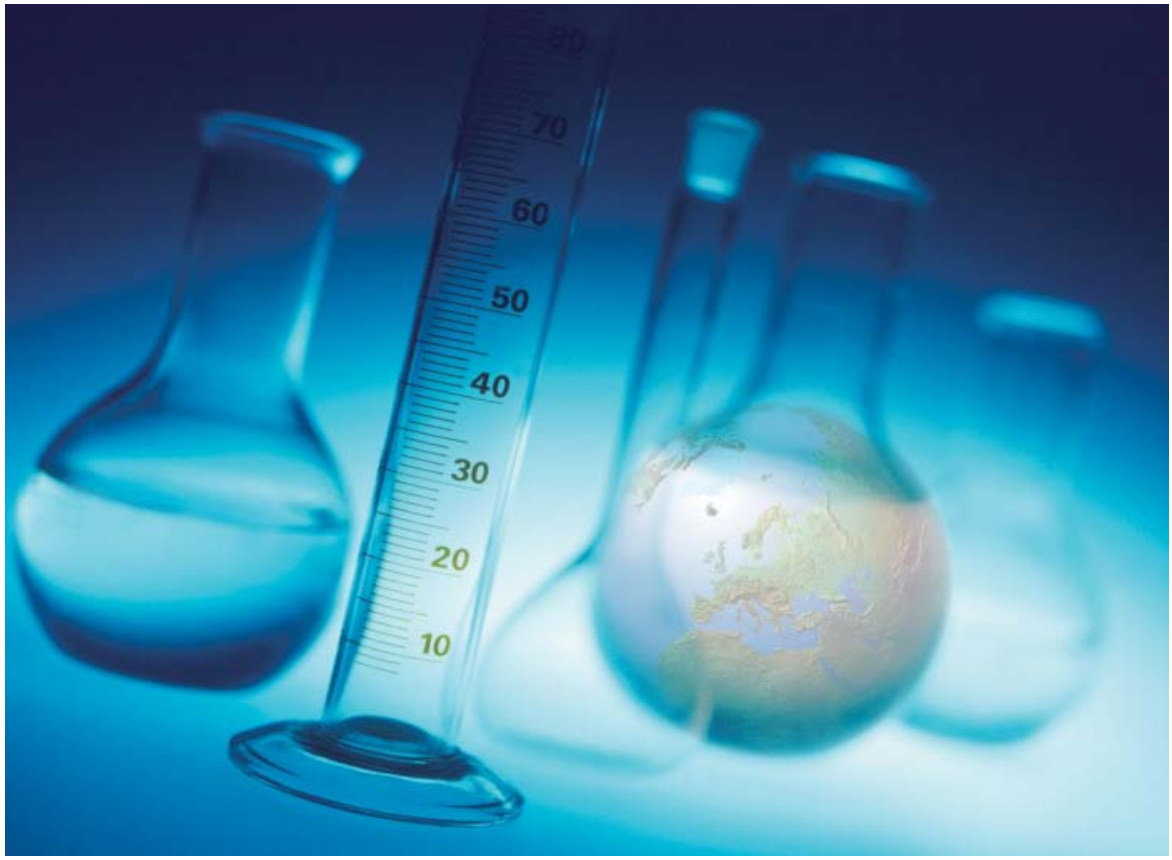
Economist Intelligence Unit

The Economist

Scattering the seeds of invention

The globalisation of research and development



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As part of the research for this project, the Economist Intelligence Unit conducted a global survey of 104 senior executives on the topic of the globalisation of research and development; the full survey results are provided in an appendix to this paper. We also interviewed senior executives in a range of industries with responsibility for planning R&D strategy for their organisations. We are grateful to Professor Rafiq Dossari of Stanford University for his help in facilitating numerous interviews.

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Executive summary

Establishing business operations in far-flung corners of the world has become a routine challenge for many companies. The practice of locating production lines in developing markets where labour is cheap, and fast-growing markets easily accessible, is almost mundane. But manufacturing products globally is one thing: creating them is another. Until recently, much of the "brain work" of the organisation has been concentrated in the home market. This has been particularly true of research and development (R&D), that part of the business that is so integral to the creation of new products and innovative ideas.

Now there are signs that companies are redistributing their product innovation, and in some cases even basic and applied research, across global R&D networks. In a new, worldwide survey of 104 senior executives conducted by the Economist Intelligence Unit for this report, 70% of respondents reported that their companies (a mix of large and small to medium-sized enterprises) already employ R&D talent overseas. A total of 52% of executives plan to increase their investments in overseas research in the next three years and–significantly–the rise in R&D spending will no longer be restricted to the traditional centres of scientific excellence. In the next three years, executives in the survey plan to make larger investments for overseas R&D in China than anywhere else. India also emerges as hugely attractive for R&D spending.

What forces are driving this redistribution of corporate R&D? On a simple level, some types of research follow hot on the heels of companies' attempts to access new markets. It is difficult for a business to sell computers or mobile phones in China, for example, without some form of product innovation to adapt technologies to the local market. But there is a bigger, and in the long run more significant, lure for global R&D. In industries where a constant stream of high-tech innovations is crucial to survival, companies will go wherever they must to access top R&D talent. A total of 70% of executives in the survey see the ability to exploit pools of skilled labour as a very important or critical benefit of globalised R&D, making this a more significant driver than cost control or the desire to accelerate innovation cycles. Increasingly, this means tapping into one or more of the R&D skills pools that are proliferating around the world.

This white paper explores the key trends, drivers and challenges behind the globalisation of R&D. Based on the findings of our survey, as well as in-depth interviews with business leaders and heads of R&D drawn from a range of technology-driven industries, the report draws a number of key conclusions.

- **Expertise is the top attraction for globalised research**. Labour costs, the quality of local infrastructure, favourable tax regimes and government incentives all play a role, but skills are the biggest magnet for R&D investment. Attracting the best R&D talent is a moderately to critically important challenge for 79% of companies in the survey. The solution is to lure the best people from around the world to come to you or, increasingly, to tap into new centres of scientific or technical talent that are mushrooming around the world. Apart from protection for intellectual property (IP), the quality of a country's education system is the most critical factor when companies evaluate countries as locations for R&D

investment. The survey also reinforces the importance of finding local expertise that is specific to any given sector, which is why hot destinations for R&D often vary from industry to industry.

● **Where there are mass markets, R&D tends to follow.** The size of the local market is an important factor in companies' decisions on where to locate R&D for 76% of executives in the survey. That is one key reason why the US, with its large and affluent markets, has long been a magnet for foreign R&D investment. In the cases of China and India, the opportunity to access fast-growing markets goes a long way to counteract other deficiencies in the business environment. To access these markets, however, companies need to tailor and enhance their products to meet local requirements. Increasingly, this means conducting R&D closer to the customer. Wherever large markets open up to foreign investment, R&D is likely to follow: hence the high correlation between countries that have opened their manufacturing sector to foreign ownership, and those that are now attracting significant levels of follow-on R&D investment.

● **Emerging markets are beginning to climb the R&D value chain.** At the moment, most foreign R&D investment in emerging markets is focused on product research (improving or extending existing products) or process research (for example, innovations in manufacturing). Since product research is the highest R&D priority for 60% of executives in the survey, this gives emerging markets plenty of scope to take a bigger slice of R&D spending. However, there are signs that the emerging giants are also beginning to stake a claim to high-end R&D: take the example of Matsushita and NTT DoCoMo, two Japanese firms that have recently announced plans to base R&D for their next-generation mobile technology in China. In the survey, 22% of respondent companies already conduct some applied research in overseas developing markets.

● **Intellectual property risks remain a key concern.** The flip side to the many benefits of globalised R&D is that, as companies set up R&D operations in markets where property rights are less established, it becomes more difficult to protect proprietary innovations. In the survey, 38% of executives cite protection of IP as a critically important challenge, a higher proportion than for any other issue. Countries where IP protection is strong have a significant advantage in attracting R&D investment, according to the survey; emerging markets like China will need to continue to improve their record in this area if their potential as centres for R&D innovation is to be fulfilled. In the absence of strong legal protection, companies will need to find new strategies to safeguard their intellectual property—for example by strengthening security and entrenching work habits that prevent proprietary information from leaking out in the first place. IP concerns explain why some of the companies interviewed for this report still prefer to keep the highest-value R&D work in countries where IP protection is most robust.

● **Success in global innovation requires new organisational strategies for R&D.** Enabling effective collaboration between international R&D teams,

managing people in diverse cultural environments and aligning global research activity with business strategy are three key organisational challenges that arise from the globalisation of R&D. Success in addressing these issues also enables companies to solve one of the biggest challenges of all: how to leverage global talent to compress the time it takes to commercialise innovation. The most successful companies will manage to nurture cultural differences, while applying core, standardised processes in ways that enable them to maximise the quality and productivity of their global R&D.

Just as manufacturing processes have been deconstructed and distributed around the world, now corporate R&D is increasingly an international effort, with different countries excelling at different stages in the innovation cycle. These global research networks create huge challenges as well as exciting opportunities for organisations. Developing strategies that enable diverse, multicultural teams to collaborate effectively against common research goals—and that also protect the fruits of their efforts—is a challenge that will distinguish consistent innovators from the "me-too" companies of global R&D.

The innovation boom

Globalisation is more commonly associated with denim jeans, canned soft drinks and burger chains than the cutting-edge world of high-tech R&D. Where companies have invested overseas, the emphasis has been on manufacturing and sales operations—in other words, the more rudimentary, process-driven aspects of the business. By contrast, the idea that all but a few of the largest companies would consider taking R&D out of the labs back at HQ, and instead create R&D networks spanning a mix of developing as well as developed countries, seemed improbable until very recently.

Now all that is changing, as evidenced by a rise in crossborder R&D spending. Foreign-owned R&D expenditure in the US, for example, grew at a real average annual rate of 10.8% between 1994 and 2000, according to a recent report from the US's National Science Board. By contrast, the percentage of research that US multinationals performed abroad at their foreign affiliates increased to 13.1% of total R&D in 2000, up from 11.5% in 1994. In a global survey of senior executives conducted by the Economist Intelligence Unit for this report, 70% of respondent companies already employ R&D staff overseas. And the trend towards globalisation of R&D is gathering pace: over half of the companies surveyed plan to increase their overseas R&D investments over the next three years, while a further 38% will sustain existing spending levels.

Many powerful forces are making the globalisation of R&D both possible and necessary. The removal of barriers to international business have created opportunities for companies to invest in and own international R&D operations. Newer markets, such as China and India, have lately developed the wealth to buy more high-tech products from other nations. The Internet has eased communications between businesses in differing locations and time zones, and has helped to solidify English as the common language for science and technology. Cost pressures, too, are driving companies to pool resources and manage some aspects of R&D together, often across national boundaries. Above all, the choice of viable locations for R&D has expanded hugely in the past decade. "The

The rise in US outward R&D investment, US$m

	1994	2000
EU	7,450	12,300
Canada	800	1,800
Japan	700	1,200
Rest of world	700	4,000
China	5	506

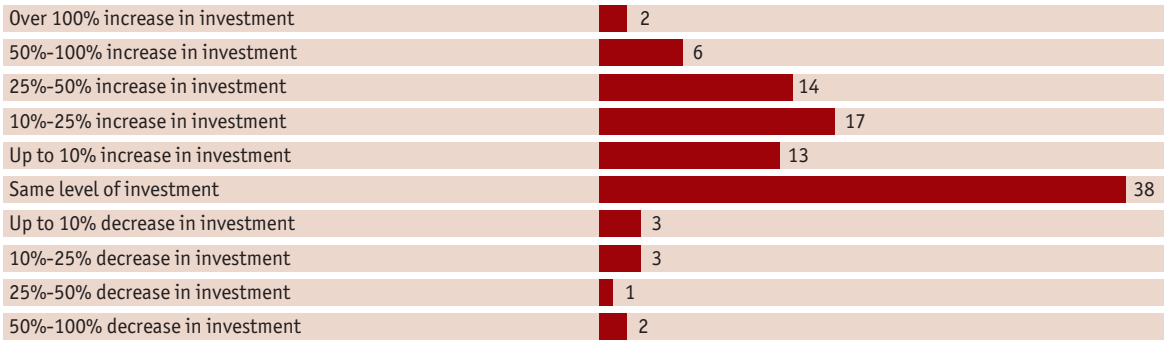
Source: OECD, January 2004.

R&D defined

R&D can be divided into four types of activity: basic, applied, product and process research. For the purposes of this study, we defined the four R&D types as follows:

- basic research is original experimental work without a specific commercial aim, a type of research done more frequently at universities than at corporations;
- applied research is original experimental work with a specific aim—its results can distinguish one company from another;
- product research involves the improvement and extension of existing products and is more on the development side of R&D;
- process research is the development of new or improved processes, such as manufacturing processes, and again is more a product of development than of research.

Does your company plan to increase or decrease its overseas R&D investment over the next three years?
(% respondents)



Source: The Economist Intelligence Unit

maturation of the offshore marketplace—and its ability to take on complex proprietary projects—has been one of the big changes we're seeing," says Tim Champion, head of product development at Cambridge Consultants, a UK-based consultancy.

Of the many possible motivations for investing in R&D operations overseas, three stand out as priorities for companies that are in the process of developing international research networks.

1. The search for global expertise

Whether it be novel drugs, software upgrades or cutting-edge mobile technology, high-tech companies constantly need to replenish the pipeline of innovative products. This creates huge demand for highly skilled researchers who are often in short supply in a company's home markets. Fortunately, an increasing number of emerging markets offer a plentiful source of R&D talent as their quality of education improves. This trend is likely to gather pace in the future as countries' investments in science and technology skills bear fruit: in China, for example, 61% of undergraduates are studying for science and engineering degrees, according to the OECD. India is also making strides in improving the quality of its higher education. The country houses three out of the top five Asian schools for science and technology, according to a ranking conducted by *Asiaweek* in 2000.

High-tech companies have traditionally sought to attract top global talent, usually through a combination of financial reward and an attractive environment in which to work and live. While this

What do you believe are the main benefits of globalised R&D today? Score from 1 to 5, where 1 is unimportant and 5 is critically important.
(% respondents)

	1 Unimportant	2	3	4	5 Critically important
1. Access to 24/7 global R&D processes	23	26	18	18	14
2. Ability to exploit pools of skilled labour	3	7	21	48	22
3. Reduced R&D costs	2	17	26	32	23
4. Higher volume of innovations	3	11	38	33	16
5. Reduced time to market for innovations	3	17	25	34	21
6. Ability to tailor goods and services to particular markets	6	10	21	37	26

Source: The Economist Intelligence Unit

practice continues, the premium on scientific and technology skills is such that a growing number of companies are also moving their R&D operations out to wherever expertise can be found. Tapping into pools of scientific or technological expertise in other countries can help companies avoid relocation expenses and excessive salary costs, and can help keep talented research teams together. This is one reason why SAP, a large German software firm, opened an R&D lab in Sophia, Bulgaria, having found and acquired a local company of exceptionally talented Java programmers. "Talent is the big driver" in SAP's globalisation of R&D, says Aliza Peleg, managing director of the North American labs at SAP America.

In the survey, 71% of executives cite the ability to exploit pools of skilled labour as a key benefit to globalising R&D. When asked to rate which aspects of a country's business environment are most important in deciding where to locate R&D, 65% of executives in the survey said the quality of the local education system is a very or critically important factor. Related to this, proximity to major universities and research labs remains an important advantage for many types of R&D activity. "We are always careful to locate [R&D] close to academic centres of excellence," says John Eaton, vice-president of finance and corporate development at Agilent, a technology solutions and services provider.

2. Meeting demand in fast-growing markets

A total of 63% of executives in the survey agreed that a local market's size is an important factor in the decision on where to base R&D. "Direct access to burgeoning markets is a huge driver," says James Andrew, senior vice-president at Boston Consulting Group, a US-based consultancy. "Consumers have different cultural beliefs and norms. If you aren't there to understand those, you can't design products for the market." Nearly two-thirds of our survey respondents agree that the ability to tailor goods and services to particular markets is a very or critically important benefit of globalised R&D.

The need to meet market demand more quickly is another driver behind the globalisation of R&D, and the third most cited reason in the survey. For example, through a semiconductor alliance with Philips of Holland and US-based Motorola, Franco-Italian STMicroelectronics, one of the world's largest semiconductor firms, has been able to research and develop chip products more quickly than it ever would have on its own. "It's a question of speed, working across time zones and distance. Even if the company's centre of gravity is in the US, the local presence gives us the ability to respond quickly to local needs," adds Thomas Connelly, senior vice-president and chief science and technology officer at DuPont, a large chemicals firm, which is building a US$15m corporate R&D centre in Shanghai.

Medium-sized firms are beginning to globalise R&D for many of the same reasons as their larger counterparts. IFS, a software company based in Linköping, Sweden has R&D in Chicago and Tucson, for example, because of acquisitions it made in those cities. But like DuPont, it also wants to respond to local markets. "We need to have our designers very close to the customers," says Michael Hallén, president and CEO, adding that about half of IFS's revenue comes from western Europe and about one-quarter from the US. "We are keeping our R&D people close to customers in the US, UK, Germany and Sweden."

3. Cost pressures

R&D costs are escalating in high-tech industries like pharmaceuticals, where the total investment required to bring a new drug to market is now estimated to be over US$800m. Not surprisingly, therefore, more than

half the companies surveyed said reduced R&D costs are important benefits of globalised R&D. According to the survey, companies weigh cost benefits in a range of areas, including lower-cost labour, cheaper land and office rental, and favourable tax regimes. Even so, cost considerations are still of lesser importance than the search for skills or expanding markets. One reason for this is that savings from cheaper labour are partially offset by the costs of co-ordinating R&D across multiple countries. "The hidden cost of R&D globalisation may shock some companies," says Dean Davison, vice-president and director at Meta Group, a US-based research company.

How companies respond to these pressures often depends on size: big companies are generally equipped to globalise R&D internally (opening their own overseas labs), whereas medium-sized firms, constrained by cost considerations, may be more likely to globalise through outsourcing or alliances. "Smaller firms must use [R&D] outsourcing to get the economies of scale and effectively leverage offshore facilities," says Mr Davison. Other alternatives to in-house development are enabling more companies, large and small, to enjoy the fruits of global R&D. One is the acquisition or licensing of existing technology in other countries (many companies buy up R&D expertise in other countries through this route). Another increasingly important strategy in cost-sensitive industries is joint R&D ventures. These strategies enable companies to reduce substantially the time, cost and risk involved in establishing overseas R&D operations.

Today's R&D hot spots

R&D hot spots are centres of innovation where companies can tap into an existing network of relevant scientific and technological expertise, good links to academic research facilities, and environments where innovation is supported and easy to commercialise. Once an area gains critical mass as a centre for a particular type of research, often whole industries begin to gravitate towards it. "We have our major competitors here," Ms Peleg says of SAP's R&D lab in Palo Alto. "And we have Silicon Valley as a fountain for ideas and talent."

So where are the new hot spots for global R&D? While there is no single location that excels in every type of research, certainly there a number of key locations that shine particularly brightly on the R&D globe. The leading destinations for R&D investment can be divided between long-time lynchpins and rising stars. First, the rising stars. When asked in the survey where they would spend the most on R&D in the next three years, companies were particularly bullish about the two Asian giants: China took the top slot with 39% of respondents and India was third with 28% of respondents.

What makes China so appealing for multinationals looking to globalise R&D? First and foremost,

In which of the following countries does your company plan to spend the most on R&D in the next three years (excluding your domestic market)? (Top ten locations out of 54.)
(% respondents)

1. China	39
2. US	29
3. India	28
4. UK	24
5. Germany	19
6. Brazil	11
7. Japan	10
8 = France/Italy	9
10. Czech Republic	8

Source: The Economist Intelligence Unit

Which of the following aspects of the local R&D environment are most important in your choice of R&D destination? Please rate the following options 1-5, where 1 is unimportant and 5 is of critical importance.
(% respondents)

	1 Unimportant	2	3	4	5 Critically important
1. Size of country's existing R&D sector	7	23	32	31	7
2. Local specialised manufacturing expertise	10	15	30	34	11
3. Existence of R&D concentrations (eg industrial parks, local hubs)	9	16	29	31	14
4. Local R&D expertise in your industry	4	5	27	38	27
5. High degree of collaboration with research institutions	11	22	30	27	10
6. Availability of R&D scientists with appropriate skills	4	13	23	38	23
7. Cost of labour for R&D	3	14	26	38	20
8. Availability of local managers with expertise	1	8	20	54	17
9. Links between firms and academia	12	24	34	19	11

Source: The Economist Intelligence Unit

companies everywhere want to sell their products to China's huge market of nearly 1.3bn people. China is also increasingly rich in R&D skills: in 2001 it had the second-highest number of researchers in the world, according to the OECD. Until recently, the focus on R&D in China had been product and process research to tailor products to local markets; multinationals have been wary of locating original research in a country where IP is hard to protect. However, as Chinese authorities begin to make some headway on this issue, China is beginning to climb the R&D value chain. And even though IP currently remains a concern, its markets are too big for companies to ignore. "China is the only country where we have grown in R&D over the past three years," says Hakan Djuphammar, vice-president of systems-management R&D at Ericsson in Stockholm. Ericsson's sales in China rose by 17% between 2002 and 2003. "Everything is growing and nothing seems impossible...there's a 'sky's the limit' kind of thinking," comments Mr Djuphammar.

India became a software R&D hub in the 1990s when companies rushed to finish software alterations before the year 2000. As a large Asian country where English is spoken, wages are modest and Western education is available, India has quickly grown as an R&D powerhouse. "Many of the Indian scholars have been trained in the West, and the costs are very low," says Frank Douglas, executive vice president and chief scientific officer of drug innovation and approval at Aventis, a pharmaceutical firm. Today, India's R&D capabilities have expanded far beyond software. According to Ernst & Young, India will generate US$5bn in revenue and more than 1m biotech jobs over the next five years. GlaxoSmithKline, for example, has formed a research partnership with an Indian drug firm, Ranbaxy, while Ernst & Young selected India—along with Singapore, Taiwan, Japan, South Korea and China—as an emerging Asian biotech leader in a recent report.

China and India will by no means monopolise growth in overseas R&D investment in the next three years, however. Three major Western countries emerge as the main developed-country lynchpins of global R&D spending in the survey—the US is favoured by 29% of respondents, the UK by 24% and Germany by 19%. Each of these countries has an established record as an R&D powerhouse: the US, for example, accounts for 44% of all R&D spending in the OECD (Europe represents 28% of the OECD total, compared with Japan which houses 17%). These countries offer a history of R&D success, established infrastructure, strong academic links and robust IP laws. They are also hospitable collaborators, all working well with other nations on R&D projects. The US does the most international scientific collaboration in the OECD, followed by the UK, France and Germany.

The US, UK and Germany also have sophisticated R&D infrastructures already in place. In Germany, for example, Munich is home to the internationally renowned Max-Planck-Gesellschaft and the Fraunhofer-Gesellschaft. The research institutes of the Max Planck Society perform basic research in the natural sciences, life sciences, social sciences and the humanities, while the Fraunhofer-Gesellschaft undertakes applied research with direct application to private and public enterprise. The Max Planck Society maintains 78 institutes and research facilities in Germany, while the Fraunhofer-Gesellschaft maintains over 80 research units at more than 40 different locations with a staff of some 12,700 throughout Germany.

With 1% of the world's population, the UK conducts 4.5% of the world's science, produces 8% of the world's scientific papers and receives 9% of the citations made by scientists. The two English cities of Oxford and Cambridge, with their renowned universities, provide fertile ground for R&D start-ups. Scotland also has a strong R&D sector: for example,

Industry focus: Mobile technologists head for China

China, like India, its rival in offshore technology development, offers multinationals several distinct advantages in their quest to develop R&D. Certainly, the low-cost and increasingly high-calibre engineering and science talent is a significant draw. China's IT talent is particularly attractive to Japanese and South Korean information technology companies, since China shares a common foundation in double-byte programming (the South Korean, Japanese and Chinese languages all require 16 bits of data—two bytes—per character instead of the single byte required for letters in most alphabet-based languages), and cultural synergies in work and design abound.

But there is another, more fundamental reason that Japanese high-tech companies in particular look to establish R&D footholds in China: "The emergence of China as a market, and the size and speed with which it is growing, make development—if not research—essential here," observes Joseph Cho, who is chief technology officer for Panasonic Mobile Communications China, and co-ordinates all of the R&D activities of its parent company, Matsushita, in China.

Mr Cho and his team originally set up a local R&D umbrella group to track trends and help localise Matsushita's mobile phones and audio-visual products in China. "But as you can imagine, there is not a lot of localisation required for a TV set," observes Mr Cho, which is why 60 of his 100 engineers were deployed in R&D activities work at Matsushita's Advanced Mobile Communication Laboratories (CMRD/AMCL) in Beijing. China's mobile-phone market has for some time been the world's largest—there are likely to be over 325m mobile-phone subscribers at the end of 2004, and an estimated 90m handsets will be sold in this year alone. This sheer size means that China's two mobile-phone operators—China Mobile and China Unicom—have increasingly influential amounts of buying power. Mr Cho believes that having proximity to the customer is a boon to product development. Now his team works with China's carriers to set new features on Panasonic handsets that take advantage of new, 2.5G services based on GPRS. Such requirements for the Chinese market often feed back into Panasonic's global R&D process.

In addition to the sheer size of the market, Mr Cho cites increasing sophistication in the choices Chinese consumers are making for their mobile phones as a large part of the drive for localising R&D. "When we started selling handsets in China, we considered it a second-tier market," he says. "Handset models and designs were at least nine months behind Japan. Now, however, that gap is less than one business quarter." And, with over 2,000 different models on the Chinese market, competition will ensure that this gap keeps closing. Inspired by this growing demand, CMRD/AMCL has even taken to developing global "firsts" for Panasonic in China. What Mr Cho believes to be the world's smallest GSM phone based on the popular Symbian operating system was developed, and is being launched first, in China.

The size and sophistication of the domestic market confer other advantages on Panasonic's R&D activities in China. While localisation still drives design and development activity at CMRD/AMCL, there is an increasing amount of 4G development (a next-generation mobile technology) being initiated in Matsushita's China facilities. 4G, while not as fully formed a technology standard as 3G, largely revolves around issues regarding broadband high-speed mobile networks. Mr Cho's team is working on algorithms that can make more effective use of network resources in congested urban markets to deploy broadband mobile services. China offers a tremendous number of high-density cities (Beijing and Shanghai, for instance, have mobile subscriber penetrations that exceed 75% of the population) in which Panasonic's engineers can test assumptions.

Matsushita is not the only mobile-technology company that is looking to build next-generation innovation for global markets from the ground up in China. Other foreign vendors include Alcatel, which has a "3G Reality Centre" to test mobile data applications, and Qualcomm, which has established a joint venture with China Unicom to support Chinese developers of games and mobile data applications and help publish them for international markets. The world's mobile data leader, NTT DoCoMo, which last year established the DoCoMo Communications Laboratories Beijing Company, is also conducting original 4G research in China.

It is China's ability to give a glimpse into the future of mobile markets globally that perhaps gives Matsushita's CMRD/AMCL facility its most significant advantage. Cost, frankly, is secondary: "R&D expenditures are but one parameter in a much larger equation," observes Mr Cho. "China is fast developing an indigenous design capability; where once Korean and Taiwanese firms controlled two-thirds of the China market, now local firms control all but the highest end of the market." Now those local firms are going global, keeping pace in China is fast becoming a competitive necessity.

Industry Focus: US increases dominance in pharma R&D

A dramatic increase in the relative importance of the US as a location for pharmaceutical R&D is under way. In 1992 the sector's R&D expenditure in Europe totalled US$10bn compared with US$9bn in the US, but by 2002 the US figure had risen to US$26bn compared with US$21bn in Europe, and all the evidence suggests the gap widened further in 2003. The impact of this trend has been striking: in 1993-97 Europe accounted for 81 unique drug launches compared with 48 in the US. In 1998-2002 these proportions were reversed, with Europe accounting for 44 and the US 85. In the words of Henry McKinnell, the chief executive of Pfizer, the world's largest pharmaceutical company, "Europe used to be the medical chest of the world, but this has changed since the 1990s...What we've seen is the pharmaceutical industry leaving Europe in droves."

Why has this happened? The absence of a single European regulatory body as well as less open attitudes towards biotechnology and innovation more generally form part of the explanation, as does the increasing ability of US universities to attract and retain the best researchers. However, the most important reason is the lower prices paid for prescription drugs in Europe compared with the US, which means that Europe accounts for a much lower level of the sector's profits. According to the US management consultants, Bain and Company, the global drug industry made profits of US$60bn in 1992, around 45% of which were generated in the US. In 2002 the industry earned US$121bn, and the proportion accounted for by America had risen to 60%.

The contrasting development of healthcare systems explains the growing discrepancy in the prices paid for prescription drugs. Public spending typically accounts for between 60% and 90% of expenditure on pharmaceuticals in Europe compared with around 40% in the US. Under pressure to reduce fiscal deficits, European governments have moved to control pharmaceutical spending by imposing caps on drug prices. For example, the drive to contain healthcare spending has meant that the prices paid for prescription drugs in Germany have barely risen since 1988. The result is that spending per head on pharmaceuticals in the US is now a full 60% more per head than in the EU; in 1992 it was 30% higher.

Investing in pharmaceutical R&D requires long-term planning—drug development times are on average 10-12 years—and, according to the Tufts Center for the Study of Drug Development, the average R&D spend per drug has risen steeply to around US$800m. The early stages of research on a drug can be done anywhere (hence the increasing interest of the pharmaceutical majors in setting up research centres in India and China) but the large majority of drug development costs—such as clinical trials—are incurred once the initial stage development is complete and need to be conducted in the drug's key prospective markets. Drug companies are understandably keen to concentrate development and drug trials in the most profitable market: the US.

This largely explains the shift in R&D activity from Europe to the US. Novartis, a Swiss pharmaceutical group, has opted to relocate most of its R&D activity to the US, citing better pricing but also a more attractive product-approval climate and greater availability of human capital. Aventis has been building up its R&D presence in the US, whereas Europe's two most successful pharmaceutical groups—the UK's GlaxoSmithKline and AstraZeneca—have become increasingly US-focused, citing their dependence on the US for profits.

The picture is not uniformly bad for Europe, however. Despite the growing presence of UK pharmaceutical companies in the US, the UK has maintained its share of global R&D spending, which has stood at around 9% since the early 1990s, in the process increasing its share of total European pharmaceutical R&D expenditure to around 35%. By contrast, pharmaceutical R&D spending in Germany actually fell between 1992 and 2002, with the result that Germany's share of global R&D declined from 11% to just 7%, taking it from first to third place in Europe, behind both the UK and France.

The quality of the UK's scientific research base and the ability of its top universities to compete for researchers with their US counterparts are key advantages, as is the fact that the UK remains home to two of the big five pharmaceutical companies in AstraZeneca and GlaxosSmithKline. Another reason is the relative strength of the biotechnology sector in the UK compared with France and Germany, where it was initially held back by cultural resistance and weak access to venture capital.

the country accounts for 34% of government spend in optoelectronics research, despite having only 10% of the UK population, and has contributed a number of major breakthroughs in biotechnology—most famously in recent years with the cloning of Dolly the sheep. Scotland also holds 9% of global patents around stem cell research. Along with Ireland and France, the UK awards the highest share of science degrees in the OECD.

Other challengers

A number of smaller Asian countries also have a strong reputation for innovation in particular fields. South Korea, long recognised as a mobile-phone hot spot, is now emerging as a life-sciences R&D centre as well. It doesn't hurt that South Korea had the highest annual growth in patents in the 1990s among OECD nations. Singapore is another rising biomedical R&D star, with the number of biomedical jobs growing by 35% in the past four years, according to government statistics. In 2003 the biomedical sector contributed US$11.3bn to Singapore's economy, strengthening its ranking behind electronics and chemicals as a key speciality.

Government incentive schemes provide an important, although not usually primary, motivation for R&D investments, according to our survey. Such incentives come in all shapes or sizes. Ericsson, a telecommunications company, does some communications R&D in Brazil where there is low-cost, fairly well-educated labour, says Mr Djuphammar. But there are other reasons. "In Brazil, you have to pay a lot of import tax on products you sell—unless you have R&D there," he says. This may be one reason why 11% of survey respondents picked Brazil as their top destination for overseas R&D spending over the next three years.

Consumer styles and preferences can also help to create an R&D hot spot. Along with Japan and South Korea, the Nordic countries are a prime area for mobile-phone research, partly because these countries have some of the highest mobile-phone penetration rates in the world. The countries are also big R&D spenders: Sweden spent the highest percentage of its GDP (more than 4%) on R&D than any OECD country in 2001, while Finland ranked as the second-biggest spender with nearly 3.5% of its GDP going to R&D. Japan ranks third and South Korea fifth, behind Iceland.

Eastern Europe's attractiveness as an R&D centre is also rising. Companies spending none of their overseas R&D budget in eastern Europe will decrease by 16%, whereas the number of companies spending between 10% and 75% of their R&D money in the region will increase significantly. Again, talent is a primary driver behind this trend. The relative skills sets in the US and western Europe appear to be on a declining trend, whereas east European skills are rising, according to Mr Eaton.

Ultimately, R&D globalisation is more of a swapping between nations than a rush on the part of rich nations to ship low-cost R&D work to less-affluent regions. Thus the new R&D model is not just about companies sending research to low-cost destinations in Beijing and Bangalore; it also encompasses German companies locating R&D labs in Herzliya, Israel or American companies opening R&D centres in Tokyo. Consider all the R&D investment in the US, hardly renowned as a source of low-cost labour: Germany, the UK, Switzerland, Japan, Canada, France and the Netherlands invested US$1bn or more in R&D in the US in 2000, according to the National Science Board's 2004 publication, Science and Engineering Indicators. As skills levels improve, however, the signs are that emerging markets will claim a larger slice of R&D spending, while more expensive locations will need to focus on high-end R&D at the top of the value chain.

R&D challenges: IP issues and the battle for talent

Globalised R&D offers huge opportunities to enhance and accelerate the innovation cycle, but there are also substantial challenges. Foremost among these, at least in the minds of executives opening R&D operations in emerging markets, is the need to protect IP. In the survey, 38% of respondents said robust protection for IP is critical in their decision on where to base R&D—more so than any other business factor. "Keeping hold of know-how is one of the reasons that companies prefer their R&D close by," notes Mr Champion.

For small or medium-sized firms, the IP challenge can be particularly daunting. "Unlike their big corporate counterparts, the only tangible asset start-ups have got is their intellectual property," says Tariq Afzal, CEO at a Silicon Valley software start-up called Streamatics. "IP forms the basis for a start-up. They guard it close to their chests and there are companies which are paranoid about it. Today, the top outsourcing outlets in the world do not enjoy a good reputation in this area."

IP issues are as significant for countries seeking to entice R&D investment as they are for the multinationals themselves. For all its advantages and potential, China loses out on investment in basic and applied research because of weak protection for property rights. Aventis, for example, has an R&D alliance in China but fears over IP have prevented it from opening R&D labs there. "As soon as you put something on the market in China, it's copied," says

15. Which of the following do you consider the biggest challenges of globalised R&D? Please rate on a scale of 1-5, where 1 is not a challenge and 5 is a critical challenge.
(% respondents)

	1 Not a challenge	2	3	4	5 Critical challenge
1. Protection of intellectual property	7	9	19	27	38
2. Working across different regulatory environments	3	14	23	43	18
3. Ensuring R&D activity is not duplicated in multiple locations	9	27	28	26	9
4. Effective collaboration between international R&D teams	9	17	23	31	21
5. Managing people in diverse cultural environments	5	27	34	22	12
6. Language barriers	16	36	27	14	7
7. Network solutions to enable global exchange of R&D information	10	31	25	20	13
8. Security implications of sharing data across countries	9	29	23	26	13
9. Monitoring progress of R&D across global operations	10	21	36	22	12
10. Compressing time to commercialise innovation	3	16	30	27	24
11. Aligning global R&D activity with business strategy	5	17	25	32	20
12. Reducing costs of global R&D operations	4	23	25	29	19
13. Attracting the best R&D talent	3	19	28	31	20

Source: The Economist Intelligence Unit

Dr Douglas of Aventis. The problem is partly a matter of different cultural perceptions: "Asia historically has a much more open view of IP than the western world," says Charlie Backof, head of corporate technology planning at Motorola, a mobile technology company. Even here, however, things may be improving. "China is putting in place stronger controls for the protection of intellectual property," says Mr Connelly, although, "it is a journey and it takes time to put protections in place".

Until then, companies working in countries with weak IP protection will need to develop other strategies to safeguard valuable ideas. Work habits that prevent IP secrets from ever leaving the lab—making the need to enforce IP regulations less critical—is a solution that many companies support. "It goes back to training staff to protect the company's IP," says Mr Connelly. It can also come down to incentives and motivation: for example, staff at Motorola get promoted on their ability to generate ideas that can be patented.

Along with IP, over half of respondents in the survey also see attracting top research talent as a very important or critical challenge of globalised R&D. So what can companies do about it? One response, already discussed, has been to take R&D out to countries and locations where the right skill pools exist, as well as attracting key personnel over to HQ. Either way, companies need strategies for attracting and keeping skills that rely on more than financial incentives alone.

Researchers are happiest when they feel like an integrated part of the firm, though this can be hard to achieve in today's disparate R&D networks. "The global village doesn't work well enough only by e-mail and phone," says Mr Champion at Cambridge Consultants. "You need to have a personal bond." At the same time, scientists also like to be able to make a difference and be recognised for their contributions. Many companies organise divisions almost like start-ups, in part to give researchers some autonomy. "Give them leeway to do their work," recommends Mr Afzal, who has been conducting semiconductor research in the US for nearly 14 years. After getting his Bachelors degree in electrical engineering in Karachi, Mr Afzal went to Boston University to earn a Masters degree and was immediately hired into corporate America. Over the past dozen years, he has done research in the US at Motorola, Samsung and Toshiba. He boils a researcher's motivation to work outside his or her home market down to four things: financial rewards, professional recognition, equal opportunity and cultural diversity. Because of the cultural diversity in Silicon Valley, for example, where Mr Afzal is now CEO at a start-up called Streamatics, "I feel at home. I'm not the odd man out." One thing that turns researchers off, he adds, is red tape. "Researchers don't like bureaucracy at all."

While working abroad appeals to many, large numbers of researchers also want to stay home—and it often pays to accommodate them. When interviewing foreign researchers on US campuses, for example, "We were starting to hear 'If I had a choice, I'd prefer to go back home'," says Alan Taub, executive director of the Science Laboratories for Research and Development at General Motors. At the Bangalore lab opened by the automotive giant in September 2003, one-third of General Motors' employees have previously studied or worked in the US—but then have returned home to India.

Discipline and diversity

Aside from intellectual property and attracting the best R&D talent, the other key challenges for companies with international R&D networks are organisational. Global R&D strategies are doomed to failure unless companies can foster effective collaboration between international teams. Yet there

Ten principles for R&D success

1. Don't be fooled by the cost chimera. Overseas salaries may be dirt cheap but any bottom-line savings of globalising R&D are rarely equivalent to wage savings. Companies that globalise primarily to save money in low-cost regions may be disappointed. "The wrong decision—made because it is cheap—is going to be very expensive," warns Ms Peleg. "Salaries are sometimes lower but that is only one slice of the cost pie," adds Mr Taub.

2. Globalisation is a flammable topic—proceed with caution. Regardless of why your company decides to globalise its R&D efforts, your home market may interpret globalisation as a threat to jobs. Prepare in advance for such reactions so they don't take you by surprise. "Companies globalising R&D have to be very cognisant of the jobs issue," says Mr Andrew.

3. Start with product and process research. When globalising R&D, start with activities such as customisation, product support and manufacturing processes. "We do outsource some portions of our R&D, mostly maintenance R&D," says Mr Eaton. But core research is done at home. Adds Mr Connelly, "It's natural to start with more easily defined research areas in overseas locations."

4. Standardise before you go abroad. Clear, direct and standard R&D approaches—down to the units of measurement—can be key to R&D success, regardless of where a lab is located. At Ericsson, for example, milestones and deliverables are noted and monitored over the life of an R&D project so that researchers know how well they—and their colleagues on the other side of the globe—are progressing. "We try to have worldwide information-technology infrastructure, processes and tools," adds Charlie Backof, vice-president and director of corporate technology planning at Motorola Corporate Labs.

5. Communicate clearly on the goals, procedures and expectations. The more you globalise, the greater you'll find the challenge of staying on course. Clear communication and constant reiteration of R&D goals is critical to keep everyone on track. At STMicroelectronics, for example, where there are 16 advanced R&D centres around the world and 39 design centres: "Missions are very well defined," says Joel Monnier, corporate vice-president and director of central R&D.

6. Don't underestimate cultural differences. Researchers may share a lot of intellectual quirks but are separated by different cultural backgrounds. Companies should recognise such differences—and in many cases nurture them. "Finding the balance" between letting overseas labs be independent enough to make a difference but similar enough so that contributions will be on target is a key challenge, notes Ms Peleg.

7. Cross-pollinate to ease cultural barriers. It's easy for cultural differences to undermine R&D. To overcome those differences, it helps if researchers know and understand one another. "We have a lot of cross-breeding of ideas across design centres," says Mr Djuphammar. Such programmes not only strengthen R&D groups but also spread corporate customs and procedures to satellite labs. General Motors offers culture classes and Agilent has sent researchers from its Scottish labs to work in Beijing and vice-versa.

8. Always have a lead team. It's fine to break up development projects among teams around the world, but always have a leader who can set the goals and verify that plans are on track. At SAP, for example, the company's NetWeaver product is developed by 2,500 developers in five locations around the world—but the Palo Alto lab heads the effort. "Execution can be done in many places," says Ms Peleg, but leadership needs to come from one location.

9. Focus on the long term. In all things, keep the company's long-term future in mind. R&D labs aren't built in a day so decisions on where and how to globalise R&D will be with you for years to come. "Make sure the location has long-term importance to you," says Mr Eaton.

10. Get moving. "Some of these offshore relationships require months and years to mature," says Mr Davison. "Companies should at least be evaluating their strategy right now, even if they don't adopt immediately." In other words, there is no time to waste. Much of globalising R&D is a painstaking process that requires years of investment. "You have to recognise that it will take a while," concludes Mr Connelly.

How do you measure the success of R&D spending? Please select as many answers as apply.
(% respondents)

Source: The Economist Intelligence Unit

are many obstacles. Communications infrastructure plays a prominent role here, with 58% of companies citing the need to establish robust network solutions as an important challenge of globalised R&D. Of course, as companies share growing amounts of often sensitive information over international networks, this raises another issue: the security implications of sharing data across countries are a key concern for over two-thirds of executives in the survey.

No matter how sophisticated or secure, communications technology can only go so far in enabling the rapid interchange of ideas that leads to technological breakthroughs. Companies need to manage and motivate researchers working in many different locations and drawn from diverse cultural backgrounds—a significant challenge for 68% of companies in the survey. It helps if these teams' efforts are co-ordinated against clear (and centrally led) business goals. Aligning global R&D activity with business strategy is a top concern, but companies adopt different management strategies to achieve this. In the survey, 46% of companies co-ordinate R&D across sites globally, but 29% say R&D is separately co-ordinated for each line of business and, more surprisingly, 16% reveal that R&D is carried out in each country separately. When asked to describe how their companies ensure globalised R&D spending matches overall business strategy, one respondent answer candidly that they did so "with great difficulty".

There was little consensus on how to measure the success of R&D, though the most popular measures adopted focused on payback from research in the form of sales.

Many experts believe that addressing these issues requires an increasingly standardised, process-driven approach to R&D. Significant changes in direction or procedure may be manageable for a small firm in a single location, but can spell disaster for corporations looking to globalise R&D because, according to Mr Davison of Meta Group, "the cost is amplified with every change". While central control makes sense for setting the strategic direction for research, however, there is considerable debate as to how best to enable teams in different countries to operate within this framework. Ultimately, the litmus test of R&D effectiveness will be the productivity levels companies achieve in driving new, commercially viable innovations out of their global R&D networks.

The globalisation of R&D is therefore a major undertaking. It takes careful planning, sophisticated communications solutions, and clever ways to increase productivity without stifling innovation, for firms to be successful. For all the challenges, companies that get it right can expect substantial rewards, including lower R&D costs, improved access to the world's fastest-growing markets, and, above all, a steady stream of innovative products. "The greater the diversity of people in R&D, the more ideas you will get," says Mr Taub. Suddenly the notion of the knowledge economy, disparaged though it has been in recent years, doesn't seem so fanciful.

Appendix: survey results

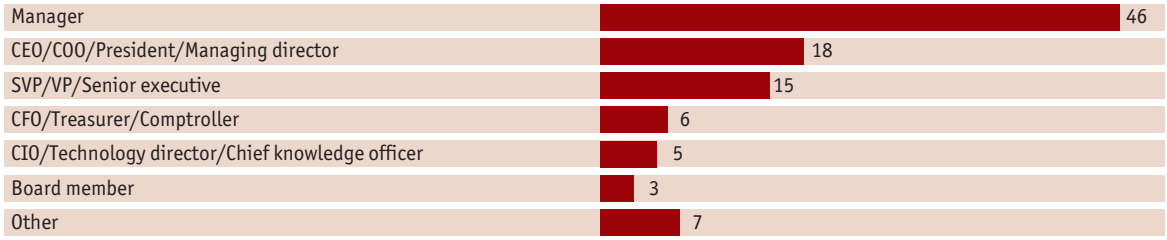
Competition for talent, new technologies and easier market access have accelerated the process of R&D globalisation, with countries such as India and China hosting significant volumes of R&D activity for multinationals. What are the drivers behind R&D globalisation, and what are the principal challenges it entails?

In July/August 2004, the Economist Intelligence Unit conducted a global online survey of 104 senior executives on the topic of the globalisation of R&D. Our sincere thanks go to everyone who took part in the survey.

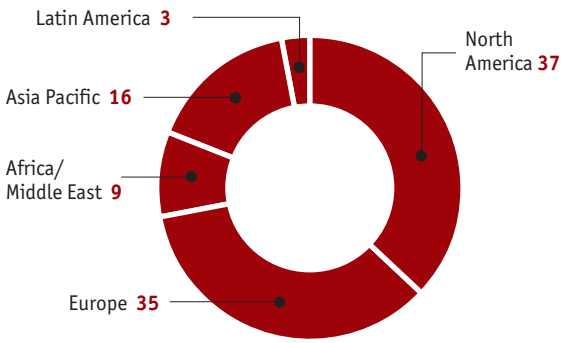
Please note that not all answers add up to 100% because of rounding or because respondents were able to provide multiple answers to one question.

Demographics

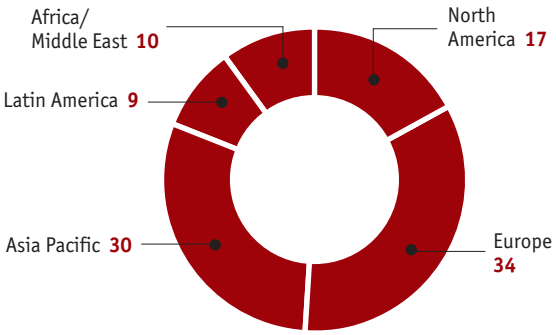
Which of the following titles best describes your job?
(% respondents)



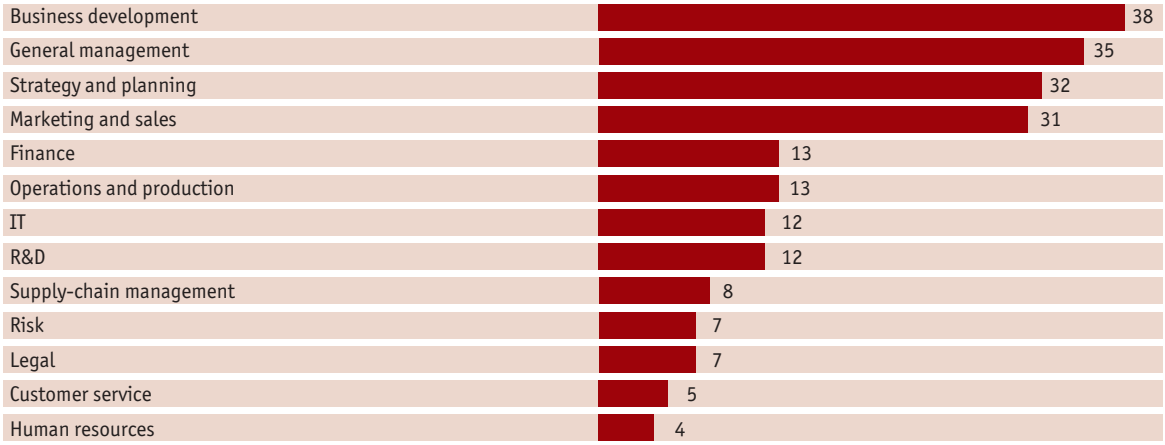
Where is your corporate headquarters?
(% respondents)



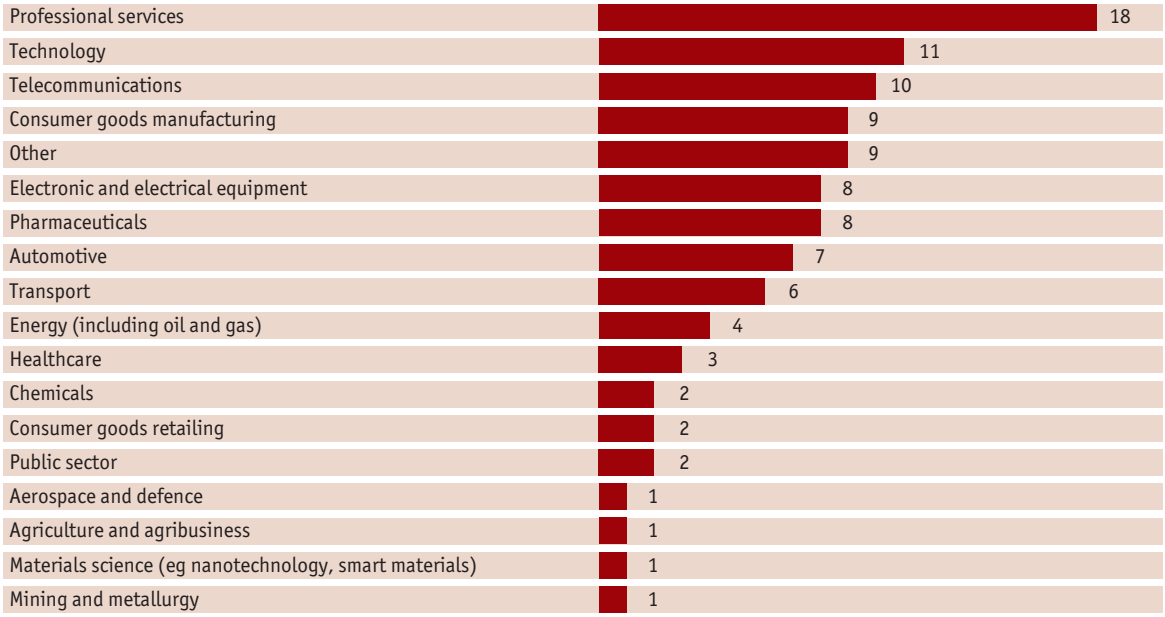
In which country are you personally located?
(% respondents)



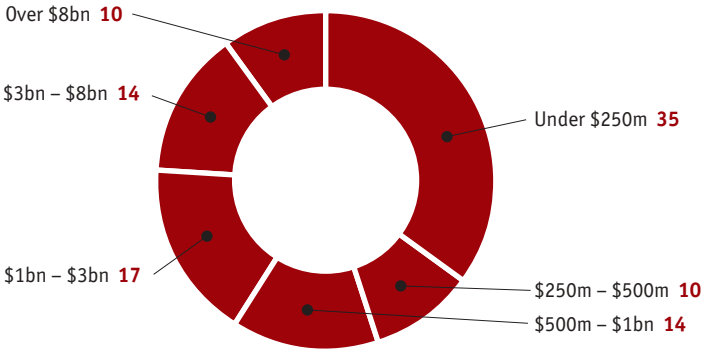
What are your main functional roles?
(% respondents)



What is your company's primary industry?
(% respondents)



What are your company's annual revenues in US dollars?
(% respondents)

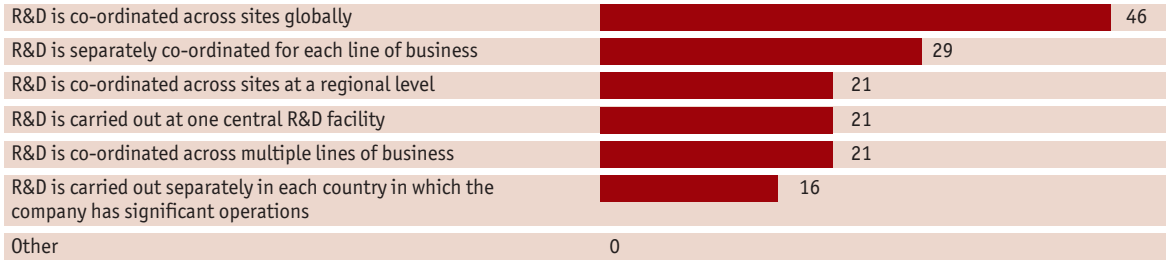


Globalisation of R&D

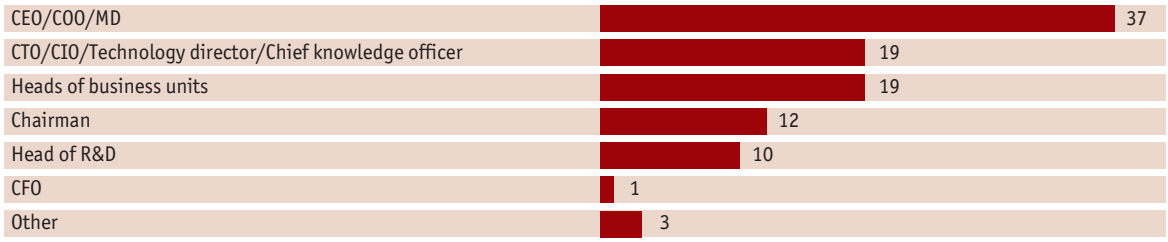
What proportion of your company's new products and services comes from the following sources?
(% respondents)

	1 0-20	2 20-40	3 40-60	4 60-80	5 80-100
1. In-house R&D	17	16	21	30	17
2. Outsourced R&D	68	20	6	2	3
3. Acquisition or licensing of existing technology	59	16	10	9	5
4. Working with partners or through joint-ventures to share R&D costs	57	27	11	3	1
5. Universities and research institutes under sponsorship arrangements	93	5	1	0	0
6. Other sources	89	7	2	2	0

How are your company's R&D operations co-ordinated? Please check all that apply
(% respondents)



Who in your company is primarily responsible for deciding where to locate R&D activity?
(% respondents)

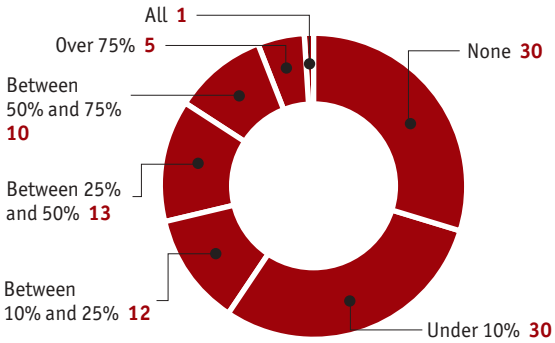


What do you believe are the main benefits of globalised R&D today? Score from 1 to 5, where 1 is unimportant and 5 is critically important.
(% respondents)

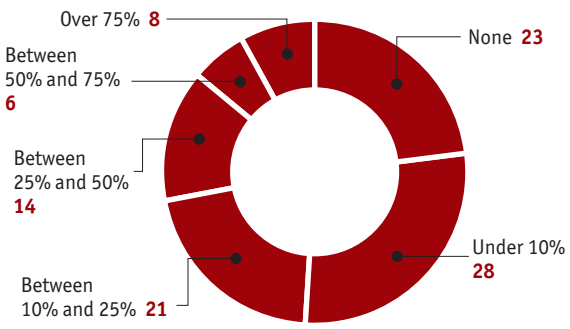
	1 Unimportant	2	3	4	5 Critically important
1. Access to 24/7 global R&D processes	23	26	18	18	14
2. Ability to exploit pools of skilled labour	3	7	21	48	22
3. Reduced R&D costs	2	17	26	32	23
4. Higher volume of innovations	3	11	38	33	16
5. Reduced time to market for innovations	3	17	25	34	21
6. Ability to tailor goods and services to particular markets	6	10	21	37	26

What percentage of sales does your company invest annually in R&D?
(% respondents)

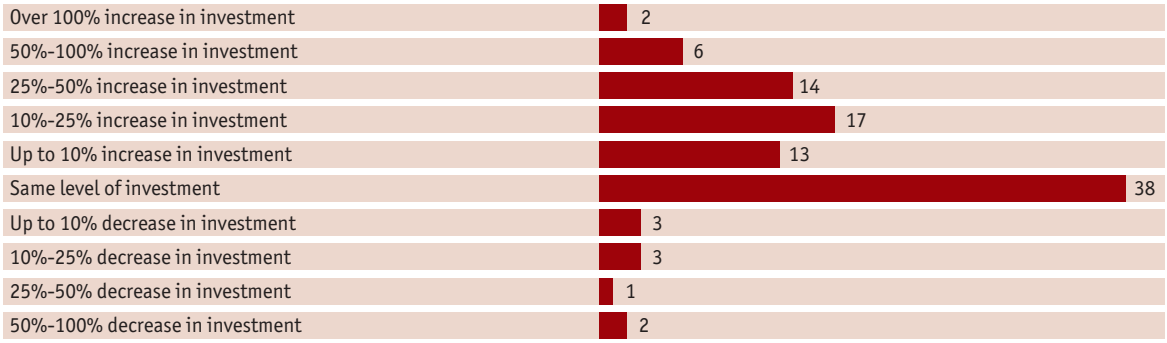
What proportion of your R&D staff are employed overseas?
(% respondents)



What proportion of your company's R&D expenditure is currently made overseas?
(% respondents)



Does your company plan to increase or decrease its overseas R&D investment over the next three years? Please select the size of the increase or decrease in investment below.
(% respondents)



Roughly what percentage of your company's overseas R&D expenditure over the past three years went to the following regions?
(% respondents)

	1 None	2 Under 10%	3 10-25%	4 25-50%	5 50-75%	6 Above 75%
1. Latin America	65	21	8	5	0	1
2. North America	38	12	13	15	10	12
3. Western Europe	22	14	24	23	9	9
4. Eastern Europe	56	22	14	4	3	3
5. Asia-Pacific	31	19	16	14	6	14

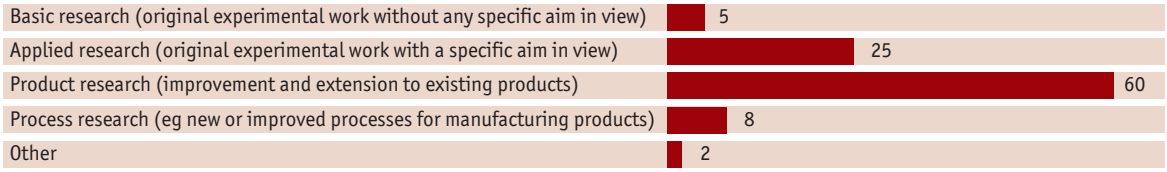
Roughly what percentage of your company's overseas R&D investment will be allocated to the following regions in the next three years?
(% respondents)

	1 None	2 Under 10%	3 10-25%	4 25-50%	5 50-75%	6 Above 75%
1. Latin America	55	28	8	7	0	1
2. North America	30	20	13	16	10	11
3. Western Europe	20	22	24	21	3	9
4. Eastern Europe	40	25	24	6	3	3
5. Asia-Pacific	21	17	17	21	7	17

In which of the following countries does your company plan to spend the most on R&D in the next three years (excluding your domestic market)? Please choose the top three countries.
(% respondents)

China	39	Israel	4	South Korea	2
United States of America	29	New Zealand	4	Switzerland	2
India	28	Norway	4	Thailand	2
United Kingdom	24	Poland	4	Turkey	2
Germany	19	Slovakia	4	Ukraine	2
Brazil	11	Finland	3	Colombia	1
Japan	10	Saudi Arabia	3	Greece	1
France	9	South Africa	3	Philippines	1
Italy	9	Sweden	3	Portugal	1
Czech Republic	8	Taiwan	3	Spain	1
Other	8	Venezuela	3	Vietnam	1
Canada	7	Argentina	2	Chile	0
Hong Kong	6	Belgium	2	Egypt	0
Russia	6	Bulgaria	2	Indonesia	0
Mexico	5	Denmark	2	Iran	0
Singapore	5	Hungary	2	Peru	0
Australia	4	Malaysia	2	Sri Lanka	0
Austria	4	Netherlands	2		
Ireland	4	Romania	2		

Which of the following areas of R&D is your company's highest priority? Please choose one answer only.
(% respondents)



In which locations are the following R&D activities primarily conducted by your company?
(% respondents)

	1 Domestic market	2 Overseas developed markets	3 Overseas developing markets	4 Mixture of locations	5 N/A
1. Basic research (experimental work without any specific aim in view)	43	6	3	14	34
2. Applied research (original work with a specific aim in view)	48	15	7	15	16
3. Product research (ie improvement and extension to existing products)	49	11	10	24	5
4. Process research (eg new or improved processes for manufacturing products)	45	15	6	12	21

Which of the following do you consider the biggest challenges of globalised R&D? Please rate on a scale of 1-5, where 1 is not a challenge and 5 is a critical challenge.

(% respondents)

	1 Not a challenge	2	3	4	5 Critical challenge
1. Protection of intellectual property	7	9	19	27	38
2. Working across different regulatory environments	3	14	23	43	18
3. Ensuring R&D activity is not duplicated in multiple locations	9	27	28	26	9
4. Effective collaboration between international R&D teams	9	17	23	31	21
5. Managing people in diverse cultural environments	5	27	34	22	12
6. Language barriers	16	36	27	14	7
7. Network solutions to enable global exchange of R&D information	10	31	25	20	13
8. Security implications of sharing data across countries	9	29	23	26	13
9. Monitoring progress of R&D across global operations	10	21	36	22	12
10. Compressing time to commercialise innovation	3	16	30	27	24
11. Aligning global R&D activity with business strategy	5	17	25	32	20
12. Reducing costs of global R&D operations	4	23	25	29	19
13. Attracting the best R&D talent	3	19	28	31	20

How important are the following aspects of a country's business environment in your company's decision to invest in R&D in that country? Please rate the following options 1-5, where 1 is unimportant and 5 is of critical importance.

(% respondents)

	1 Unimportant	2	3	4	5 Critically important
1. Size of local market	8	17	15	32	29
2. Communications infrastructure of local market	5	15	24	39	17
3. Transport infrastructure of local market	8	29	35	19	9
4. Low corporate tax burden	15	28	28	18	12
5. Low cost of capital	13	31	20	25	11
6. Quality of financing environment for early stage technology	16	29	31	18	5
7. Low costs of land	24	30	27	8	12
8. Low costs of office rental	17	28	30	13	12
9. Tax and other local or national government levies	13	23	33	18	13
10. Presence of government incentive schemes	13	20	31	23	14
11. Protection of intellectual property rights	0	8	18	35	38
12. Proximity of country to home market	17	23	28	26	7
13. Quality of education system	4	9	20	37	30

Which of the following aspects of the local R&D environment are most important in your choice of R&D destination? Please rate the following options 1-5, where 1 is unimportant and 5 is of critical importance.

(% respondents)

	1 Unimportant	2	3	4	5 Critically important
1. Size of country's existing R&D sector	7	23	32	31	7
2. Local specialised manufacturing expertise	10	15	30	34	11
3. Existence of R&D concentrations (eg industrial parks, local hubs)	9	16	29	31	14
4. Local R&D expertise in your industry	4	5	27	38	27
5. High degree of collaboration with research institutions	11	22	30	27	10
6. Availability of R&D scientists with appropriate skills	4	13	23	38	23
7. Cost of labour for R&D	3	14	26	38	20
8. Availability of local managers with expertise	1	8	20	54	17
9. Links between firms and academia	12	24	34	19	11

How do you measure the success of R&D spending? Please select as many answers as apply.

(% respondents)

How important are the following sources of information when deciding where to invest in R&D? Please rate 1-5, where 1 is unimportant and 5 is critically important.

(% respondents)

	1 Unimportant	2	3	4	5 Critically important
1. Central government	13	30	23	23	12
2. Local government	12	31	25	20	12
3. Chambers of commerce	19	25	37	18	2
4. Investment agencies	16	20	30	30	5
5. Business information providers	5	10	25	39	22

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