Anti-pollution Innovation Strengths Indicators Based on US Patents

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Abstract: This paper uses innovation strengths indicators based on pollution prevention and abatement (or anti-pollution) patents lodged at the US Patent and Trademark Office for the period 1975-2002 to: (i) analyse trends in the patenting of anti-pollution technologies in the USA; and (ii) provide international rankings for the development of anti-pollution technologies. Annual data used for the innovation strengths indicators are patent shares to represent international presence, the technological specialisation index to represent national priorities, and the rate of assigned patents to represent potential economic benefits. The empirical results demonstrate the clear advantage held by Japan and France among the leading twelve foreign countries with patents in the USA.

Keywords: *Anti-pollution patents, trends, innovation strengths, national priorities, economic benefits, international rankings.*

1. INTRODUCTION

Pollution from volcanoes, winds, fires, flood, land erosion and other natural phenomena has existed from the beginning of time. Remains in caves from prehistoric time have also manifested signs of pollution caused by the use of fire. From the industrial revolution, pollution has become a major cause of the deterioration of the ecology. The Collin's English Dictionary (2000) defines pollution as the act of introducing harmful or poisonous substances into the natural environment. Behind this simple definition lies a large spectrum of issues which have gradually become a focus of international concern.

Issues of cleaner production have become a major concern in attempts to rectify the damage caused to the natural environment by industrial development. According to Nagel (2003, p.1), each production facility generates an environmental load in terms of negative contributions to environmental effects such as acidification, greenhouse effect, smog or global warming. Particulate and gaseous emissions from automobile exhausts are additionally "responsible for the rising discomfort, increasing airway diseases, decreasing productivity and the deterioration of artistic and cultural patrimony in urban centres" (Puliafito et al., 2003, p. 105) in both the developing and developed worlds.

Pollution control and abatement has been an expensive exercise for individual companies and national economies. In general, only relatively rich economies can afford such control and abatement. For example, Kelly (2003) examined the relationship between economic growth and the environment, and found that the benefits and costs of pollution control rise directly with income.

The environmental behaviour of individuals, companies and countries, their levels of pollution, and consumption of resources, are directly related to the technologies used. Renewable energy technologies are considered to be an alternative to fossil fuels, not only in terms of preventing resource depletion but also as a way of reducing air pollution. Fuel cells have emerged as an alternative to the internal combustion engine, resulting in lower emission levels and zero noise pollution. New ecological technologies (see Marinova and McAleer, 2003) are expected to decrease human pressures on the environment while simultaneously raising standards of living.

Pollution is a very complex technical as well as social issue For example, air pollution can be caused by a mixture of particulate matter, acid gases (such as SO_x, NO_x and HCl), green house gases (such as CO_x, N_xO_y and PFCs), ozone depletion substances (such as Freon and Halon), volatile organic compounds (such as TCE, TCA, toluene and xylene) and toxic gases (such as Hg and dioxins) (see Chang, 2003). River sediments in proximity to mining sites are polluted with Fe, Mn and potentially toxic trace elements such as As, Cd, Cr, Cu, Ni, Pb and Zn (Galána et al., 2003), which can be in particulate, colloidal or dissolved fractions. The technological solutions of preventing or abating these and other types of pollution require substantial intellectual effort, as well as large investments in research and innovation. In order to gain full industrial and economic advantages from such investments, companies and individuals use patent protection as part of the development of new technologies.

Technological innovation is also affected by country-specific policies and regulations. In comparison with the USA or Australia, the European Union has made greater efforts to reduce CO_2 emissions, and has imposed heavier taxes on raw materials used by consumers and companies (Focacci, 2003). This outcome has required the European Union to include environmental and particularly pollution considerations in the introduction of any new technologies, including those that are not necessarily intended to solve or abate a pollution problem. It is expected that certain countries would have established greater expertise and knowledge, and would be better placed in combining the economic, social and environmental benefits from the prevention and abatement of pollution.

This paper analyses the innovation strengths of several leading countries in the development of anti-pollution technologies. In order to analyse global expertise, the paper examines the information contained in annual patents registered in the USA by twelve leading OECD countries for the period 1975-2002.

2. ANTI-POLLUTION PATENTS IN THE USA

As the world's largest and technologically most advanced economy, the USA attracts the most ambitious innovators and investors. This is particularly evident in the very large number of foreign patents that are lodged at the US Patent and Trademark Office (PTO). Although the USA does not have the most stringent environmental regulations by international standards, it has had the Clean Water Act since 1987, the Pollution Prevention Act since 1990, and associated national pollution prevention strategies.

The various methods of dealing with pollution have been to: (i) reduce pollution at the source by avoiding or reducing the generation of pollution; (ii) recycle pollution in an environmentally friendly way; and (iii) include new or modified technology and equipment, process and procedure modifications, and reformulate and redesign products, which are often subject to patent protection.

In this paper, "anti-pollution" patents are defined as any patents which include "pollution" in the description of their abstracts, claims or specifications. Annual data regarding anti-pollution technological innovations were obtained from the US PTO on-line database. The data were extracted on 26 January 2003.

Figure 1 gives the annual anti-pollution patents registered at the US PTO from 1975 to 1999 by date of application. Rather than using the date of issue, the date of application is regarded as a more accurate measure of patent activity (see Chan et al. (2001) and Marinova and McAleer (2002, 2003)). Data for the years 1999-2002 are as yet incomplete as delays in administering patent applications can take from 2-3 years. From the mid-1970s to the mid-1980s, the number of anti-pollution patents fell from 1,816 in 1975 to 997 in 1983. Then there was a steady increase to 2,324 in 1995, after which anti-pollution patents seem to have stabilised[1]. It is clear that after rather strong innovations in the mid-1970s, the interest in pollution diminished in the mid-1980s, was resurrected until the mid-1990s, and then levelled off in the late-1990s. In Figure 2, the annual ratios of anti-pollution patents to total US patents have also declined over time, falling from 2.7% in 1975 to 1.2% in 1998. Such a declining trend suggests a decreasing relative importance of anti-pollution technologies, which does not augur well for the prevention and abatement of pollution in the short to medium term.

Notwithstanding this somewhat pessimistic view of the development of new technologies, it is important to analyse the performance of the leading OECD countries, especially in terms of analysing if and how various countries have capitalised on their technological knowledge. Innovation is commonly defined as the commercial application of new inventions. As patents represent new technological inventions, patent-based indicators are used to describe the innovation process. In order to address this issue, the paper examines three innovation strengths indicators of anti-pollution technologies. The three indicators are patent shares to represent international presence, technological specialisation index to represent national priorities, and rate of assigned patents to represent potential economic benefits. These indicators are based on US patent data, specifically patents registered by foreign companies or individuals at the US PTO. The twelve OECD countries to be examined are Australia, Canada, France, Germany, Great Britain, Italy, Japan, Korea, the Netherlands, Sweden, Switzerland and Taiwan, which represent the leading foreign countries according to the total number of US patents registrations.

3. INNOVATION STRENGTHS INDICATORS

The three innovation strengths indicators based on patents are given by:

[1] Although the trend from 1995 to 1999 may appear to be slightly downward, the patent figures will increase as applications from more recent years are approved.

(1) Patent share: This is an indicator of a country's contribution to the global development of new technologies, and hence is a measure of innovation strength in terms of *novelty*. According to Patel and Pavitt (1991), the patent share (PS) is:

$$PS_j = P_j/\sum_j P_j, \qquad 0 \leq PS_j \leq 1,$$

where PS_j denotes the patent share of country j to total patents. The larger is the patent share, the higher is the innovation strength of the country.

(2) Technological specialisation index: This is a measure of the *national importance* of technologies, or the comparative advantage of a local technology relative to international standards. Paci et al. (1997) stress the informative value of the index, which accommodates sectoral differences in patenting in the domestic (national or local) economy as compared with the world (or global) economy. The technological specialisation (TS) index is given as:

$$TS_{ij} = (P_{ij}/\sum_i P_{ij}) / (\sum_j P_{ij}/\sum_i\sum_j P_{ij})$$

where P_{ij} denotes patents in technology sector i (such as anti-pollution technology) invented by residents of country j. The ratio $P_{ij}/\sum_i P_{ij}$ denotes patents in sector i for country j relative to all patents in country j, whereas the ratio $\sum_j P_{ij}/\sum_i\sum_j P_{ij}$ denotes total patents for sector i in all countries relative to all patents in all countries. Therefore, TS_{ij} reflects the relative strength of sector i in country j to sector i in all countries. If $TS_{ij} > 1$ for sector i in country j, this represents a technological strength at a national level compared with international standards. The higher is the value of TS_{ij}, the greater is the relative technological advantage of sector i in country j.

(3) Rate of assigned patents: When a patent application is approved, the applicant has the right to assign the commercial application of the patented technology to one or more individuals and/or companies. Not all patents are commercially transformed into innovations. For example, Tsuji (2002) discusses the decoy and defence functions of patenting. However, when a patent has been assigned, the legally-protected prototype is clearly intended for *commercialisation*. Although this does not mean that an unassigned patent cannot be commercially exploited, assigning a patent indicates an explicit intention to use the patent for commercial purposes. The rate of assigned patents (RAP) is given by Marinova (1999) as:

$$RAP_j = AP_j/P_j,$$

where AP_j is the number of patents assigned to the residents of country j. The RAP_j equals 0 when there are no assigned patents, and equals 1 when the number of patents assigned to residents of country j equals the number of patents invented by residents of country j. This rate can exceed 1 when $AP_j > P_j$, that is, when patents invented by residents of non-j countries (such as non-Australian residents) are assigned to country j (such as Australia).

In the following section, the three innovation strengths indicators are calculated for the leading twelve OECD countries for the period 1975 to 2002. As none of these indicators has a time dimension, the innovation strengths in anti-pollution technologies could have been established through: (i) evenly-spread patenting activities over a relatively long period; or (ii) concentrated efforts over a short period during which a large number of patents could have been generated.

4. INTERNATIONAL RANKINGS OF ANTI-POLLUTION TECHNOLOGIES

Table 1 presents the number of patents, patent intensity (or the number of patents per million of population in 2000), and the three innovation strengths indicators for anti-pollution technologies, namely patent share (PS), technological specialisation (TS) index, and rate of assigned patents (RAP), for the top twelve foreign patenting countries in the USA. The three indicators have been calculated using patent data from the US PTO, which were extracted on 26 January 2003, for the period 1975-2002. Even though the annual data for the years 1999-2002 are as yet incomplete owing to administrative delays in assessing patent applications, the aggregated annual data for the period 1975-2002 allow reliable comparisons to be made across countries according to the total number of approved anti-pollution patents. Patents by US inventors have not been included in the empirical analysis because of limitations in the search engine of the US PTO site[2] and the domestic nature of these patents[3] .

Of the leading twelve foreign countries with anti-pollution patents in the USA, Japan has the highest number of patents for the period 1975-2002 at 9,837 (see Table 1), or 51% of the patents held by these countries. Germany is second with 2,497 (13%) and France is third with 2,233 (12%). Japan and France maintain their respective rankings when the performance of the twelve countries is compared on the basis of patent intensity.

[2] The US PTO site does not allow for a straightforward search of patents for inventors residing in the USA. Instead, the site requires the search to be performed by state of residence which, combined with the word limitation on the search string, leads to multiple counting of patents with overlapping states.

[3] Inventors tend to patent only their "best" technologies in a foreign country but patent a larger number of technologies domestically (see Tsuji (2002)).

Specifically, Japan has a patent intensity of 78, which is 2.5 times the mean of 31, while France has 38. Switzerland is second in patent intensity with 64, which is more than twice the mean of 31 and a drastic change from position 8 based on the number of anti-pollution patents. Germany, however, drops to position 6 with 30, which is just below the mean. Italy and Korea fall from positions 6 and 7 to 10 and 11, respectively, when patent intensity is used rather than the number of patents, while Sweden rises from position 12 to 7 when patent intensity is used rather than the number of patents.

The PS of anti-pollution patents for Japan, which is a clear leader, is the highest at 23.05%, with Germany second at 5.85% and France third at 5.23%. One-third of the countries (namely the Netherlands, UK, Australia and Sweden) have their PS less than 1%, and account for less than 3% of US anti-pollution patents in total. If any of these countries aspire to have any impact on the global development of anti-pollution technologies, their contributions need to be improved dramatically.

France has the highest TS index of 1.76, which indicates an existing specialisation and *national* importance of anti-pollution technologies, followed by Japan at 1.28 and Italy at 1.26. Four other countries, namely Korea, Australia, Canada and Taiwan, have a TS index higher than 1. Thus, at the national level, seven of the twelve countries are concentrating their R&D efforts and producing innovative anti-pollution technologies at a higher rate than for other technologies. The remaining five countries have a TS index less than 1. As the mean TS value is 1.03, anti-pollution technologies would seem to be of "average" national importance for this leading group of twelve countries.

The RAP, which is an indication of the proximity of patents to commercial development and export orientation, is 0.95 for Japan, 0.90 for Sweden, 0.85 for France, 0.81 for Germany, 0.79 for Korea and 0.75 for Italy, with a mean of 0.71. These six countries appear to have strong market aspirations in anti-pollution patenting in the USA. The protection of intellectual property in anti-pollution technologies for Taiwan, which has the lowest RAP of 0.38, does not appear to be particularly strong.

Table 2 gives the individual rankings of the top twelve foreign anti-pollution patenting countries in the USA according to the three indicators, namely PS, TS and RAP, as well as their overall mean rank score. Japan is ranked first, followed by France, with Germany and Italy equal third, so these four countries have the strongest performance of the leading twelve anti-pollution patenting countries outside the USA. The performance of Japan is particularly outstanding, as this country ranks among the top two countries for all the indicators, with actual values significantly above the mean in all cases. France is also ranked very highly, being in the top three for all three indicators and well above the mean in each case. Germany performs well on two of the three indicators, but the development of anti-pollution technology does not appear to be a technological specialisation in terms of its TS in position 9. The reverse holds for Italy, where anti-pollution technologies attract a greater technological specialisation in position 3 for TS, but are lower for the other two indicators. The strength of Sweden is in the proximity of its patents to commercialization, where its RAP is second. Australia does reasonably well in TS in position 5, but is much lower for the other two indicators. The remaining six countries perform reasonably similarly for all three indicators, with no pronounced advantages.

5. CONCLUSION

Anti-pollution technologies are expected to prevent the deterioration of the natural environment and to contribute to sustainable development. Innovation strengths indicators were shown to be a useful tool for assessing the potential in the field of anti-pollution technologies across several leading OECD countries outside the USA. Innovation strengths indicators based on patent statistics for the twelve leading foreign patenting countries in the USA for the period 1975-2002 revealed some striking similarities between Japan and France, which were ranked first and second overall, respectively. Although Japan significantly outperformed France in terms of the patent share and the rate of assigned patents for commercialisation, anti-pollution technologies are a more pronounced technological specialisation for France.

Based on innovation strength indicators, the best performing country is Japan, with PS and RAP both ranked first in the group of twelve countries outside the USA, and TS second. France is ranked second overall, with TS first, and both PS and RAP third. Germany and Italy are ranked equal third overall, with Germany ranked second in PS, fourth in RAP and ninth in TS, while Italy is ranked third in TS, and sixth in both PS and RAP. Sweden demonstrates strong interest in commercialising anti-pollution technologies on the US market, with its RAP ranked second. With this exception in one indicator, none of the remaining seven countries exhibits any particular innovation strengths.

The findings of this paper demonstrate that Japan and France are the clear leaders in innovation, expertise and strength in anti-pollution technologies. Of the remaining ten countries, some are more successful than others according to different innovation strengths indicators.

6. ACKNOWLEDGMENTS

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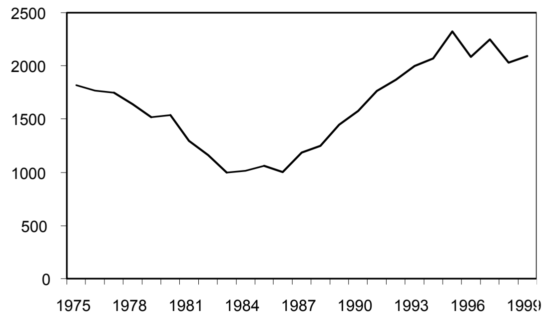
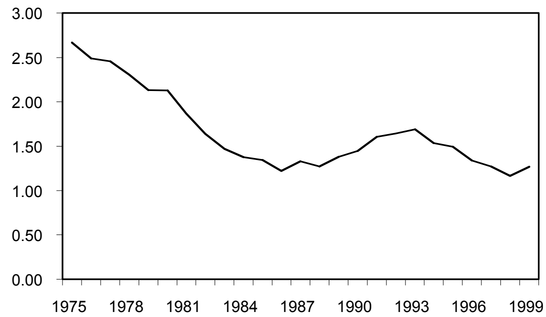
Figure 1. Annual US anti-pollution patents, 1975-1999



Note: The annual data are by year of application and were extracted on 26 January 2003.

Figure 2. Ratio of anti-pollution to total US patents, 1975 – 1999



Note: The annual data are by year of application and were extracted on 26 January 2003.

Table 1. Innovation strengths for US anti-pollution patents for the period 1975-2002

Country	Number of patents P	Patent intensity PI	Patent share PS	Technological specialisation index TS	Rate of assigned patents RAP
Japan	9837	78	23.05	1.28	0.95
Germany	2497	30	5.85	0.82	0.81
France	2233	38	5.23	1.76	0.85
Canada	1028	33	2.41	1.09	0.58
Taiwan	735	33	1.72	1.06	0.39
Italy	680	12	1.59	1.26	0.75
Korea	494	10	1.16	1.16	0.79
Switzerland	462	64	1.08	0.78	0.66
Netherlands	406	26	0.95	0.94	0.62
UK	285	5	0.67	0.59	0.61
Australia	255	13	0.60	1.11	0.61
Sweden	236	27	0.55	0.57	0.90
Mean	*1596*	*31*	*3.74*	*1.03*	*0.71*

Notes: 1. The data were extracted on 26 January 2003.
2. The patent intensity is given per million of population in 2000.

Table 2. Rankings by innovation strengths for US anti-pollution patents for the period 1975-2002

Country	PS	TS	RAP	Mean	Rank
Japan	1	2	1	1.33	1
France	3	1	3	2.33	2
Germany	2	9	4	5.00	3
Italy	6	3	6	5.00	3
Korea	7	4	5	5.33	5
Canada	4	6	11	7.00	6
Taiwan	5	7	12	8.00	7
Switzerland	8	10	7	8.33	8
Netherlands	9	8	8	8.33	8
Australia	11	5	9	8.33	8
Sweden	12	12	2	8.67	11
UK	10	11	9	10.00	12

Note: The data were extracted on 26 January 2003.