But there is also a need to do something about the shortages of qualified personnel, because this represents a further bottleneck for research-intensive and knowledge-intensive company start-ups and restricts their possibilities.

C 6 PATENTS IN INTERNATIONAL COMPETITION

The following section draws on an international comparison of transnational patents.[114]

Long-term increase in patent applications globally

Patents are an innovation indicator which reflect the output of technological activity, being a result of research and development and innovation activity. Patents serve to secure competitive advantages, and their number is therefore also in direct relationship to the strategic significance of the market for which patent protection is sought. It is also important where a patent is registered. The following analyses draw on the concept of "transnational patents" or "world market patents". These are patents aimed at various markets and are therefore particularly significant.[115]

In the past ten years there have been three key phases of development, similar to those observed for production. In the second half of the 1990s there was a clear overall increase in transnational patent applications. This was related to an increasing relevance of technology in the competition between highly-developed countries. In parallel, the euphoria of the New Economy Boom also stimulated patent applications, so that in this phase the growth of patent applications in the individual countries was greater than that of research and development expenditures. From 2000 to 2002 there was then a decline in patent applications, especially in cutting-edge technologies such as IC technology, pharmaceuticals and biotechnology. Countries which specialised in these sectors experienced a sharp drop, in particular the United States. The fact that Germany is more specialised in high-value technology protected it to some extent. Great Britain, which is oriented towards the US market, showed a slighter but longer lasting decline; a reversal of this trend only became apparent in 2006. The numbers of British patent applications are currently at about one third of the German level. Since 2002, the numbers of applications for transnational patents from most countries have risen again appreciably.

Regarding the intensity of world market patents (patents per head of population) , Switzerland is in the lead, as in the previous year, but closely followed by Finland and Sweden. Germany is in fourth place (Tab. 07). Since 2002, Germany has experienced a gradual decline in the specialisation in cutting-edge technology relative to other countries, mainly due to the advance of China and Korea, and also of other countries such as Finland, Sweden or Canada (Fig. 27).

Rapid advance of Korea and China

A remarkable structural change in the international patent system has followed the advances made by Korea and China (Tab. 07). The Koreans already overtook the British levels in 2005 and the numbers are continuing to rise steeply. With the growth of Chinese patent applications it is to be expected that they will also reach the British level in the next year. In terms of the total number of transnational patent applications, China is behind Italy in eighth place. Looking only at applications in R&D-intensive technology, it is well ahead of Italy in seventh place (Tab. 07).

Regarding intensity,[116] China is currently far behind, because its technological activities are concentrated in a few regions and it is without a broad industrial base. This is precisely why considerable growth should be expected in the coming years. The bulk of Chinese patents in the R&D-intensive sector is supported mainly by the high specialisation in cutting-edge technology, which has developed from a negative index of −20 in 1996 to a current positive value of +40, which is considerably better than the USA (Fig. 27). This specialisation is based on patents in IC-technology and increasingly also in biotechnology and pharmaceuticals.

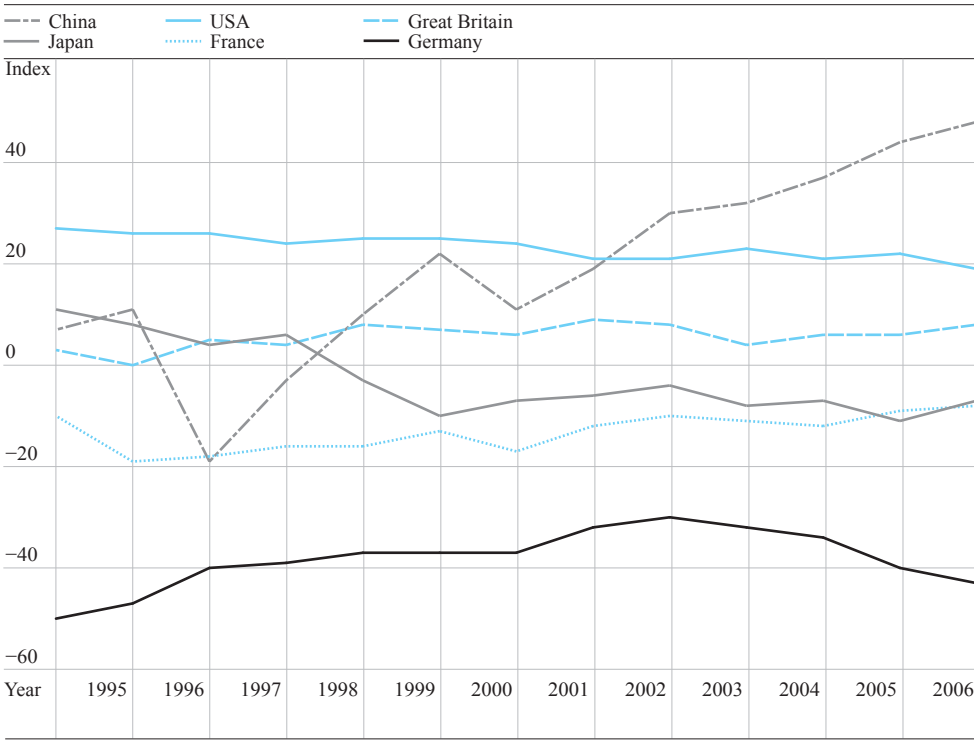
A comparison in the current specialisations of Japan, China and Korea in fields of R&D intensive technology shows clearly that Korea and/or China have penetrated many areas where Japan has been very strong, e.g. office equipment, electronics, optics, and entertainment electronics. Considering Germany, the United States and Japan, there is some overlap between the German and Japanese profiles, for example

TAB 07 **Overview of transnational patent applications in R&D-intensive technology 2006**

	Absolute no. of patents	Growth 2000 bis 2006 (%)	Intensity (Patents/ Employee)
Total	120742	19	–
EU-27	42340	9	192
USA	38327	2	261
Japan	20034	14	312
Germany	17516	7	448
France	6687	20	265
Korea	6277	236	271
Great Britain	5442	−7	173
China	4377	524	6
Italy	2973	26	119
Canada	2847	27	170
Netherlands	2618	−3	312
Switzerland	2472	18	576
Sweden	2408	6	544
Finland	1367	−1	560

Source: Questel (EPPATENT, WOPATENT). Calculations by Fraunhofer ISI.

FIG 27 **Specialisation of selected countries in cutting-edge technology for transnational patent applications**



Neutral value of RPA = 0. Positive indices show above-average specialisation.
Values above +15 show high-levels of specialisation.
Source: Questel (EPPATENT, WOPATENT). Calculations by Fraunhofer ISI.

BOX 24

Specialisation indices

Comparisons between countries relating to patents, publications, production or foreign trade on the basis of absolute figures are only of limited value, because these are affected by the size of the countries, their geo-strategic situation, and other specific factors. Therefore, specialisation indices are often used which express the importance of a specific field or sector of a country in relation to a general reference value, usually a global average. Specialisation indices have no dimensions, and the mean or neutral value can conveniently be set to 0. The indices may be formulated mathematically so that a positive value is above-average, and there is a symmetrical distribution. It is also common to set an upper and lower limit for the range, in order to reduce distortions due to outlier values. Comparison relative to the global average mean that increasing national activities in a special field only lead to a higher value if most other countries do not increase their activities to the same extent.

cars and engines, or surface coatings. The German and American profiles, on the other hand, are complementary. In an international comparison, the German profile has a unique structure. It remains to be seen how Japan can withstand the growing competition from China and Korea if the classic rivals in Germany and the USA maintain their positions.

International patent cooperation is growing steadily

The number of international co-patents, that is patents with inventors of different nationalities, has been growing rapidly since the 1990s. This development is mainly due to the fact that multinational companies increasingly draw on the cooperation of inventors from various locations. From the point of view of R&I policies, the development of co-patents is an indication of how a country is linked to the centres of inventive activity in other countries.

The rise in co-patents is closely related to the increase in the number of patent applications, although the 11 percent annual growth in co-patents is considerably higher than the 7.2 percent overall growth in patents. The rates of co-patents in the periods 1998 to 2000 was 10 percent and this rose to 11 percent for the period 2004 to 2006. For 13 of the countries considered, the rate of co-patents grew – the exceptions being Japan, Canada and Korea. Switzerland had the highest rate, and since the end of the 1990s this has further increased from 27 to 34 percent. This reflects the geographic and cultural links to neighbouring countries such as Germany and France, and in particular the large proportion of multinational companies. International co-patents are an indicator in this case for the cooperation between various subsidiaries of these companies. The rate of co-patents is also very high in Canada and in Great Britain. Germany currently has a co-patenting rate of 12 percent which places it in the middle ranks of European countries.

The very low co-patenting rate of Japan (2.5 percent) is perhaps not surprising, because this country has always had a reserved attitude to foreign companies. Korea has opened itself up somewhat more, but since the mid-1990s the rate has sunk from 8 percent to 4 percent and is thus following the Japanese example. The strategy of China is very different, and the rate of international co-patents is currently 14 percent.

USA is Germany's most important partner for co-patents

The rate of international co-patenting of a country depends to a large extent on its technological profile. In 2006, the global average rate for chemistry was 25 percent, which is particularly high, compared with only 11 percent co-patents in mechanical engineering. The strong co-patenting in chemistry reflects the considerable globalisation of this sector. Germany's most important partner countries for co-patents are firstly the USA with 27 percent, followed by Switzerland and France (20 and 12 percent, respectively). In total, 48 percent of German co-patents were generated in cooperation with other EU-15 countries. More than two-thirds of all German co-patents relate to USA and the old EU member states, whereas the combined cooperation with Japan, Korea and China account for no more than 6 percent. However, there is a declining trend of co-patents with the USA, whereas the cooperation with Asian countries has grown. Co-patenting with the USA is primarily in electrical engineering and technical instruments; with Switzerland it is technical instruments and chemistry; and with France it is chemistry. Thus the co-

operation is mainly in the fields in which the partner countries are particularly strong. Overall, co-patents in Germany are mainly in the field of chemistry, but there are relatively few in mechanical engineering, so that German companies are following the general pattern in these sectors.

These comments are based on the study by Frietsch and Jung (2009). The study also investigates:

- General trends and structures for transnational patent applications,
- Patent applications of small and medium-sized enterprises,
- Trends and structures for international co-patents.

C 7 SPECIALIST PUBLICATIONS AND THE EARNINGS OF SCIENCE

This section is based on the results of a study of international specialist publications.[117] The scientific potential of a country is a crucial basis for its technological performance. The contribution to technology development and knowledge-intensive services lies primarily in the education of qualified personnel, and their quality in turn is dependent on the ability of the researchers. Also, the results of scientific research form an important basis for technical development. The links between science and business are frequently indirect and not obvious, because there is often a time lag between the scientific activities and their effects in the economy.

It is difficult to measure scientific performance because the structures in the various disciplines can be very different. One method is the statistical analysis of the numbers of specialist publications and the frequency with which these are cited. In the natural sciences, engineering, medicine, and life sciences the database "Science Citation Index (SCI)" has established itself as the international standard.

Increasing integration of German science in the international community

The German share in international publications has fallen since the year 2000 by 12 percent, a trend which can also be observed for many other large industrialised countries. This development is attributable to the growth in the activities of emerging markets, which have meanwhile acquired a considerable significance. Their share of SCI-publications in 1990 was at 9 percent, but by the year 2000 this has increased to 15 percent, and by 2007 had risen further to 25 percent. Korea's specialist publications have been increasing appreciably since about 1992, after a long period of low publication activity. Since 1997, Korea has also experienced a massive growth in transnational patent applications. In the case of China, the publications trend changed in about 1996, and for patents in 1999. This demonstrates the indicator function of specialist publications for the availability of highly-qualified professionals who go on to induce a strengthening of the technological capability.

The relative citation frequency[118] is a central indicator for the scientific quality of publications, and here German scientists have maintained a mid-table position, slightly behind their American colleagues. Only Switzerland has an outstanding international position here.

The indicator "international orientation"[119] has for many years shown the orientation of German authors towards high-profile international journals and thus towards closer involvement in the international discourse, although in this case German scientists are following a general trend which is also apparent in other countries (Fig. 28). Switzerland, the USA and the Netherlands occupy the first three places for international orientation. In the cases of Switzerland and the Netherlands (Index-values of 31 and 27) this demonstrates their very intense integration in the international discussion, whereas in the case of the USA (Index 31) it is above all due to their direct access to American journals, which have a broad international readership and thus a considerable influence on the international discussion. However, the index for the USA is declining, and this reflects an upward trend for other countries.

German strengths in physics and medical engineering

For the analysis of publication activities according to subjects, it is usual to calculate specialisation indices, because the publication habits are very different in the various disciplines and therefore a comparison of ab-