ELSEVIER
ADVANCED
TECHNOLOGY

Technovation, 26(5) (1996) 245–253

0166-4972/96 $15.00 + 0.00

Sweden's technological profile*

What can R&D and patents tell and what do they fail to tell us?

Staffan Jacobsson and Joakim Philipson
Department of Industrial Management and Economics, Chalmers University of Technology, S-412 96 Göteborg, Sweden

Abstract

The paper has two objectives. The first is to analyse technological specialization in Sweden, including the trends which can be discerned regarding the share of Sweden in the technological efforts of the OECD countries. The second is to contribute to the methodological debate on technology indicators by simply comparing patents and R&D as technology indicators and discussing the degree to which they are consistent with respect to what they say about the Swedish 'technological landscape' and changes therein. We find that the two indicators are consistent as regards Swedish strength in mechanical engineering and weakness in electronics and computer science. They diverge, however, both with respect to Sweden's position in pharmaceuticals and, most importantly, to Sweden's share in the technological activities of the OECD countries. These divergences illustrate the danger of relying on only one indicator when assessing the technological position of firms and countries. Copyright © 1996 Elsevier Science Ltd

1. INTRODUCTION

It is clear that competitive advantage is, to a growing extent, based on the ability of firms and nations to generate, diffuse and utilize knowledge, primarily scientific and technological. Grupp (1990), for example, points out that there is a quite consistent correlation between the ranking of nations according to the state of their civilian-market technologies and their trading positions.

An understanding of the size and distribution (across technologies, firms and industries) of scientific and technological efforts ought therefore to be central to any analysis of competitive advantage and economic growth. Indeed, Rappa *et al.* (1992, p. 133) stress that "the ability of managers and policy makers to comprehend the pace and direction of technological advancement will largely determine their firm's or nation's competitive performance in world markets in the next century".

The main purpose of this paper is to attempt to analyse the Swedish 'technological landscape'. The analysis will focus on two questions: first, what are the directions of technological specialization in Sweden and, second, what trends can be discerned regarding the share of Sweden in the technological efforts of the OECD countries? In other words, we will discuss the orientation and magnitude of Sweden's technological activities in an international perspective.

There is, of course, already a large literature of national studies based on technology indicators (e.g. Archibugi and Pianta, 1992; Engelsman and van Raan, 1990; IVA, 1993a). Often, however, though by no means always, the methodological problems involved in capturing the technological activities in a country appear to be underplayed. This is particularly serious in cases where the issues raised above are analysed using only one indicator, often patents (e.g. IVA, 1993a and b).

Whilst patents constitute an indicator of formidable

*This paper was kindly financed by the Swedish National Board for Industrial and Technical Development and the Swedish Council for Planning and Coordination of Research. We are grateful to Bo Carlsson, Anders Granberg, Lennart Stenberg and an anonymous referee for useful comments on an earlier draft.

0166-4972(95)00070-4

use (e.g. Patel and Pavitt, 1994), its inherent weaknesses (Pavitt, 1988) strongly suggest that it should, when possible, only be used together with other indicators. A second objective of the paper is therefore to contribute to the methodological debate on technology indicators by a very simple exercise. In this we will compare patents and R&D as technology indicators and discuss the degree to which they are consistent with respect to what they say about the Swedish 'technological landscape' and changes therein. Although the two indicators are well known and much tried, this simple comparison demonstrates the risky venture of relying on patents as the sole indicator and raises serious questions about the real orientation and magnitude of Sweden's technological activities.

The paper is structured as follows. We begin, in Section 2, with a brief recapitulation of the advantages and disadvantages of the two indicators used: patents and R&D data. Section 3 analyses Sweden's technological specialization, as well as changes therein, whilst Section 4 focuses on Sweden's share of the technological efforts in the OECD, and changes therein. The final section summarizes the paper and discusses some implications of the main conclusions.

2. ADVANTAGES AND DISADVANTAGES OF PATENTS AND R&D AS TECHNOLOGY INDICATORS

Several technology indicators have been used extensively, e.g. patent statistics (Schmookler, 1966; Griliches, 1957; Grupp and Hohmeyer, 1986; Grupp, 1990; Archibugi and Pianta, 1992; Pavitt, 1985 and 1988; Patel and Pavitt, 1994); bibliometric techniques (e.g. Walsh, 1982; Granberg, 1986) and R&D statistics (e.g. Kodama, 1986).[1] Each of these indicators exhibits its own particular characteristics in terms of what type of activity is measured and its strengths and weaknesses. Below, we will briefly review the literature on R&D and patent statistics.

R&D expenditure reflects formal expenditure on research and development as these are reported to the Central Bureau of Statistics. The main advantage of this indicator is that data are available at the firm, industry and national level.

The main disadvantages are:

- as data are normally collected according to the firms' principal product area, R&D data neglect both the range and the specific mix of technologies in firms and industries (Patel and Pavitt, 1994);
- the data do not reflect R&D which is not reported to the Government and would therefore be expected to underestimate the technological activities. This is particularly serious for smaller firms (since these may not have a formal R&D department and, depending on the sampling procedure, may not be identified by the Bureau of Statistics).

A *patent* application is evaluated using three criteria. First, a patent has to be novel to the world. This suggests that patents reflect scientific and technological activities (mainly the latter according to Archibugi, 1992) which are 'leading edge'. Second, the invention described in the patent application needs to be technically reproducible and industrially exploitable. This suggests that a patent is filed in order to create a business impact.[2] It may also suggest that patents are a particularly appropriate indicator to capture proprietory technical change (Archibugi, 1992).[3] Third, a patent must contain solutions that are not obvious to the average practitioner.

The main advantages of patents are:

- that they cover virtually every field of technology, with the major exception of software not directly linked to technical processes and products;
- the amount of detailed information available;[4]
- information is today easily obtained and rapidly disseminated through information technology.

TABLE 1. Revealed technological comparative advantage (RTCA*) of Sweden using R&D data, 1981 and 1989†

	1981 RTCA	1989 RTCA
Metal/mechanical engineering	1.98	1.95
Electrical engineering/Electronics/Computers	0.91	0.87
Chemistry	0.93	1.11
pharmaceutical	1.70	1.83
other chemistry	0.72	0.79

*RTCA is the share of Swedish R&D in each of the three areas divided by the Swedish share of all business level R&D in a set of OECD countries. The countries included in the analysis were: Belgium, Canada, Denmark, Finland, France, Germany, Italy, Japan, Norway, Spain, Sweden, UK and US. Note that the sum of R&D in the three areas does not add up to the total business level R&D in the countries. Some sectors were not classified into the three areas: agriculture, mining, aerospace, textile and clothing, stone, clay and glass; wood, cork and furniture; other manufacturing, utilities and the service sector. In both 1981 and 1989, R&D in the three areas accounted for 80% of the total *manufacturing* R&D in the countries mentioned. See Appendix 1 for the method of classifying the other sectors into our three areas.
†*Sources*: Elaboration on OECD (1991, 1993).

[1] Diffusion data on products (e.g. robots) incorporating new technologies (e.g. electronics) (see e.g. Edquist and Jacobsson, 1988) and data on industrial output dividing industries into low, medium and high tech industries (OECD, 1986) can also be regarded as technology indicators.

[2] Defensive patenting often occurs, however.

[3] However, patents are not the only way to exploit firm-specific technology and hinder imitation. Numerous other ways can be found, including relying on secrecy, imitation lags and firm-specific skills and know-how (Pavitt, 1988; Archibugi, 1992). Despite this, empirical work demonstrates that a large share (66–87%) of all patentable inventions are patented (Archibugi, 1992).

[4] They provide information not only on the amount, but also on the composition and direction of inventive and innovative activity at a very detailed level (Archibugi, 1992; Mogee, 1991). Patents also include a lot of other useful information such as year of invention, assignee and citations, which can be used for numerous analyses at the technology, firm, industry and national levels.

TABLE 2. Revealed technological comparative advantage* in Swedish industry, patent statistics, 1963–90†

	1963–68	1969–74	1975–80	1981–86	1987–90
Metal and mechanical engineering	1.36	1.32	1.47	1.53	1.55
Electrical engineering/Electronics/Computers	0.89	0.78	0.74	0.71	0.63
Chemistry	0.47	0.50	0.52	0.49	0.61
pharmaceuticals	1.12	1.12	1.02	0.66	0.88
other chemistry	0.42	0.45	0.42	0.45	0.53

*The share of Swedish patents in the US patent system in each of the three areas divided by the Swedish share of all patents taken in the USA in each time period. For the method of aggregation, see Appendix 1.
†*Source*: Elaboration on data supplied to the Science Policy Research Unit by the US Department of Trade and Commerce, Patent and Trademark Office.

The disadvantages include:

- variation in the propensity to patent between firms and countries;
- variation between technologies and industries in the costs of developing a patentable solution;
- an inertia in the patent system. It takes a while before a new technology is given its own class in the patent system. Until then, it is hidden because the patent is classified in an old class. Thus, for a new technology to become visible, a prior alteration in the classification system is required. Such alterations are not instantaneous with respect to the emergence of new technologies.[5]

TABLE 3. Sweden's share of R&D* in the OECD countries†

	1981	1989
All manufacturing	1.15	1.26
Metal/Mechanical engineering	2.28	2.45
Electrical engineering/Electronics/Computers	1.05	1.09
Chemistry	1.07	1.40
pharmaceuticals	1.95	2.31
other chemistry	0.83	1.00

*See Appendix 1 for the method of aggregation.
†See Table 1 for the list of countries included. *Sources*: Elaboration on OECD (1991, 1993).

3. SWEDEN'S REVEALED TECHNOLOGICAL COMPARATIVE ADVANTAGE

This section analyses the technological specialization of Sweden, as well as changes therein during the past decade. Technological specialization is measured by calculating the revealed technological comparative advantage (RTCA). This is the share of Swedish R&D (or patents) in a particular technology (or set of technologies) divided by the Swedish share of all R&D (or patents) in a set of OECD countries.[6]

As far as R&D[7] is concerned, two features can be discerned from the data given in Table 1. First, Swedish industry exhibited a very heavy specialization in metal/mechanical engineering[8] and pharmaceuticals, in both 1981 and 1989. Electrical engineering/electronics/computer science[9] and chemistry, other than pharmaceuticals, were relatively weak. Second, while chemistry (both with and without pharmaceuticals) improved its position in the period studied, that of electrical engineering/electronics/computer science remained weak.

The growing strength of R&D in the chemical field, including pharmaceuticals, is also reflected in Sweden's *scientific* specialization (using bibliometric techniques). It is well known that Sweden's scientific activity has a relative strength in the bio/medical sciences whilst the engineering field is relatively weak (Persson, 1991). What is, perhaps, less well known is that *within* the relatively weak engineering field, the 'winners' in the period 1970–1990 were to be found in chemistry, chemical processes, biotechnology and environmental and waste technology, areas which would appear to be relatively close to the fields of natural science and medicine (see Appendix 2, Table A1). On the other hand, scientific activity in the electronics and computer science field (as well as optics) is still relatively weak in Sweden.[10]

Turning to patents, Table 2 underlines the prior observation of Sweden's strength in metal and mechanical engineering and its relative (and escalating) weakness in electronics etc. However, there is a wide discrepancy in the field of pharmaceuticals. While the R&D data suggested a strong and growing specializa-

[5] International comparisons are made difficult by different patent systems in various countries. This has led to the frequent use of patenting in a 'third country', often the US.
[6] Details are given in Table 1.
[7] R&D is classified according to principal product area, as was mentioned in Section 2.
[8] See Appendix 1 for a description of the databases used and how the aggregation took place.
[9] Electrical is merged with electronics for two reasons. First, and most importantly, it is difficult to separate these two areas, especially with the growing importance of power electronics within electrical engineering. Second, as is evident in Appendix 2 and Fig. 1, the two areas exhibit the same trend with respect to RTCA.
[10] Moreover, perhaps surprisingly, several of the metal and mechanical engineering areas have undergone a major deterioration in their revealed scientific advantage. A shift is therefore occurring from metals and mechanical engineering to fields linked more to natural science (Persson, 1991).

TABLE 4. Sweden's share of patents granted in the US, 1963–90, as percentages†

	1963–68	1969–74	1975–80	1981–86	1987–90
All patents*	0.83	1.11	1.30	1.16	0.96
Metal and mechanical engineering	1.13	1.47	1.91	1.77	1.49
Electrical engineering/Electronics/Computers	0.74	0.87	0.96	0.82	0.60
Chemistry	0.39	0.56	0.67	0.57	0.59
pharmaceuticals	0.93	1.24	1.32	0.76	0.84
other chemistry	0.35	0.50	0.55	0.52	0.51

*The sum of the 34 classes included in the analysis. The data have been aggregated as in Appendix 1.
†*Source*: As in Table 2.

tion in that field, the patent data suggest a weak position in the 1980s.

Thus, the two technology indicators confirm our picture of Swedish firms' strength in metals and mechanical engineering and a continued relative weakness in electronics (Jacobsson, 1993). More thought provoking is the wide discrepancy in the message that they give us regarding the pharmaceutical field.

4. SWEDEN'S SHARE OF TECHNOLOGICAL EFFORTS IN THE OECD

Revealed technological comparative advantage measures the relative strength of technological efforts in different fields. It says nothing, however, about the share of the absolute level of technological activities, which, after all, is what matters in linking technological efforts to economic performance.[11] We turn, therefore, to studying how the development of Sweden's technological efforts compares with that of other OECD countries in the three technological fields.

In Table 3 we can see that Sweden increased its share of R&D in the OECD[12] from 1.15% in 1981 to 1.26% in 1989. Indeed, Sweden's share of R&D in the OECD grew in all areas, but only very marginally for electronics etc.[13]

Sweden's strength varies greatly, however, from one area to another. While Sweden has quite a large share of the R&D in metal/mechanical engineering and pharmaceuticals, it is quite small in electronics etc. and in chemistry, other than pharmaceuticals.

In terms of the market share of *patents* granted in the US (Table 4), we can note that, as in the case of R&D statistics, Sweden has a substantial share of the technological efforts in metal and mechanical engineering and a weak position in electrical engineering/electronics/computers and in chemicals other than pharmaceuticals. Again, however, the two indicators show a wide discrepancy as regards pharmaceuticals. Whilst the R&D data suggest a strong Swedish position, the patent data suggest the opposite for the 1980s.

Equally importantly, there is a disturbing discrepancy in the *trends* of Sweden's share of the OECD countries' technological efforts between R&D and patent data. In the case of patents, a fairly positive trend may be seen from 1963–68 to 1975–80 where Sweden's share (for all patents) increased from 0.86% to 1.30%. After 1980, its share declined in all areas, and quite dramatically so in electrical engineering/electronics/computers. Sweden's share of R&D behaved quite differently, though; it *increased* for all categories (although extremely slightly for electrical/electronics/computer science) in the same period.[14,15]

[11] There may, of course, be significant differences in efficiency in the use of the R&D resources between firms and countries.
[12] See Table 1 for the list of countries included.
[13] A closer look at the electrical engineering/electronics/computer data reveals that the increase in Swedish R&D is less than that of most countries; it is the relatively slow growth of the US which improves our share; see Appendix 2, table A2. Thus, in spite of an increase in engineers and scientists (see Appendix 2, Table A3) as well as in R&D, the electrical/electronics/computer science field is not managing so well in an international perspective.

[14] This discrepancy appears to have been created in the 1980s. Sweden's share of US patenting and OECD R&D amounted to about 1.15% in 1981 (the R&D data are, however, for a subset of all countries patenting in the US but include as much as 86% of all non-US patents in 1979—see Table 3 in Freeman and Hagedoorn, 1992). Subsequently, Sweden's share of US patents decreased to 0.88% in 1989 whilst the share of OECD R&D increased to 1.26% (elaboration on data supplied to the Science Policy Research Unit by the US Department of Trade and Commerce, Patent and Trademark Office for the patent data and OECD (1991, 1993) for the R&D data).
[15] One source of error may be that US statistics on patents over-represent the share of the US (Freeman and Hagedoorn, 1992). Another source of error may be found in the R&D statistics, which cover fewer countries than do the patent data. This, of course, automatically increases Sweden's market share. If we exclude the R&D by US firms and patenting in the US by US firms, and compare exactly the same set of countries (the countries included were Belgium, Canada, Germany, Denmark, Finland, France, Spain, the UK, Italy, Japan, Norway and Sweden), we find that Sweden's share of US patenting decreased from 3.5% in 1981 to 2.1% in 1989 while the R&D share remained at 2.5%. The same trend therefore emerges; indeed it is even more pronounced.

These figures may have a whole set of explanations.[16] One important explanation is probably connected to the changing behaviour of Japanese firms. While Japan increased its share of the total R&D performed by a set of OECD countries[17] from 32.6 to 39.5% in 1981–89, its share of patents in the US[18] increased from 33.4 to as much as 51.1%. This pattern could, for instance, reflect an increase in the propensity to patent abroad and/or a growing tendency for Japanese firms to apply for 'easier' patents (although the latter is unlikely; see IVA, 1993a); both reflecting two disadvantages of patents as a technology indicator (see Section 2).

Another set of contributory factors might be found in features of Swedish industry. Much of the increase in R&D in the 1980s took place in a very limited number of firms, e.g. Ericsson, chiefly in telecommunications, Astra and Kabi-Pharmacia in pharmaceuticals and Volvo in automobiles. This concentration of the growth in formal R&D expenditure implies that the inherent 'patentability' of their R&D efforts,[19] as well as the patent strategy of these firms, will have a significant effect at the national level. Again, this illustrates the weakness of patents as a technology indicator.

Until we know more about the reasons for the discrepancy between the two indicators, we cannot exclude the possibility that patent statistics may underestimate Sweden's share of the OECD countries' technological activities.[20] Reliance on patent statistics alone for analysing the technological performance of Sweden ought therefore to be avoided.

5. CONCLUSIONS AND IMPLICATIONS FOR FURTHER RESEARCH

In this final section, we will summarize the main results, point to what patents and R&D data fail to tell us with regard to Sweden's orientation and magnitude of technological efforts, and elaborate on the dangers of drawing firm conclusions without solving two 'mysteries'.

First, we measured the direction of Sweden's technological activities using both the country's revealed technological comparative advantage and its share of the OECD's technological activities. What comes out of both analyses is that Sweden's technological specialization is heavily oriented towards metals and mechanical engineering and is relatively weak in electrical engineering/electronics/computers and in chemistry, other than pharmaceuticals. In this, there seems to be little room for doubt. In both analyses, however, the R&D and patent data differ widely about pharmaceuticals; the R&D data suggest a strong specialization in pharmaceuticals whilst the patent data do not. Here is the first mystery that needs to be solved by future research.[21]

Second, at the scientific level, the dominance of the biomedical area is very strong. Within the engineering field, it would seem as if those areas most closely connected to biology[22] and chemistry are gaining at the expense of metal and mechanical engineering. Although the patent analysis suggests a poor performance in chemistry, there is some room for arguing that there is a growing Swedish scientific and technological strength in areas related to natural science. Moreover, as in the case of our technological specialization, electronics/computer science is not improving its position.

Third, whilst patent and R&D data are consistent in what they suggest to be Sweden's technological specialization, with the great exception of pharmaceuticals, they are not so consistent when it comes to analysing the trend in Sweden's share of the OECD's technological activities. While a patent analysis would indicate that Sweden's technological performance rapidly deteriorated in the 1980s, an analysis of R&D data would indicate otherwise. Indeed, Sweden's share of the OECD's technological efforts *increased* in all our fields during that period studied.

[16] Differences between countries in the ability of the statistical agencies to statistically capture the R&D undertaken in the nation may, of course, also affect the ratio between market shares of R&D and patents.
[17] See footnote 15 for a list of the countries included in the analysis.
[18] Japan's share of patents granted to the sub-set of countries mentioned in footnote 15.
[19] Sweden may specialize in software as opposed to hardware in electronics and computer science.
[20] To the extent that there are technology-specific differences in the discrepancy, patents may also wrongly portray the relative distribution of such activities (indeed, the widest discrepancy between R&D and patents is in pharmaceuticals). Such possible biases should then supplement those revealed in Jacobsson *et al.* (1996), where it was shown that in relation to educational statistics, patents tend to overstate the specialization towards metal and mechanical engineering at the expense of chemistry.

[21] The bulk of patents granted to Swedish pharmaceutical companies are in 'drugs and bio-engineering' and quite little in chemicals. Hence, the 'mystery' cannot be explained by Swedish pharmaceutical firms patenting in classes other than 'drugs and bio-engineering'.
[22] For an interesting description of some activities in applied biotechnology at the Royal Institute of Technology in Stockholm, see *Teknik & Naturvetenskap* (1993).

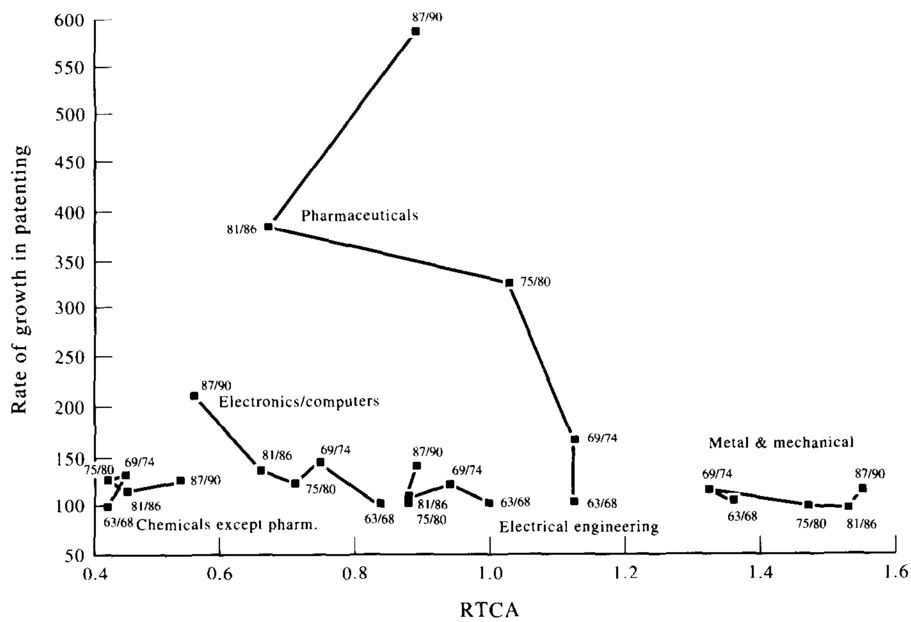

Fig. 1. Sweden's RTCA in relation to the rate of growth of patenting in five technology areas, 1963–68 to 1987–90.

Here is the second 'mystery' that needs to be solved by future research.[23,24]

[23] The understanding of the methodological problems involved in using patents alone appears to have been weak in a recent large Swedish study on 'Sweden's position in global technology development' (IVA, 1993a). Only one indicator, patents, is used to reflect technological development. The use of this indicator alone is partly justified by a figure which portrays the relationship between the number of patents and R&D expenditure at national level. With R^2 of 0.99, the following conclusion is drawn (IVA, 1993a, p. 19): "...a changing share in foreign patenting over time will be an accurate reflection of changing share of technological activities". The main problem with the high correlation is that there is an 'outlayer' which hides the very substantial differences between countries in how many patents they are granted in the US set in relation to the R&D expenditure. As demonstrated by Rosenberg and Zetterlund (1995), that relationship varies from less than 50 patents per billion US$ R&D (in 1989 dollars and purchasing power parity) in Greece, Portugal and Spain, to slightly more than 150 in UK and France, to about 225 in Sweden and 350 in Japan. With such large differences, there is no basis for drawing conclusions of the kind cited above. First, with a constant number of patents per billion US$, an increase in the share of foreign patenting reflects a smaller increase in R&D (and in technological activities) in the case of Japan in contrast to, say, France. Second, the very substantial differences in the number of foreign patents per billion US$ in R&D means that changes in the propensity to apply for foreign patents can have major implications for a country's share in foreign patenting without any prior changes at all in the amount of R&D spent, or in the underlying technological activities.

[24] A comment from a referee suggested that this mystery may be explained by the high propensity of Swedish firms to patent abroad a long time ago. This may be true but, nevertheless, the rate of increase in external patenting by Swedish firms was very high in the period 1979–88, indeed, only second to Japan's (IVA, 1993a, p. 21, drawing on Archibugi and Pianti, 1992).

Clearly, the two 'mysteries' are quite disturbing, from both methodological and policy perspectives, and illustrate the dangers of relying on only one indicator when assessing the technological behaviour of firms and nations.[25]

To elaborate on this point, take, for instance, an example where we cross-tabulate, using patent data, the RTCA of Sweden in various technological fields and the rate of growth of these fields (see Fig. 1). The latter variable is supposed to capture the future economic significance of patents. As Archibugi (1992, p. 366) explains: "...the fields of rapid expansion of patents today are at the technological frontier, and will represent the common technologies of future economic systems". That is, a quickly growing patent class is assumed to correspond not only to original developments in scientific and technological knowledge but also to a growing number of applications of that knowledge.

We would therefore conclude that our RTCA is declining fastest in the most rapidly growing fields, namely pharmaceuticals and electrical engineering/ electronics/computer science. Moreoever, the decline is, as noted above, very considerable in the latter. This is, of course, an extremely important observation which, if valid, should give rise to much concern (IVA, 1993b). However, if the same exercise is undertaken with R&D data, a quite different picture emerges (see Appendix 2, Table A4). First, in the area

[25] On this issue, see also Jacobsson *et al.* (1996).

of most rapidly growing R&D, pharmaceuticals, Sweden increased its RTCA. Second, in the second fastest growing area, electrical engineering/electronics/computers, although Sweden's RTCA declined, it did so very marginally. The need for concern is, suddenly, considerably reduced.

Perhaps the firmest conclusion to draw from this is that more work of a methodological nature still remains to be done in the field of technological indicators. Until this is done, and our two 'mysteries' are solved, our simple exercise teaches us that we do not really know enough to ascertain Sweden's technological profile and, most importantly, we are much confused over the trend in Sweden's share of the OECD's technological efforts.

REFERENCES

Archibugi, D. (1992). Patenting as an indicator of technological innovation: a review. *Science and Public Policy*, 19(6) (December), 357–368.

Archibugi, D. and Pianta, M. (1992). *The Technological Specialization of Advanced Countries*. Kluwer Academic Publishers.

Edquist, C. and Jacobsson, S. (1988). *Flexible Automation. The Global Diffusion of New Technology in the Engineering Industry*. Basil Blackwell, Oxford.

Engelsman, E.C. and van Raan, A.F.J. (1990). *The Netherlands in Modern Technology: A Patent-based Assessment*. Research Report to the Ministry of Economic Affairs, Centre for Science and Technology Studies, University of Leiden.

Freeman, C. and Hagedoorn, J. (1992). Convergence and divergence in the internationalization of technology. *MERIT Conference on Convergence and Divergence in Economic Growth and Technical Change, Maastricht, 10–12 December.*

Granberg, A. (1986). A bibliometric survey of fibre-optics research in Sweden, West Germany and Japan. In: Grupp, H. (ed.). *Problems of Measuring Technological Change*. Verlag TÜV Rheinland, Köln, pp. 207–241.

Griliches, Z. (1957). Hybrid corn: an exploration in the economics of technological change. *Econometrica*, 25, 501–522.

Grupp, H. (1990). Technometrics as a missing link in science and technology indicators. In Sigurdsson, J. (ed.). *Measuring the Dynamics of Technological Change*. Frances Pinter Publishers, London, pp. 57–76.

Grupp, H.. and Hohmeyer, O. (1986). The ISI-approach to technometrics: outline of the conceptual framework and assessment of technological standards. In: Grupp, H. (ed.). *Problems of Measuring Technological Change*. Verlag TÜV Rheinland, Köln, pp. 146–170.

IVA (1993a). *Profit from Innovation. A comparison of Swedish and Japanese Intellectual Property Management*. Royal Swedish Academy of Engineering Sciences, Stockholm.

IVA (1993b). *Halkar Sverige efter? Sveriges position i det globala patentlandskapet*. Royal Swedish Academy of Engineering Sciences, Stockholm.

Jacobsson, S. (1993). Sweden's technological system and future development potential—The case of electronics and computer technology. *20th Annual EARIE Conference, Tel Aviv, September.*

Jacobsson, S., Oskarssson, C. and Philipson, J. (1996). Indicators of technological activities—A comparison of educational, patent and R&D statistics in the case of Sweden. *Research Policy* (forthcoming).

Kodama, F. (1986). Technological diversification of Japanese industry. *Science*, 233 (18 July), 291–296.

Mogee, M.E. (1991). Using patent data for technology analysis and planning. *Research–Technology Management*, 34(4), 43–49.

OECD (1986). *OECD Science and Technology Indicators*. Paris.

OECD (1991). *Basic Science and Technology Statistics*. Paris.

OECD (1993). *Basic Science and Technology Statistics*. Paris (on diskettes).

Patel, P. and Pavitt, K. (1994). The continuing, widespread (and neglected) importance of improvements in mechanical technologies. *Research Policy*, 23(5), 533–545.

Pavitt, K. (1985). Patent statistics as indicators of innovative activities: possibilities and problems. *Scientometrics*, 7(1–2), 77–99.

Pavitt, K. (1988). Uses and abuses of patent statistics. In: Van Raan (ed.). *Handbook of Quantitative Studies of Science and Technology*. Elsevier North-Holland, Amsterdam, pp. 509–536.

Persson, O. (1991). *Forskning i bibliometrisk belysning*. INUM, Umeå.

Rappa, M., Debackere, K. and Garud, R. (1992). Technological progress and the duration of contribution spans. *Technological Forecasting and Social Change*, 42, 133–145.

Rosenberg, J. and Zetterlund, F. (1995). *Är Sverige i Patentbotten*. Mimeo, Department of Industrial Management and Economics, Chalmers University of Technology, Göteborg, Sweden.

Schmookler, J. (1966). *Invention and Economic Growth*. Harvard University Press, Cambridge, MA.

Teknik & Naturvetenskap (1993). Nr.2, Årgång 9.

Walsh, V. (1982). The use of patents and other indicators in the study of invention and innovation in the chemical industry. Conference Paper at *STIU/OECD*, Paris.

Appendices overleaf

APPENDIX 1

We have used two databases in our work. First, the patent data stem from the Science Policy Research Unit's data on patenting in the United States. This database was kindly made available to us by Keith Pavitt and Pari Patel. The R&D data come from the OECD (1991, 1993). The patent and R&D data are aggregated into the following main technological fields: metals and mechanical, electrical/electronics/ computers and chemistry. Chemistry is then divided into pharmaceuticals and chemistry other than pharmaceuticals.

The *R&D data* from the OECD (1991, 1993) were aggregated as follows:

Metals and mechanical
Motor vehicles, ships, other transports, ferrous metals, non-ferrous metals, fabricated metal products and machinery.

Electrical/Electronics/Computers
Electrical machinery, electronic equipment and components, instruments and office machinery and computers. For 1981, we have assumed $30 million's worth of R&D in office machinery and computers in Sweden (in 1985 US$ and purchasing power parity).

Chemistry
Chemicals, drugs, petroleum refineries, food, drink and tobacco, rubber and plastics, paper and printing. Paper was included in this group simply because paper and pulp manufacturing is to a large degree a chemical process, as is indicated by the fact that nearly three-quarters of the engineers working in the three largest firms in Sweden are chemical engineers. Drugs is assumed to be synonymous with pharmaceuticals.

As far as *patents* are concerned, we aggregated the initial 34 classes into three categories:

Metal and mechanical
Metallurgical and other mineral processes, apparatus for chemicals, food, glass, etc., general non-electrical machinery, non-electrical specials, industrial equipment, metallurgical and metal-working equipment, assembling and material handling apparatus, nuclear reactors and systems, power plants, road vehicles and engines, other transport equipment, mining and wells machinery and processes and miscellaneous metal products.

Electrical/Electronics/Computers
General electrical industrial apparatus, electrical devices and systems, instruments and controls, photography and photocopying, image and sound equipment, calculators, computers and office equipment, semiconductors and telecommunications.

Chemistry
Inorganic chemicals, organic chemicals, agricultural chemicals, chemical processes, hydrocarbons, drugs and bio-engineering, mineral oils and fuels etc. and bleaching, dyeing and disinfecting, plastics and rubber products. Drugs/bio-engineering is assumed to be synonymous with pharmaceuticals.

APPENDIX 2

TABLE A1. Revealed scientific advantage within the engineering field in Sweden, 1970–75 and 1985–90*

	1970–75	1985–90
Electrical	0.72	0.82
Electronics and telecommunications	0.90	0.73
Computer science	0.71	0.75
Optics	0.98	0.91
Material handling	0.68	0.90
Railroad	0.70	0.74
Shipbuilding	0.90	0.81
Hydraulics	0.52	0.75
Machinery	1.35	0.69
Metallurgy, metals	1.81	1.01
Metallurgy, process	1.67	1.06
Solid mechanics	1.25	0.93
Aerospace	0.33	0.73
Transport	0.95	1.23
Chemistry, general	1.05	1.30
Chemical, process-industry	0.92	1.20
Biotechnology	1.79	2.18
Environmental and waste	1.39	1.81
Agriculture and food	0.90	1.28

**Source*: Persson (1991, p. 91), based on an online study of Compendex.

TABLE A2. Annual cumulative growth rates of R&D in the electronics industry in a set of OECD countries, 1981–89, in constant 1985 US$ and purchasing power parity*

Country	Growth rate (%)
Spain	19.0
Japan	12.1
Finland	9.9
Italy	9.7
Norway	9.6
Germany	8.7
Belgium	8.5
Sweden	6.9
ALL COUNTRIES	6.4
France	6.0
USA	4.3
UK	1.9

**Source*: Elaboration on OECD (1991, 1993).

TABLE A3. Distribution of engineers and scientists† in Swedish industry and industry-related services‡ over four areas, 1985 and 1990, as percentage of total stock*

	1985	1990	Growth rate (annual)
Metal/Mechanics	41.1	35.4	5.6%
Electrical, electronics and computer science	36.7	39.1	10.2%
Chemistry§	14.8	16.6	11.2%
Medicine	7.4	8.9	12.8%

**Source*: Elaboration on data supplied by the Swedish Central Bureau of Statistics.

†We have excluded physicists, industrial economists and civil engineers from the engineers, and natural scientists other than chemists.

‡These include railroad traffic, harbour services, air transport, telecommunications, computer consultancy (ISIC 8323), technical consultancy (ISIC 8324), other consultancy (ISIC 8325, 83292, 83299), defence, research and development (ISIC 932).

§Natural scientists with a specialization in chemistry are included in this group.

TABLE A4. Growth in R&D in a number of OECD countries† and Swedish RTCA for four groups of industries*

	RTCA (1981)	RTCA (1989)	Growth in R&D‡ (1989/1981)
Metal and mechanical engineering	1.98	1.95	1.47
Electrical engineering/ Electronics/Computers	0.91	0.87	1.64
Pharmaceuticals	1.70	1.83	2.31
Chemistry, other than pharmaceuticals	0.72	0.79	1.36

**Sources*: as in Table 1.

†See footnote to Table 1 for the list of countries included.

‡In constant US$ and 1985 purchasing power parity (1981 = 1.00).

Staffan Jacobsson is Professor in Industrial Management at Chalmers University of Technology, Göteborg, Sweden. He received his DPhil (Economics) from the University of Sussex, UK, in 1985. He has written extensively on the relationship between technical change and industrial development, both in the newly industrializing countries and in the OECD.

Joakim Philipson is an MSc from Chalmers University of Technology and is currently working at Ericsson Infocom in Stockholm, Sweden.

Jaana Woiceshyn and Diana Hartel

Technovation, 16 (5) (1996) 231–243

Stratégies et performances des firmes canadiennes de biotechnologie — une enquête empirique

Résumé

Un sondage chez des firmes de biotechnologie a permis d'enquêter sur l'impact de leur situation sur leurs stratégies et leurs performances. Ce papier rend compte de deux types de découvertes d'exploration: un profil descriptif des deux sociétés et de leurs stratégies pour gérer des situations politiques et financières, et des comparaisons statistiques entre trois groupes de performances. Trois aspects de la situation financière de la firme sont soulignés:

- coût de production élevé, rareté des capitaux propres
- un manque de personnel qualifié,
- et en particulier le personnel d'encadrement

Alors que les firmes essaient de réduire leurs problèmes de capitaux et de coûts, en s'impliquant dans des coopérations interentreprises, la petite taille, le fait que les entreprises soient financées par capitaux privés, et les problèmes de ressources humaines montrent la variété des barrières qui ralentissent le succès commercial. Les firmes ont perçu l'action ou l'inaction du gouvernement comme étant un obstacle majeur, qu'elles ont essayé de surmonter par des tactiques diverses. Lorsque les firmes sont comparées dans trois groupes de performances, les différenciateurs principaux entre celles qui sont performantes et celles qui le sont moins, sont la mise au point de compétences complémentaires, qui se situent en dehors de la R&D, et des transferts efficaces de l'apprentissage organisationnel. Les implications pour le personnel d'encadrement seront abordées ainsi que des recherches plus poussées.

Strategien und Leistung kanadischer Biotechnologiefirmen: eine empirische Untersuchung

Abriss

Eine Umfrage unter kanadischen Biotechnologiefirmen untersuchte die Auswirkungen ihres Kontextes auf ihre Strategien und Leistung. In dieser Arbeit berichten wir über zwei Arten von Forschungsergebnissen: ein deskriptives Profil der Firmen und ihrer Strategien zur Bewältigung des Geschäfts- und politischen Kontextes und statistische Vergleiche zwischen drei Leistungsgruppen. Drei Aspekte des Geschäftskontextes der Firmen wurden hervorgehoben: hohe Kosten für Produktentwicklung, Kapitalknappheit und Mangel an qualifiziertem Personal — besonders Managern. Während die Firmen versuchten, die Kosten- und Kapitalprobleme durch Beteiligung an gemeinschaftlichen Allianzen zu verringern, deuten kleine Größe, Privatbesitz und Personalressourcenprobleme auf Hindernisse für kommerziellen Erfolg. Die Firmen betrachteten Regierungshandlungen oder Untätigkeit im politischen Kontext ebenfalls als wesentliches Hindernis, das sie durch verschiedene Beeinflussungstaktiken zu überwinden versuchten. Beim Vergleich der Firmen in den drei Leistungsgruppen waren die wesentlichen Unterscheidungsmerkmale zwischen höheren und niedrigeren Erfolgsunternehmern die Entwicklung von ergänzenden Fähigkeiten außerhalb der Forschung und Entwicklung und effektiver Transfer von organisatorischem Lernen. Die Implikationen für Manager und weitere, zukünftige Forschung werden diskutiert.

Las estrategias y el rendimiento en las empresas de biotecnologia canadiensas: una investigación empirica

Resumen

Un sondeo llevado a cabo entre empresas canadiensas de biotecnología examinó el impacto del propio contexto de la empresa en las estrategias y en el rendimiento. Se documentan dos tipos de resultados explorativos: un perfil descriptivo de las empresas y de sus estrategias de funcionamiento en cuanto a los contextos comerciales y políticos y unas comparaciones estadísticas de tres grupos de rendimientos. Se destacaron tres aspectos del contexto comercial de una empresa: el alto costo de desarrollo del producto, la falta de capital y la falta de personal cualificado, especialmente en administración. A pesar de que las empresas trataron de aliviar los problemas de costo y de capital creando alianzas colaborativas, el tamaño pequeño, la privatización y el problema de los recursos humanos indican barreras al éxito comercial. Las empresas también perciben la acción o la falta de acción de parte del gobierno en el contexto político como un obstáculo importante, que intentaron superar por medio de varias tácticas de influencia. Comparando empresas de los tres grupos de rendimientos, los factores principales de diferenciación de los grupos de rendimientos más altos o más bajos resultaron ser el desarrollo de capacidades complementarias fuera de I & D y la transferencia efectiva de los conocimientos organizativos. Se comentan las implicaciones para la dirección de la empresas y para más investigación.

Sweden's Technological Profile. What

can R&D and patents tell and what do they fail to tell us?

Staffan Jacobsson and Joakim Philipson

Technovation, 16 (5) (1996) 245–253

Profil technologique de la Suède — Qu'est-ce que la R&D et les brevets disent, et que ne disent-ils pas?

Résumé

Ce papier a deux objectifs. Le premier est d'analyser la spécialisation technologique en Suède, et y compris les tendances en ce qui concerne le partage de la Suède dans les efforts technologiques au sein de l'OCDE.

Le second est de contribuer à la polémique méthodologique sur les indicateurs technologiques, en comparant tout simplement les brevets et la R&D en tant qu'indicateurs technologiques et en discutant du degré de cohérence sur ce qu'ils disent sur le "paysage technologique" suédois, ainsi que ses changements internes. Nous trouvons que ces deux indicateurs sont cohérents en ce qui concerne les forces de la Suède en ingénierie mécanique et les faiblesses en électronique et en informatique. Toutefois, ils divergent à la fois sur la position de la Suède dans le secteur pharmaceutique et plus important encore, il divergent quant à la participation de la Suède dans les activités technologiques au sein de l'OCDE. Ces divergences illustrent les dangers de se baser sur un seul indicateur, lorsqu'on affirme la position technologique des entreprises et des pays.

Schwedens technologisches Profil — was können F&E und Patente uns sagen und was nicht?

Abriss

Diese Arbeit hat zwei Ziele. Das erste Ziel besteht in der Analyse von Schwedens technologischer Spezialisierung einschließlich der Trends, die hinsichtlich Schwedens Anteil an den technologischen Bemühungen der OECD Länder wahrgenommen werden. Das zweite Ziel besteht darin, zur methodologischen Debatte über Technologieindikatoren beizutragen, indem wir einfach Patente und F&E als Technologieindikatoren vergleichen und das Ausmaß, in dem sie beständig in bezug auf das, was sie über die schwedische "Technologielandschaft" und Veränderungen darin aussagen, sind. Wir haben festgestellt, daß die beiden Indikatoren in bezug auf Schwedens Stärke im Maschinenbau und seiner Schwäche in der Elektronik und Informatik beständig sind. In bezug auf Schwedens Stellung in der pharmazeutischen Industrie und, am wichtigsten, Schwedens Anteil an den technologischen Aktivitäten der OECD Länder, weichen beide Indikatoren jedoch voneinander ab. Diese Abweichungen illustrieren das Risiko, sich bei der Beurteilung der technologischen Stellung von Firmen und Ländern nur auf einen Indikator zu verlassen.

El perfil tecnológico de suecia — ¿qué significan la I & D y los patentes y qué no nos dicen?

Resumen

Este documento tiene dos objetivos. El primero es el análisis de la especialización tecnológica en suecia, incluídas las tendencias percibidas con relación a la participación de suecia en los esfuerzos tecnológicos de los países OCDE. El segundo es una contribución al debate metodológico acerca de los indicadores tecnológicos por simple comparación de los patentes y de la I & D como indicadores tecnológicos y se comenta hasta qué punto son consistentes en cuanto a lo que dicen del panorama tecnológico sueco y los cambios inherentes. Encontramos que los dos indicadores sí son consistentes en que indican la fuerza sueca en ingeniería mecánica y la debilidad en electrónica e informática. Difieren, sin embargo, tanto con respeto a la situación sueca en farmaceúticos y, sobre todo, en la participación sueca en las actividades tecnológicas de los países OCDE. Estas divergencias demuestran el peligro de apoyarse en un sólo indicador al asesorar la situación tecnológica de las empresas y de los países.

Product design as a means of integrating differentiation

Sudi Sharifi and Kulwant S. Pawar

Technovation, 16(5) (1996), 255–264

La conception de produits comme manière d'intégrer la différenciation

Résumé

Ce papier examine quelques unes des questions associées à la gestion de la conception de produits. On examine tout particulièrement le rôle de la conception dans le contexte de l'ingénierie concomitante (CE) [Concurrent Engineering]. On avance que la