

the level of the universities. It has to be borne in mind that the non-university institutions frequently provide supporting services for innovations which are not directly classified as research and development, and that as a result their importance for the innovation processes are considerably underestimated if only R&D projects are considered. Public institutions are above all an important partner for the external orders from SMEs. In general, external R&D activities increase with the level of technology involved. In cutting-edge technology, a particularly large proportion of R&D work is carried out by external commissions.

R&D expenditure currently increasing

In 2006, overall R&D expenditure increased by 7.4 per cent over 2005. The figures for 2007 are expected to show a further increase of 4.2 per cent. This is the start of a necessary process of catching up with a number of other countries who have steadily increased the proportion of added value spent on R&D. The rates of increase for 2006 and 2007 are above the rate of inflation and the growth rate of the gross domestic product; companies have invested more in research and development in real terms.

The numbers of personnel employed in R&D and innovation has been increased in 40 per cent of companies, and the total is expected to increase by 3.5 per cent. However, more than 20 per cent of companies were not able to recruit as many R&D personnel as planned. This is obviously already a consequence of the shortage of qualified specialists.

D 3 SPECIAL TOPICS OF RESEARCH AND DEVELOPMENT

The following section addresses three special topics which are closely related to research and development. Additional information is included on production, foreign trade, patents and publications.⁷⁹

D 3-1 GERMANY IN GLOBALISATION

The past decade, in particular up to 2001, has been marked to a strong trend to globalisation. The German public have been increasingly worried about a growing trend for German companies to relocate production in other countries. But another key aspect is the relocation of R&D activities. In 2005, 76 per cent of R&D activities in Germany were being carried out by companies which did R&D in other countries.

Ten years earlier the figure had been 69 per cent. On the one hand, companies who are not involved in the internationalisation of R&D have been contributing less and less in recent years to R&D in the German economy; on the other hand, increasing numbers of companies involved in R&D are also becoming active in other countries – a reflection of the growing export orientation of the German economy.

The internationalisation of the innovation activities of companies has in particular been reinforced in the second half of the past decade in a wave of transnational mergers and acquisitions. But of course many foreign companies have also been carrying out R&D work in Germany for a long time. Foreign companies spent EUR 1.2 billion more for R&D in Germany than German companies did in other countries. German companies carry out about a quarter of their R&D in other countries; equally, about a quarter of R&D activities in Germany are carried out by foreign companies.

Germany is the second largest R&D location for foreign companies

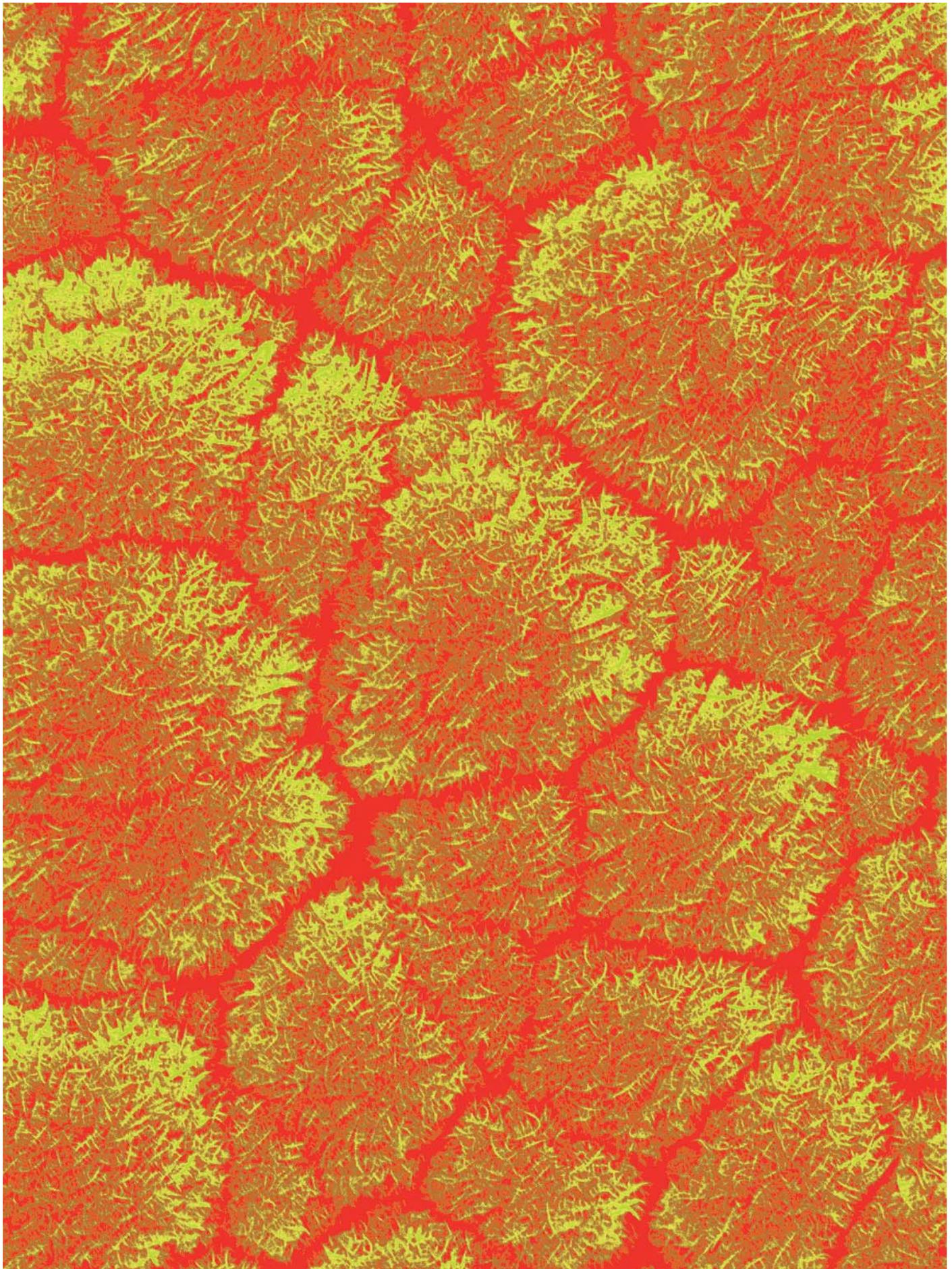
After the USA (25.5 billion euros) and before Great Britain, Germany is the second most important R&D location for foreign companies with an expenditure of 12.6 billion euros.

Germany is also the second most important location after Great Britain for US-subsidaries, and these show the highest R&D intensity in comparison with other location countries. In the dynamic of R&D expenditure by American companies, however, Germany and Great Britain are both far behind countries such as Sweden, Ireland, China, Israel, and Canada. Overall, Europe has become less important for R&D investments by American companies than locations in Asian newly industrialising countries.

Germany shows overall benefits from R&D globalisation and has proved particularly attractive for foreign subsidiaries. In the mid-1990s, foreign companies accounted for some 15 per cent of R&D potential in Germany, and this share has since increased to 26 per cent, mainly due to mergers and acquisitions from 1997 to 2001. These have resulted in existing R&D capacities being acquired and then extended in parallel to the activities of German companies. In recent years, the globalisation of industrial research in Germany has slowed down. Between 2001 and 2005 the



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Nanostructured surface layer for the electrophysiological functionalisation of vascular implants
© Fraunhofer-Institut für Werkstoffmechanik IWM

share of foreign companies in research only increased slightly. Nevertheless, Germany has reached a high level of internationalisation for R&D in comparison to other large industrialised countries, only bettered by smaller countries, e.g. Switzerland, the Netherlands, Canada or Sweden, and also by Great Britain, with nearly half of R&D expenditure by foreign companies.

The importance of foreign companies for R&D capacities is greatest in the chemical industry, accounting for 32 per cent (including the pharmaceutical industry with 40 per cent), but levels of 26 per cent have also been achieved in the computer industry, electrical engineering, precision engineering, and in vehicle construction.

Foreign companies have about the same priorities for their R&D activities in Germany as their domestic competitors. In general multinational companies adapt their investment decisions to the structures of the country in question. This is also expressed in the research intensity, so that foreign companies have meanwhile reached the R&D intensity of German companies. In vehicle construction and mechanical engineering, they carry out research and development on average with a somewhat higher intensity. The greater emphasis on R&D rather than production activities in comparison with local competitors speaks for the very good conditions for R&D in Germany in the sectors in question.

The high level of internationalisation in the chemical and pharmaceutical industry not only leads to a large proportion of foreign companies in Germany, but also the involvement of German companies in other countries. In 2005, German chemical and pharmaceutical companies spent 40 per cent of their overall R&D budget in other countries. Indeed, for the pharmaceutical industry alone it was 55 per cent, mainly in North America, but increasingly also in Southeast Asia. At least until 2005 there was a general pause in globalisation for R&D, which can be interpreted as a period of consolidation after the very rapid globalisation. This should also be seen in the light of the fact that the R&D capacities in the USA in this period were reduced considerably in the highly globalised sectors of industry, and the rate of expansion after this was considerably reduced.

Since 2001, the proportion of R&D expenditure by German companies in other countries declined from 26.7 per cent to 24.4 per cent. Both the 'outward' and

'inward' internationalisation of R&D in multinational companies has come to a standstill in the new millennium. In spite of these moderate changes in recent years, a remarkable level of globalisation has been reached. German companies carry out about a quarter of their research and development in other countries, and conversely about a quarter of R&D activities in Germany are carried out by subsidiaries of foreign companies.

High R&D intensity of German companies in the USA

German companies have the second-highest R&D intensity in the USA after Swiss companies. This shows that in the USA not only market access is important but also the acquisition of knowledge, particularly for the cutting-edge technologies. This motive has grown in importance since the end of the 1990s. German companies not only see considerable potential for the future, but also the need to further expand their R&D in other countries. After some quiet years, it must therefore be expected that there will be increased international mergers and acquisitions (M&A) and thus a further diversification of the production and R&D locations. Worries that multinational companies could withdraw their R&D activities from Germany have so far proved unfounded.

The transnational networking of company R&D locations and the exchange of knowledge has so far taken place within and between the knowledge-intensive regions of the USA and Western Europe. 59 per cent of total R&D expenditure of foreign subsidiaries in Germany came from European companies and 38 per cent from North American ones, particularly in vehicle construction. R&D expenditure by companies from Asia and the rest of the world is of little significance in Germany so far, accounting for only two per cent. The involvement of the traditionally important target countries in worldwide R&D expenditure has already showed a slow decline in the case of American companies. Increasingly they are also carrying out their R&D in new dynamic economies. The proportion in Israel increased between 1999 and 2004 from 2.1 per cent to 3.6 per cent, in China from 1.6 per cent to 3.5 per cent.

German companies in almost all sectors expect to expand their R&D and innovation activities in other countries. But they are planning the expansion more in newly developed and emerging economies in Asia than in Western Europe. It is not possible yet to make any reliable predictions about the extent of this.

Gradual increase in direct investments also after 2000

There is little statistical data available about direct investments by German companies in other countries. According to the Bundesbank, in 2005 there were some 24 000 companies in other countries with German direct investments, of which 7 500 were in the manufacturing industries. An evaluation of a companies' database⁸⁰ suggests that in the case of the research-intensive manufacturing industries about 6.5 per cent of German companies with at least 20 employees have at least a ten per cent holding in one or more companies in foreign countries.⁸¹ The corresponding figure for other manufacturing sectors is only 3.5 per cent. The percentage is also lower for technology-oriented service providers at 3.5 per cent. The level of 6.5 per cent for research-intensive industrial companies may seem modest at first sight, but there are a very large number of small enterprises in the dataset. Between 2002 and 2004 the proportion of companies with foreign direct investments has risen slowly. These investments are aimed initially at production in other countries, but will also involve research and development in due course.

D 3–2 ASIAN NEWLY INDUSTRIALISING COUNTRIES IN THE KNOWLEDGE ECONOMY

An important trend in recent years has been the rapid rise of the newly industrialising countries, in particular in Asia. High growth rates in small countries starting from a low base are a common phenomenon which at first has little effect on international developments. However, it is remarkable in this case that these countries have meanwhile achieved considerable weight, including in absolute terms, and this has worldwide consequences for innovation. The role of the Asian newly industrialising countries can be demonstrated by a comparison of gross domestic product. China is in second place behind the United States, in front of Japan and Germany, India is in fifth place (Table 03). The data used for the table is based on a recalculation of purchasing power parities,⁸² and the gross domestic product of China is about 40 per cent lower than some earlier figures. This does not alter its importance and its strong growth rates for all economic data. But it will take at least another decade until China has reached the economic significance of the United States.

Strong growth of patent applications from Asia

There has been a marked increase in world market patents in Asian countries, in particular with Korea and China specialising in ICT. Korean patent applications have tripled since 2000, and Chinese applications have increased 2.5-fold. Looking only at high technology, the development for China is even clearer, underlining not only the focus but also the considerable potential of this economy in cutting-edge technology. Since these are international applications which have to meet the corresponding standards and which are exposed to international competition, these values and developments should not be underestimated. In absolute terms, China has already outstripped countries such as Sweden, Finland or also the Netherlands. Korean companies register three times as many patents in the USA as in Europe, but the Chinese companies have no exclusive focus on the American economy, and are equally involved in Europe.

Newly industrialising countries catching up in terms of publications

The growing activity of newly industrialising countries, and in particular China and Korea, is also reflected in a process of displacement in publications in internationally relevant journals, i. e. to a steady decline in the share of publications from the major industrialised countries. Since the year 2000, the rate for the USA has sunk by four per cent, that of Germany by

ten per cent. In contrast, China's share has increased by 66 per cent, Korea by 62 per cent. It is also important to note that the citation indices for both Chinese and Korean publications, an indication of their quality, have meanwhile reached average levels, whereas Japan has had a significantly negative index since the start of the 1990s. However, the index for the international orientation remains definitely negative for South Korea and China, whereas here Japan is approaching an average level. Asian authors are increasingly succeeding in placing their publications in high-profile international journals. The data on patents and publications show an increased orientation of these countries to the knowledge-intensive sector.

R&D-efforts of the newly industrialising countries are rising significantly

This development is particularly marked for expenditure on research and development. The most important newly industrialising countries only accounted for a twelve per cent share of worldwide R&D expenditures, but by 2005 this had increased to 24 per cent (Figure 14). The newly industrialised (threshold) countries in this case consist of China and South Korea, eastern European countries such as the Czech Republic, Hungary or Poland, as well as Israel, Singapore, India, Brazil, Mexico and South Africa. The figures are still based on old purchasing power parities which make the growth seem more dramatic than it has actually been. But this does not alter anything about the massive increase and the high absolute impact that it is now exerting.

Among non-OECD countries, R&D intensity is particularly high in Israel (4.5 per cent), Taiwan (2.5 per cent) and Singapore (2.4 per cent). If the increases in R&D intensities in the established countries Japan and South Korea are also taken into account, the extent of the global shift towards Asia becomes clearer. The Asian states are meanwhile international engines of research and development. In India, spending on research has almost reached 28 billion euros, putting it in eighth place worldwide. Foreign investors are attracted in particular by the scientific tradition and the human resources. The government continues to play a dominant role in R&D, in particular in the military sector, agriculture, space research, health, and energy. Foreign companies often set up production-independent R&D centres in India, and with 26 per cent R&D is the most-frequently cited reason for foreign direct investments. The conditions are regarded as being particularly favourable in the sectors chemicals, pharmaceuticals, electronics, and software.

The growing importance of the newly industrialising countries, in particular China, is meanwhile also impacting on the German balance of trade. German imports from China have increased between 2000 and 2006 by a factor of 2.6, the German exports to China by a factor of 2.9. Currently, some seven per cent of German imports are from China, although to a large part these are products of German subsidiaries in China.

The orientation of the newly industrialising countries, in particular China and India, towards knowledge-intensive sectors is an opportunity for German companies, because these countries need investment goods to set up their industries which correspond well with the German specialisation profile. For this it will be necessary for German companies to maintain or even increase the current high innovation level. Japan is currently making efforts to withstand competition from its direct neighbours by increasing its research expenditure. This is probably also the best approach for Germany to adopt.

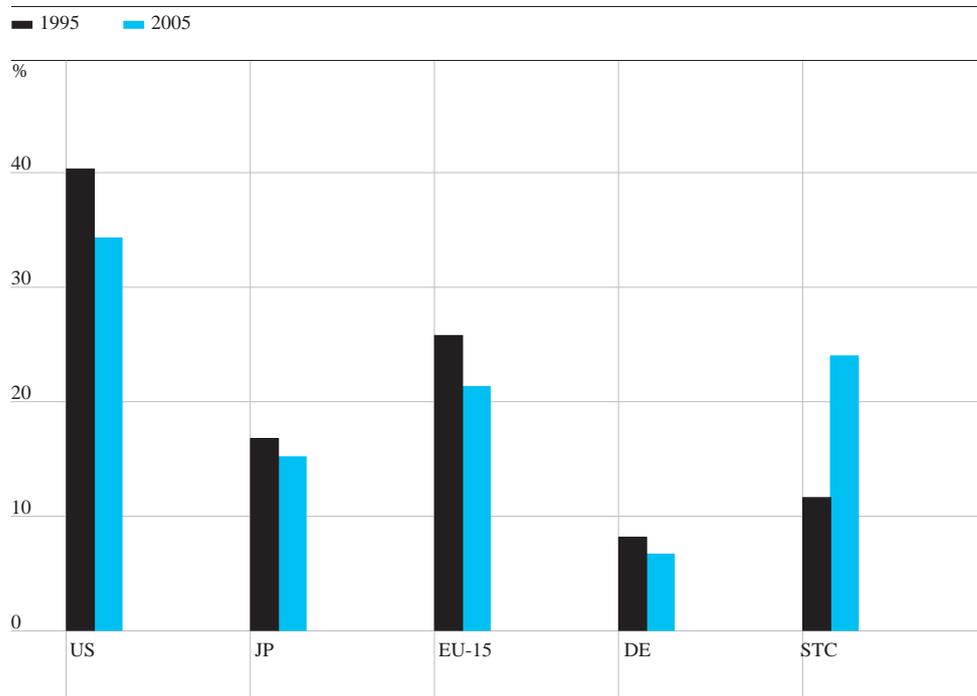
Large companies make a decisive contribution to the macroeconomic volume of innovations and R&D and also for the innovation and R&D intensity. The large numbers of

TAB 03 Shares of the largest countries in the global gross domestic product, 2005 in dollars PPP

Country	per cent
USA	23
China	10
Japan	7
Germany	5
India	4
United Kingdom	3
France	3
Russian Federation	3
Italy	3
Brazil	3
Spain	2
Mexico	2

Source: World Bank 2007.

FIG 14 World regions and their shares of internal business R&D expenditure



STC: Selected threshold countries, Calculations in current prices.
 Source: OECD, Main Science and Technology Indicators (2007/2). IMD World Competitiveness Yearbooks (various).
 DST. IFM. Federal Office of Statistics, Statistisches Jahrbuch. Ministerio da Ciencia e Tecnologia do Brasil.
 Calculations and estimates of NIW.

small and medium-sized enterprises (SMEs) determine the extent to which the innovations and R&D are anchored in the economy. To this extent their R&D involvement is a critical parameter for innovation policy developers. However, there has been a long-term decline in the proportion of SMEs with R&D activities. The R&D activities are increasingly being concentrated in a relatively small number of large companies. In 1995, 21 per cent of the small industrial companies with less than 100 employees reported R&D activities, but in 2003 it was only twelve per cent. For the slightly larger companies with 100 to 500 employees, this proportion declined over the same period from 34 per cent to 29 per cent.⁸³ The R&D activities have thus lost breadth in the economy, although this process has slowed down recently.

In an international comparison, the regular participation of SMEs in R&D in Germany is still relatively high. However, this important advantage of the German innovation system has weakened in recent years, and the number of researching companies in Germany has been declining, while most other European countries have seen an increase. SMEs have increased their share of the external R&D expenditure between 1995 and 2005 from eight per cent to ten per cent, but are considerably below the values of the large companies (1995: ten per cent, 2005: 20 per cent). Within the external R&D of SMEs, universities receive more than 20 per cent of the commissions, a proportion which is comparable with that of large companies.

For international comparisons of R&D participation it is important to consider that the government contribution towards financing R&D in Germany has fallen steadily since the start of the 1990s from ten per cent to currently about 4.5 per cent. In absolute terms, a large part of state aid (78 per cent) goes to large companies, with the focus here on the aeronautics and astronautics industry. In general, since the mid-1990s large companies no longer receive preferential government treatment. On average, the intensity of state intervention, measured as the proportion of state aid in total R&D expenditure, in 2005 was 8.1 per cent for small enterprises, 4.2 per cent for medium-sized companies, but only 3.1 per cent for large companies. And with the overall decline in state aid for R&D, there is also a loss of leverage. Experience shows that every Euro of state aid for R&D will mobilise an additional 80 Eurocent of business R&D investment.⁸⁴

Decline in innovation participation of SMEs

The rate of innovators varies with the size of the companies. For companies with more than 500 employees it is 90 per cent, for medium-sized companies with 50 to 500 employees 70 per cent, and 51 per cent of small industrial enterprises with 5 to 49 employees are innovators. This comparison shows clearly that the average of 58 per cent innovators for the manufacturing industry is strongly influenced by the large number of small companies. For the knowledge-intensive services the percentages in the three size categories are only slightly lower than those for manufacturing. However, in particular for small and medium-sized enterprises there is clear decline in the innovation participation. In absolute terms, the importance of the innovation expenditure of SMEs is limited. In 2006, SMEs provided only 28 per cent of all entrepreneurial innovation expenditure, in the mid-1990s their share had been about a third. As with R&D, there is a declining trend here. In the industrial sector, the proportion of innovations expenditure from SMEs is only 22 per cent, but it is considerably higher in the knowledge-intensive services with 42 per cent and other services with 41 per cent. It would seem that SMEs are considerably more important for service sector innovations than for the manufacturing sector. In terms of successes with market innovations, SMEs reached peak values in both manufacturing industry and in knowledge-intensive services in the years 2000 and 2001; since then, however, they have declined considerably.

Tax support for R&D increasingly significant internationally

As has already been mentioned, many other OECD member countries have also been reducing their direct state contributions to R&D financing since the start of the 1990s. However, there has been a shift in many countries to more indirect state aid for R&D by means of tax credits or tax allowances. Indirect R&D aid is regarded as a good way of broadening the base of companies carrying out R&D, in particular among small and medium-sized enterprises. A number of countries which already offer more state aid for R&D by SMEs than for large companies have recently also introduced fiscal R&D aid. In 1995, twelve OECD member countries used indirect tax aid, but in 2006 the number had risen to 20. Considerable funds have been mobilised. In 2005, direct state financial aid for

R&D in enterprises in Austria accounted for 6.4 per cent of expenditure, but including tax aid it amounted to 17.4 per cent. In Great Britain the figures were 8.6 per cent and 12.9 per cent, and in the USA 9.7 per cent and twelve per cent, respectively. The conclusion is that in recent years the state R&D aid for SMEs in other countries has progressed more than in Germany.

D 4 INNOVATION AND PATENT BEHAVIOUR IN THE GERMAN ECONOMY

D 4 – 1 INNOVATION BEHAVIOUR IN THE GERMAN ECONOMY

In the context of companies the concept of innovation refers to bringing new goods and services to the market and introducing new processes. Whereas research and development generate new knowledge, innovations involve the development of market-relevant products and their marketing. This section presents key results of a recent annual company survey.⁸⁵

Innovator rate in long-term decline

Despite improving economic conditions, there was no increase in the proportion of companies in Germany with product or process innovations in the manufacturing and services sectors in 2006, and the figure remained at about 46 per cent. Differentiated in terms of sectors, the innovator rate was highest in the manufacturing industries at 58 per cent (Figure 15). For the knowledge-intensive services it fell to 52 per cent (from 55 per cent in the previous year). Here the innovation participation of companies has been very irregular in recent years, which is an indicator perhaps of a shorter-term orientation of innovation activities. For other services the innovator rate rose slightly, but at 33 per cent it is much lower in this sector than in manufacturing or the knowledge-intensive services. Many companies can obviously achieve market success without continuous innovation activity.

Innovation activities can either aim at introducing new products or new processes within the company for production, service provision, or marketing. Within a three-year period, a considerable proportion of the innovators – 47 per cent in the industry sector, and some 40 per cent in the services sector – realised both product and process innovations. 20 per cent to 25 per cent of the innovators introduced only process innovations, and 35 per cent to 40 per cent are solely product innovators.

Decline in innovations after the New-Economy boom

For the first time in some years, a slight rise could be observed in 2006 in the numbers of companies introducing products new to the market. These are companies launching at least one innovation on the market which none of their competitors had previously offered in this or a similar form. It is not sufficient for the commodity in question to be a novelty for the company in question. The proportion of product innovators rose to 47 per cent in the manufacturing sector and to 31 per cent for other services; in the case of knowledge-intensive services it fell slightly to 33 per cent.

The overall proportion of companies innovations new to the market decreased over the past seven years – obviously it is becoming more difficult to market original new products. The high figures at the end of the 1990s are related to the dynamism of IC technology in that period. As with production, balance of trade, and R&D, the figures for innovations clearly reflect the effects of the New-Economy boom and its collapse in 2001. As already noted for