The capacity of firms to innovate depends on a multitude of factors, not least the efforts they make to create new products or improve production processes, the extent of skills in their workforce, their ability to learn, and the general environment within which they operate. Of all the innovation-related activities of firms – research and development (R&D), design, marketing, ‘tooling up’, acquisition of patents and licenses, hiring of skilled personnel – R&D expenditures are particularly important, and their volume and intensity help determine both gains in productivity and success in international markets.

In the OECD economies, more than half of all R&D spending is financed by industry, and two-thirds of all R&D investment is performed in the business sector. Although the services sector is responsible for an increasing share of R&D, most new technologies are developed in the relatively small number of high-technology manufacturing industries, not least computers, semiconductors, pharmaceuticals and aerospace.

Yet it is less the invention of new products and processes and their initial commercial exploitation which generate major economy-wide benefits than their timely and widespread diffusion and use. The economic performance of most manufacturing and services industries depends on putting technology to work by adopting and using ideas and products developed elsewhere. Of all sectors in the economy, it is the services sector that are the heaviest users of technology (Figure 1): services industries as diverse as social and personal services, finance and insurance, transport and communications are the main acquirers of technologically sophisticated machinery and equipment.

The rapid increase in the international transfer of technology reinforces the importance of understanding the process of technology diffusion. The share of technology obtained through imported intermediate and capital goods has increased over time in most OECD countries. In general, larger countries obtain less of their technology from abroad than smaller ones, which depend on imports for more than half – although some large countries, such as Canada and the United Kingdom, also obtain more than 50% of their acquired technology from abroad. For most countries, the United States is the main source...
of imported technology (especially for computers and aerospace); for the United States, the dynamic Asian economies and Japan are the most important (Figure 2, p. 8).

The bulk of technology acquired in OECD countries comes from the information technology (IT) ‘cluster’ of industries (computers, communication equipment and semiconductors, electrical machinery, instruments), although the materials cluster (chemicals, basic metals, rubber, plastics) is also important (Figure 3, p. 8). The role of IT has increased over time, and it is the fastest-growing cluster.

Specific types of technology tend to gravitate to specific sectors: IT to advanced manufacturing, communication services, finance, insurance and real estate; consumer-goods technology to wholesale and retail trade; materials technology to agriculture and to less advanced manufacturing; and fabrication technology (metal products, non-electrical machinery) to mining, utilities and construction.

**What Effects on Productivity?**

The development of new products and processes is crucial for improvements in productivity. But innovating firms are not the only ones to profit from successful innovations; instead, as these advances are diffused, they ultimately contribute to higher productivity, competitiveness, employment and standards of living in the economy as a whole. Diffusion shapes productivity through several channels: the purchase of technologically sophisticated machinery, equipment and components; the acquisition of licenses or patents that enable one to use ideas developed elsewhere; or the simple borrowing of ideas and expertise. But at the same time an innovating effort of one’s own is important to allow the benefits of outside technology to be enjoyed, since one of the functions of R&D is to help firms learn.

Empirical results on the importance of R&D and of technology diffusion for productivity growth in manufacturing and services during the 1970s and ’80s in ten OECD countries – the G7 group, Australia, Denmark and the Netherlands - show a contrasted picture. In manufacturing, growth in productivity can be traced mainly to the R&D expenditures made by industries themselves, in particular in the machinery sector of manufacturing. In contrast, for the services, it is technology diffusion that matters. Productivity growth in services, and in particular in the information and communications technologies (ICT) segment (comprising transport and communication services, finance, insurance, real estate and business services), benefited considerably from the purchase of technologically sophisticated intermediate and investment goods from the manufacturing sector.

Analysis of these results also confirms the importance of foreign R&D for productivity growth. Gains in the ICT segment of services can be traced to the increasing international procurement of electronic investment goods and to the world-wide process of technology diffusion. Domestic technology flows are more important for productivity growth in large countries such as Japan and the United States and, to a lesser extent, Germany. In countries such as Australia, Canada, Denmark and the Netherlands, technology obtained through imported intermediate and capital inputs is more important.

Rapid technological advance has for some time now in OECD countries co-existed with lower productivity growth, as measured from aggregate statistics. This apparent inconsistency has given rise to the so-called ‘Solow paradox’ (named after the American economist Robert Solow, who coined the phrase ‘we see computers everywhere but in the productivity statistics’). The aggregate data sit uneasily with increasing evidence from firms in a number of countries that it is the companies which develop new products and processes or which adopt efficiently new technologies developed by others that enjoy the fastest growth in productivity. Such evidence suggests that perhaps the key to the

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Technology and Industrial Performance

The OECD Observer No. 204 February/March 1997

Technology both destroys and creates jobs. But, beyond net gains or losses in employment, it is increasingly apparent that workers with different characteristics are affected differently. In most OECD countries, the employment of highly-skilled workers has increased faster than that of low-skilled workers, at an average rate of 2-3% during the 1980s (Figure 4). White-collar, high-skill occupations (officials, managers, professionals, technicians and the like) have tended to grow the fastest. In practically all countries where jobs in manufacturing declined in the 1980s, those in white-collar high-skill manufacturing increased. In the services, by contrast, the employment increase in most countries entails increases in both high- and low-skill white-collar jobs.

The decline in the wages or employment opportunities of unskilled workers as well as improvements in the pay or opportunities of skilled or ‘knowledge’ workers have been attributed largely to technical progress. An examination of the role of technology in explaining the growth of the skill-base in the G7 countries in the 1980s shows a direct relationship between ‘upskilling’ and technical change: industries which invested more in research and were more innovative tended to acquire more human capital during the period examined. This suggests that accumulation of skills and innovative effort act jointly to raise economic performance. Moreover, technology affects the accumulation of human capital either directly through R&D investment or indirectly through technology diffusion. In the high-technology sectors, which by definition have a higher intensity of R&D expenditure, direct R&D plays a major role. Human-capital formation in low-technology manufacturing sectors, by contrast, benefits considerably from imported technology.

International Competitiveness

International trade has been transformed in recent years: new patterns of specialisation, increasing intra-industry and -firm trade and complex patterns of international sourcing are all characteristic of the globalisation of industrial activities and trade. Technology is central to this process; it is both what has allowed many of these developments to take place, and it is a competitive tool in itself, since innovation and the successful adoption of technology are essential for success in international markets.

High-technology exports now constitute about 10% of OECD manufactured exports, a share that increased considerably during the 1980s, at the expense of low-technology products (Figure 5, p. 10). Individual products which made impressive gains were computers and semiconductors, telecommunication equipment, pharmaceuticals and scientific instruments; air-

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principally from favourable developments in the United States, by contrast, benefited from the petitiveness in Canada and the European economies. Export competitiveness and, to a certain extent, the larger size of the market have also made important gains in market shares since 1980.

There is little empirical evidence on how R&D and technology diffusion affect the contribution of individual industries to national shares in export markets. Empirical analysis of the impact of changes in price (such as movements in exchange or wage rates) and non-price or technology-related factors (such as R&D or technology diffusion) on the export performance of given industries indicates that an initial presence in high-growth markets is important and self-sustaining. This result draws attention to the importance of managerial decisions on the choice of geographical markets and of medium-term investments in export networks.

But the main conclusion of such an analysis is that the determinants of export performance vary substantially from one industry to another. R&D helps competitiveness in high-technology industries but also in many others. Non-technology variables (low wage-growth, say, or favourable exchange-rate movements) play an important role in industries where substitutability between products is high and/or which export low-technology products (such as textiles, metal products or non-metallic minerals). A country-by-country analysis suggests that technological factors were the driving force behind the export competitiveness of Japan and, to a certain extent, the larger European economies. Export competitiveness in Canada and the United States, by contrast, benefited principally from favourable developments in wage and exchange rates.

**What Change for Policy?**

Technology policy used to consist almost exclusively of incentives for R&D investments through subsidies and tax credits or through strong property rights and standards. This approach has slowly been complemented by a parallel concern for an economic environment conducive to the diffusion of innovation. Several countries have instituted measures aimed at encouraging firms to adopt new technologies efficiently, either by removing regulatory and other obstacles, or by using the tax system and fiscal measures to encourage investment in new machinery or in assimilation of knowledge developed elsewhere. Practically speaking, this approach implies diversity in policy measures aimed at facilitating best practices – for example, through technology-extension centres which provide advice and information to firms (and which cover services as well). It also points to an important role for government in encouraging the diffusion of new technologies in services that are publicly provided, not least education and health care.

Another policy issue concerns the importance for realizing the social returns to innovative activity of competitive pressures, both on the industries that supply new technologies and on the main users. Monopoly allows industries which develop new technologies to charge prices that enable them to capture most of the benefits of innovation; productivity gains in user industries are then lower than where supplier markets are competitive. Similarly, lack of competition and excessive regulation in service industries will blunt incentives to modernise by adopting new technologies, and will certainly not spur innovation. Further liberalisation of service industries as diverse as wholesale and retail trade, telecommunications, electricity and even some aspects of health and education will encourage product innovation and variety, as well as higher productivity, lower prices and increased demand for these services.

Policies to promote technology diffusion should be co-ordinated with those that promote the development of adequate human capital. In an environment where technology can quickly change the skills that are in demand, systems that rapidly provide adequate new skills to workers are necessary. Countries are presently in a period of experimentation and flux, testing ways to link education and learning more closely to work requirements, while they also try to provide the broader skills that will underpin continuous learning. In preparation for the closer connection between learning and work, public education is exploring work-based learning opportunities for students. Public-sector training programmes have recently come under scrutiny, and more effort is required to determine which training programmes work well, and which do not.

The predominance and increasing importance of the IT cluster for tech-

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**Figure 4**

**Employment Growth of High-skilled** and Low-skilled Workers

<table>
<thead>
<tr>
<th>Country</th>
<th>Average annual growth rates (%)</th>
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<tr>
<td>Canada 1981-91</td>
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<tr>
<td>Japan 1960-90</td>
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<td>Germany 1980-90</td>
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<td>United States 1983-93</td>
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<td>France 1982-90</td>
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<tr>
<td>Italy 1981-91</td>
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</table>

1. ‘High-skilled’ workers are defined as those in the following occupational groups: legislators, senior official and managers (ISCO-88 Group 1); professionals (ISCO-88 Group 2); technicians and associate professionals (ISCO-88 Group 3). For Germany, ISCO-88 Group 1 covers legislators and senior officials only and ISCO-88 Group 3 excludes teaching associate professionals so that high-skilled workers are underestimated.
2. All others.

Source: OECD.
nology diffusion and the growing weight of high-technology products in international trade both imply that technology policy has to pay particular attention to the network characteristics of IT and to the potential for realising economy-wide gains from its widespread application. Governments could therefore stimulate the creation of networks of firms and encourage public institutions to facilitate the generation of future IT applications, endorsing market-driven rules for standards, and liberalising product markets, in manufacturing as well as in services, so as to increase the incentives for widespread adoption and diffusion.

Rapid industrial globalisation and the widespread international sourcing of technology suggest that for most countries the option of developing an exclusively national capacity in certain technology areas does not really exist. Attempts to stimulate the development of new products or processes in domestic manufacturing industry through discriminatory trade practices will simply mean higher costs to other domestic firms that rely on access to the best available components, machinery or materials technology, whether from domestic or foreign sources. The costs of trade protection will then include, in addition to traditional welfare costs borne by consumers, those incurred by manufacturing and services producers who import technologically advanced equipment and components. An open regime for trade and investment is thus also important for productivity growth because the international spill-overs of high-technology products benefit both importing and exporting countries.