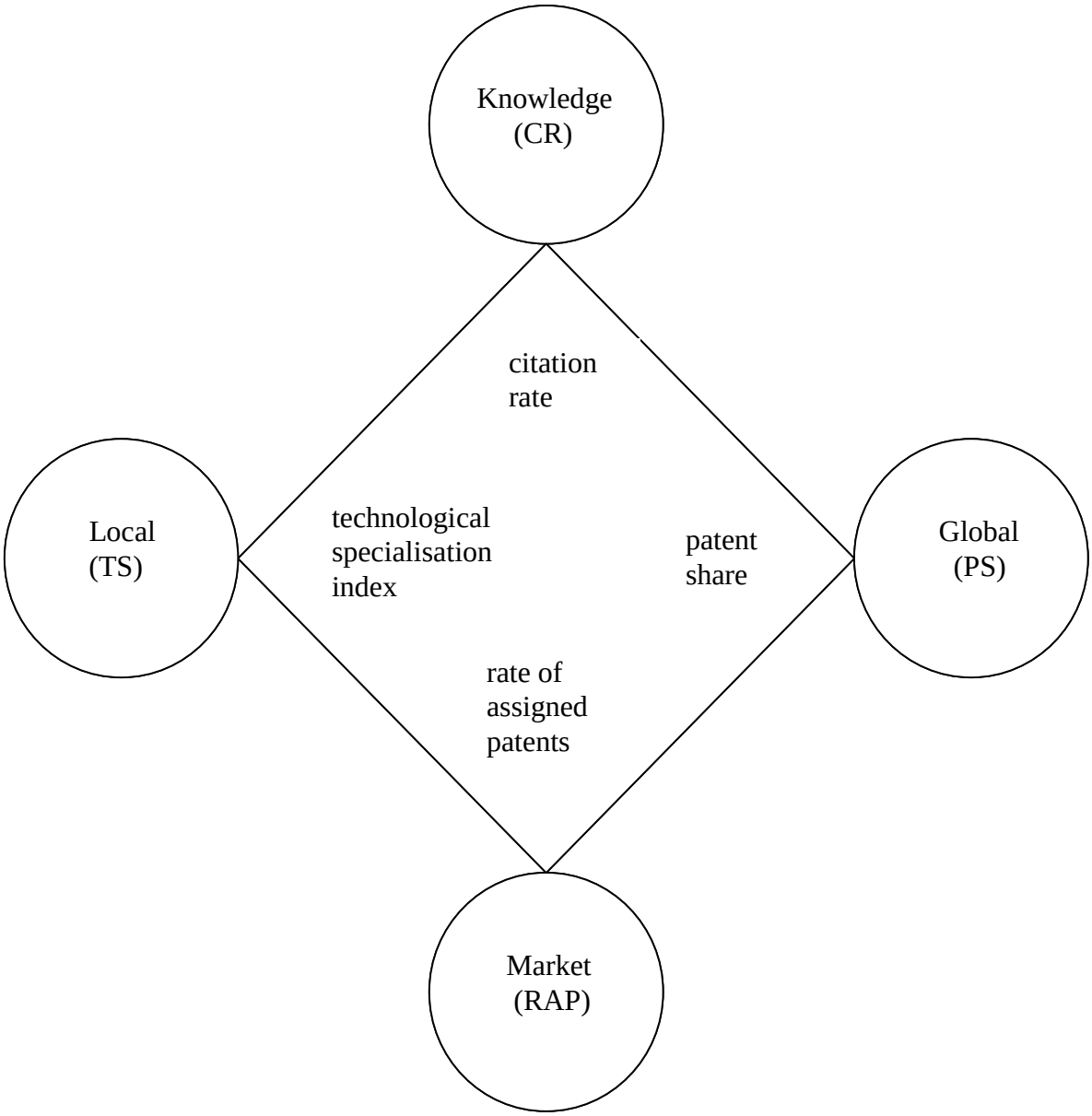
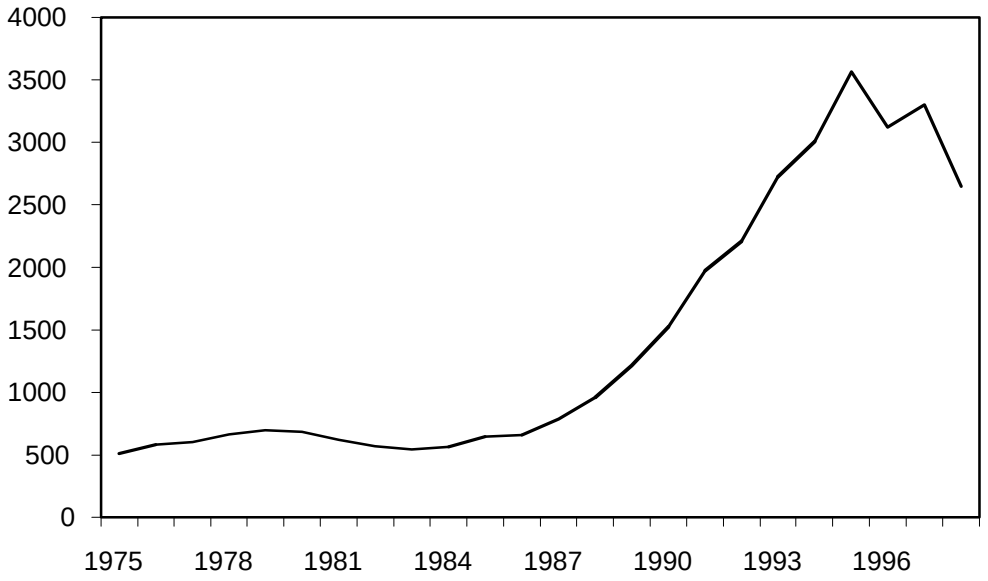
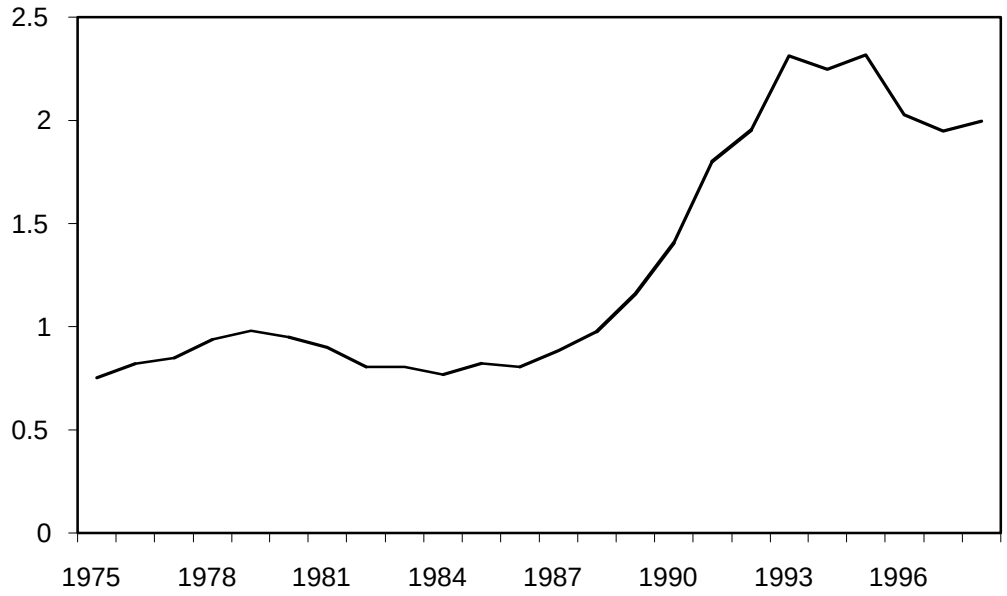


Figure 2. Annual US environmental patents by year of application, 1975-1998



Note: The data were extracted on 5 March 2002.

Figure 3. Annual share (%) of US environmental patents to total US patents by year of application, 1975-1998



Note: The data were extracted on 5 March 2002.

Table 1. Technological strength indicators for US environmental patents by country, 1975-2000

Country	Number of patents P	Patent intensity PI	Technological specialisation index TS	Patent share PS	Rate of assigned patents RAP	Citation rate CR
Australia	316	16	1.40	0.81	0.77	1.93
Canada	1260	40	1.34	3.25	0.54	3.96
France	467	8	0.37	1.2	0.57	3.40
Germany	4067	49	1.34	10.48	0.83	3.18
Great Britain	463	8	1.05	1.19	0.58	1.73
Italy	391	7	0.72	1.01	0.65	2.64
Japan	1147	9	0.15	2.95	0.88	5.29
Korea	97	2	0.25	0.25	0.75	1.04
Netherlands	344	22	0.80	0.89	0.66	2.96
Sweden	308	35	0.75	0.79	0.76	3.16
Switzerland	782	108	1.29	2.01	0.55	3.10
Taiwan	111	5	0.17	0.29	0.47	1.84
Mean	*813*	*26*	*0.80*	*2.09*	*0.67*	*2.85*

Notes: 1. The data were extracted on 5 March 2002.

2. The total number of US environmental patents is 38,825.

3. The patent intensity is given per million of population in 2000.

Table 2. Ranking of countries for US environmental patents, 1975-2000

Country	TS	PS	RAP	CR	Mean	Mean score rank
Germany	2	1	2	4	2.3	**1**
Canada	2	2	11	2	4.3	2
Japan	12	3	1	1	4.3	2
Australia	1	9	3	9	5.5	4
Switzerland	4	4	10	6	6.0	5
Sweden	7	10	4	5	6.5	6
France	9	5	9	3	6.5	6
Netherlands	6	8	6	7	6.8	8
Italy	8	7	7	8	7.5	9
Great Britain	5	6	8	11	7.5	9
Korea	10	12	5	12	9.8	11
Taiwan	11	11	12	10	11.0	12

Note: The data were extracted on 5 March 2002.