SPECIAL EDITION

Science, Technology and Industry Outlook

DRIVERS OF GROWTH: INFORMATION TECHNOLOGY, INNOVATION AND ENTREPRENEURSHIP

SCIENCE AND INNOVATION

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2001

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ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

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Pursuant to Article 1 of the Convention signed in Paris on 14th December 1960, and which came into force on 30th September 1961, the Organisation for Economic Co-operation and Development (OECD) shall promote policies designed:

- To achieve the highest sustainable economic growth and employment and a rising standard of living in Member countries, while maintaining financial stability, and thus to contribute to the development of the world economy.
- To contribute to sound economic expansion in Member as well as non-member countries in the process of economic development. And
- To contribute to the expansion of world trade on a multilateral, non-discriminatory basis in accordance with international obligations.

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Les moteurs de la croissance : technologies de l'information, innovation et entreprenariat

FOREWORD

This special edition of the *Science, Technology and Industry Outlook* has further advanced on the extensive analysis undertaken by the Committees and Working Parties of the DSTI in connection with their work over the last years on the horizontal OECD project "New Determinants of Economic Growth". It synthesises, and examines in greater depth, key findings in the areas of ICT, innovation and entrepreneurship, both as regards new analytical findings on their relationship to economic performance and on the policy implications. A major feature of the latter is the discussion on which policy messages should be taken at national level and which require international co-operation.

The effort to undertake this work was initiated by Risaburo Nezu, former Director of Science, Technology and Industry at the OECD. Thomas Andersson, Deputy Director, co-ordinated the work and served as general editor. The individual parts were developed by Graham Vickery and Sam Paltridge (ICT), Jean Guinet and Jerry Sheehan (innovation) and Frank Lee (entrepreneurship). Peter Avery, Benedicte Callan, Mario Cervantes, Alessandra Colecchia, John Dryden, Michael Freudenberg, Dominique Guellec, Vladimir Lopez, Daniel Malkin, Dirk Pilat, Candice Stevens and Andy Wyckoff also made valuable contributions to the report, and useful input was provided by many other colleagues in STI. Constructive comments which improved the document were made by the Directorate for Financial, Fiscal and Enterprise Affairs. Finally, the oustanding support, active contributions and comments made by the delegates of the STI committees, CIBE, CSTP and ICCP, and their working parties, have been invaluable to the work.

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Chapter 1

INTRODUCTION

The final decade of the last Millennium was characterised by a renewed interest in the longstanding issue of what determines economic growth, and how policy makers could, and should, aid the process in desirable directions. The interest was not least fuelled by new and partly surprising variations in growth patterns across, as well as within, countries. Also, the apparent importance of "new" factors in growth, notably new technologies and how they interact with changes in innovation, in human capital, and in industrial restructuring and organisation, triggered novel ways of thinking.

Against this background, in 1999 Ministers requested the OECD to study the causes of growth disparities and identify new factors and policies that could strengthen long-term growth performance. The interim report (OECD, 2000*a*) presented new evidence on significant changes in growth dynamics and underlying factors, not only in the United States, but also in a number of other OECD countries. Following a renewed request by Ministers, the final report, prepared for the Ministerial in May 2001, provided the overriding policy conclusions of this work (OECD, 2001*a*). Meanwhile, a parallel report on sustainable development has taken steps towards integrating the various aspects of growth within a framework that can ensure that policies and economic developments are viable for the long term, including in terms of social and environmental values (OECD, 2001*b*).

The OECD Directorate for Science, Technology and Industry (DSTI) has been intensively involved in the OECD Growth Project, in close co-operation with the Economics Department (ECO) and the Directorate for Education, Employment, Labour and Social Affairs (DEELSA). All the main DSTI committees, *i.e.* the Committee on Industry and Business Environment (formerly the Industry Committee), the Committee for Science and Technology Policy (CSTP), and the Committee for Information, Computer and Communications Policy (ICCP), as well as many of the Working Parties of these committees, have contributed actively to the project. The work of DSTI has focused on the areas of ICT, technology and related innovation issues, and entrepreneurship. This special edition of the Science, Technology and Industry Outlook brings together some of the pertinent findings, to provide an in-depth. It is more detailed in its treatment of these issues than the final report, although it remains more of a survey and synthesis than the underlying expert reports and working papers, which are referenced in the ensuing chapters.

It should be made clear that the report draws on a work agenda which stretches back several years in time, although a more consolidated effort was made in recent years in order to fully respond to the Ministerial mandates of 1999 and 2000. The area is an evolving one, in which it is more difficult to find standard solutions and provide policy conclusions "cast in stone" than is the case in some domains. This is because the factors addressed here are, like the growth process itself, genuinely dynamic in nature. The role of technology and organisational structures and changes cannot be understood in a static framework, and cannot be examined as the outcomes of more or less well-functioning markets alone: outcomes are inherently shaped by an interplay between markets and institutions, individuals and organisations, firms and governments. The set-up is becoming altogether more complex as globalisation, in the form of intensified trade, investment and technology flows, brings a host of new opportunities – but also pressures – and contributes to speeding up the processes of creation and diffusion of knowledge. At the same time, a range of regulatory as well as institutional conditions, and therefore the nature of the interactions, continue to differ widely across societies and national economies.

While globalisation makes all countries increasingly interdependent and as numerous issues simply cannot find meaningful responses on a national basis alone, it is crucial to approach these conditions with an open mind and a willingness to understand the specifics of individual countries. On the other hand, while their manifestations differ, the challenges confronted by different countries have much in common, and there is tremendous scope for mutual learning and shaping better joint solutions in these evolving areas.

Chapter 2

NEW GROWTH PATTERNS

A renewed interest

The mechanisms determining economic growth have long defied full understanding by economists and policy makers alike. Several decades ago, it was recognised that traditional investment and employment growth could explain only a minor part of the observed variation in growth performances across countries. The remaining factors were lumped together in a residual referred to as "technical progress" (Solow, 1957), viewed by many as a "black box" of undefined, exogenous forces. While some studies showed the importance of better measurement of the various inputs of growth (Jorgenson and Griliches, 1967), and other work, such as the "new growth theory" (Romer, 1990) explicitly sought to unravel endogenously determined processes, the challenge of revealing the factors that fundamentally shape the observed outcomes, and how policy makers should behave in respect to growth, has remained.

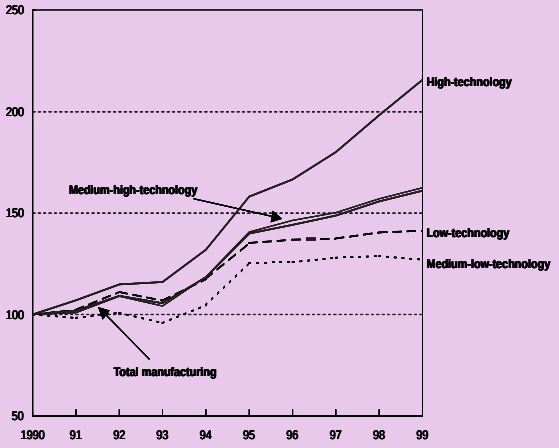
Towards the end of the last Millennium, there was an intensified interest in these issues. This was basically triggered by two broad sets of developments. One has to do with the many signs at micro and industrial level of the increasing importance of new technologies, and associated structural and organisational change. This has shown up, for instance, in a rapid advance in the share of technology- and skill-intensive activities in the economy in virtually all OECD countries (OECD, 2001*c*). A second example is the phenomenal rate of growth of high-technology products in international trade, as shown in Figure 2.1. Meanwhile, advances in ICT have made it possible to diffuse and access information at a speed and on a scale never seen before. There are rapidly evolving needs for new skills, while old ones are becoming obsolete. Science-industry linkages are vital for the dynamism of local, regional and national production structures. Many services are taking on entirely new configurations, enabling them to be stored and traded like goods. Markets are being subjected to new forms of competition; industries are restructured internationally on a new scale through various forms of globalisation, including mergers and acquisitions and strategic alliances. The organisation of enterprises and of the workplace is being revamped with the arrival of new tools and novel ways of doing things (OECD, 2000*a*; OECD, 2001*d*).

The second set of developments has to do with observed macroeconomic changes in the patterns and nature of growth among the OECD countries in the 1990s, and especially towards the end of the decade.[1] Contrary to popular belief, these changes have not amounted to any general increase in growth compared to previous decades. A comparison of trend growth rates adjusted for differences in the business cycle, shows that only three OECD countries, Australia, Ireland and the Netherlands, registered markedly stronger growth of GDP per capita over the past decade compared with the 1980s (Figure 2.2). Several other countries, including the United States, also experienced a certain improvement in the trend growth of GDP per capita in the 1990s, with a further acceleration occurring in the second half of the decade (and which occured at a very late stage of the business cycle). In contrast, many other OECD countries, including Japan and much of Western Europe, displayed slower growth, in some cases quite notably so. Consequently, for 24 OECD countries, the coefficient of variation in trend growth of GDP per capita nearly doubled between the 1980s and the 1990s (Scarpetta *et al.*, 2000).

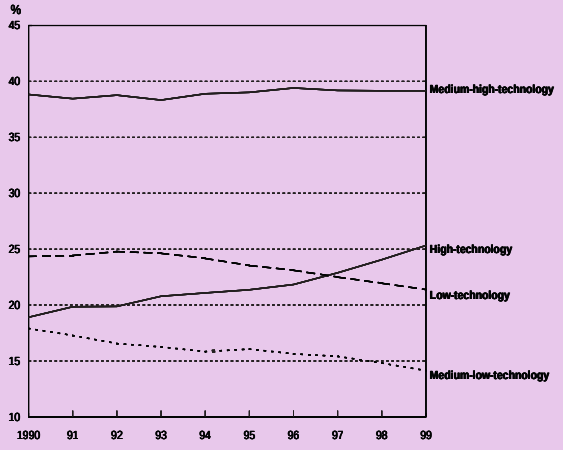
While the absolute change in trend growth per capita in the United States during the 1990s as opposed to the 1980s was small, it has attracted a great deal of attention, partly because the United States already had the world's highest level of GDP per capita in 1990. Sustaining rapid growth (the

Figure 2.1. **OECD manufacturing trade by technology intensity**

Trends in OECD manufacturing trade
by technology intensity
Indices: 1990 = 100



Structure of OECD manufacturing trade
by technology intensity
Share in total manufacturing trade



Note: OECD Members excluding the Czech Republic, Poland, Hungary and Korea.
Source: OECD (2001), *International Trade by Commodities Statistics*.

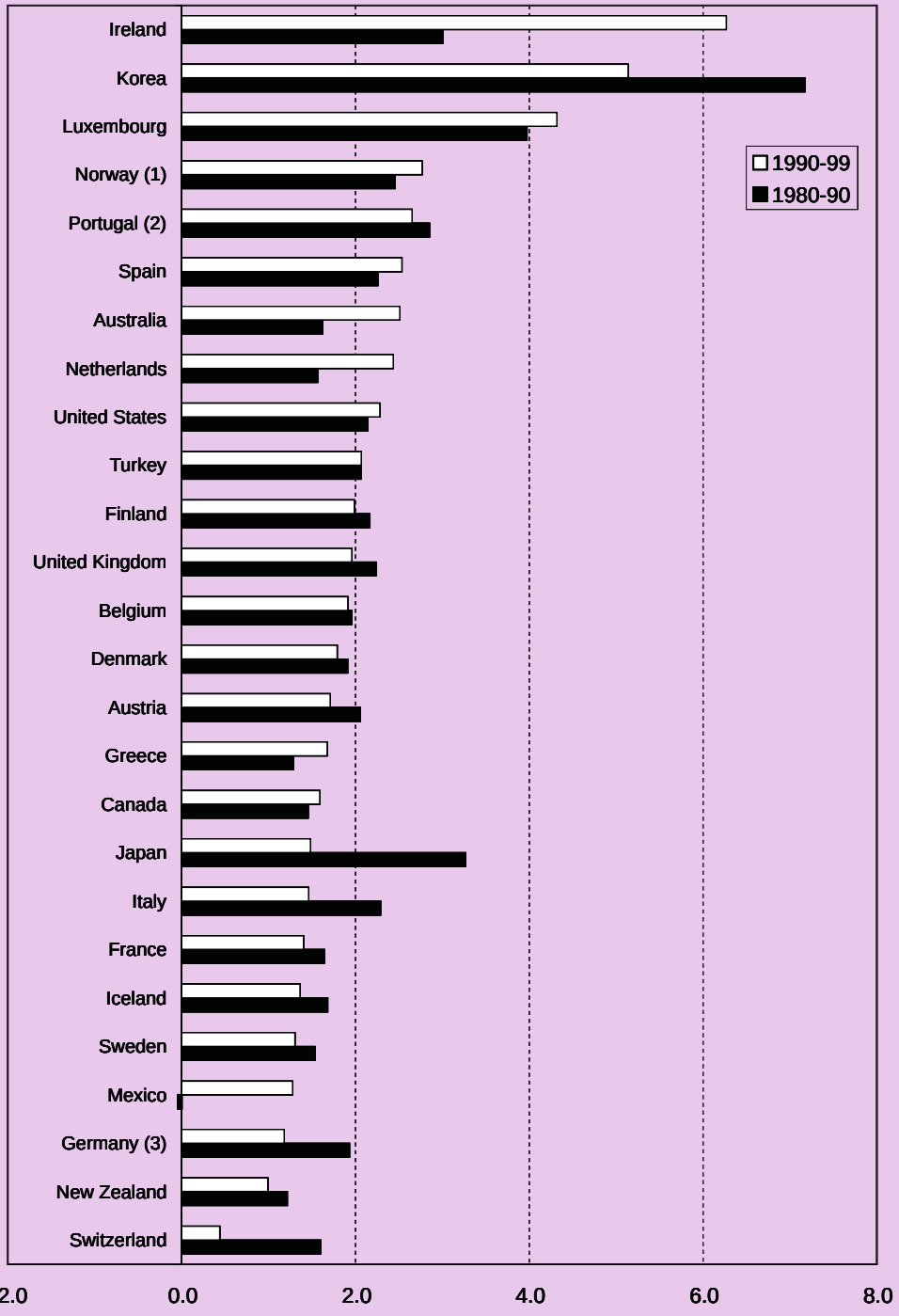
longest upswing in US modern history) entails pushing back the technological frontier in many fields; this is less difficult for countries in the catching-up phase. Second, growth in the United States has been accompanied by rapid productivity gains, low inflation and falling unemployment. While US economic growth slowed sharply in late 2000, as will be further discussed below, the country's impressive and prolonged growth record over the past decade still provides an important laboratory for understanding the determinants of growth and the policy lessons that can be drawn for other OECD countries. In some respects, there are also parallels elsewhere, such as an observed tendency towards less inflationary growth in a number of other countries.

Furthermore, looking across countries, there has been a reversal in the long-standing trend towards the international convergence of per capita income in the OECD area (Figure 2.3). This change is in contrast to the trend established after World War II whereby per capita incomes across the OECD area were predominantly converging. This convergence was evident regardless of whether it was measured in relation to the average per capita income or to that of the most advanced country, the United States. There were many contributing factors, including increased international trade, expanded foreign direct investment and the diffusion of technologies. Nevertheless, from the mid-1970s through the late 1980s, the rate of convergence slowed relative to the average, reflecting both a slowdown in trend growth throughout the OECD and uneven adjustment to the two oil shocks. Convergence picked up again in the mid-1980s, but as of the early 1990s, catch-up towards the most advanced country reversed dramatically, even as convergence towards the mean continued.

These changed patterns cannot be understood in terms of a turnaround as regards globalisation trends. As can be seen from Figure 2.4, globalisation has continued to accelerate as measured by portfolio and direct investment flows. In addition, there is ample evidence at both industry and firm level to highlight increasingly intensive restructuring of economic activities across national borders. Foreign affiliates now account for a significant share of production and research activities in most OECD economies, ranging from around 70% in Ireland and Hungary down to a few percentage points in Japan in manufacturing (Figure 2.5). It is more difficult to obtain corresponding information for services but, as can be seen from Figure 2.6, there tends to be a much higher reliance on presence abroad compared to

Figure 2.2. **Uneven trend growth in GDP per capita**

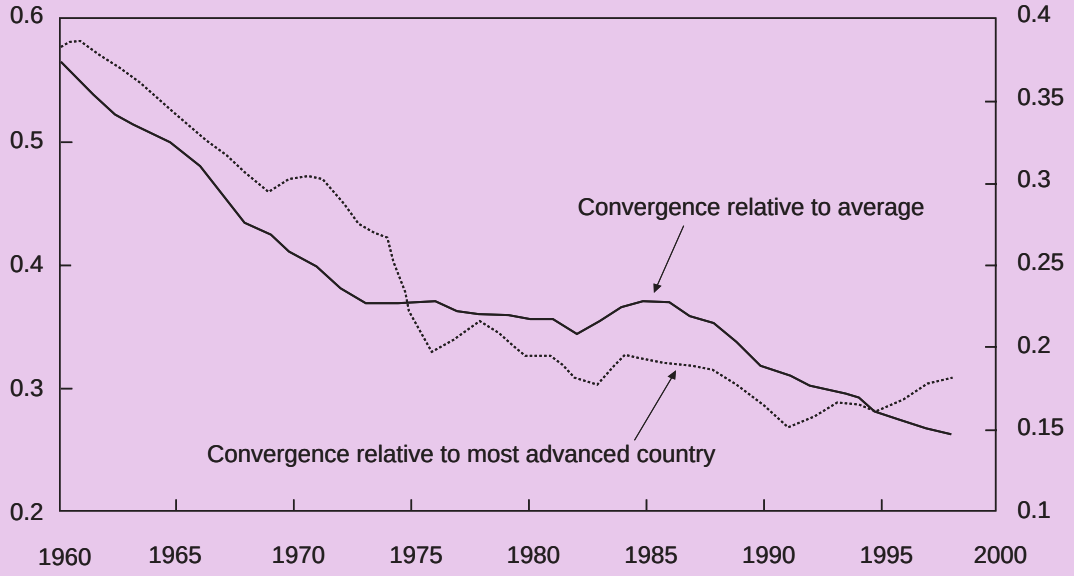
Total economy, percentage change at annual rate



1. Total Norway.
2. 1990-98.
3. West Germany for 1980-90; Germany for 1991-99.

Source: OECD, based on data for the *OECD Economic Outlook*, No. 68. See Scarpetta *et al*. (2000) for details.

Figure 2.3. **Differences in GDP per capita**



Note: *Convergence relative to average* is measured as the standard deviation of the log of GDP per capita in the sample of countries. *Convergence relative to most advanced country* is measured as the mean of the log difference of GDP per capita in a country relative to the most advanced country in the sample.
Source: Verspagen (2001).

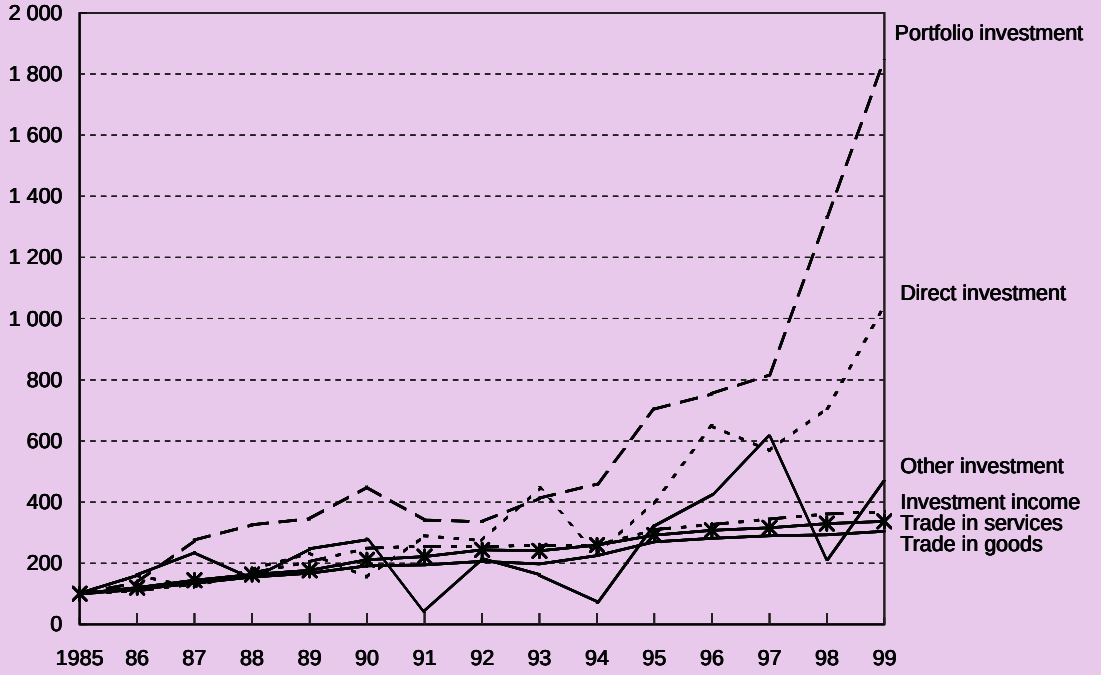
exports in services than in manufacturing. Meanwhile, the bulk of direct investment now consists of mergers and acquisitions (M&A), accompanied by a proliferation of strategic alliances. Both these forms of internationalisation are closely linked with the need to better manage rapidly evolving information, research and innovation processes (OECD, 2001*e*).

There is thus no doubt that globalisation remains a formidable force and that economies are becoming increasingly interdependent. Yet there are signs of growing income differences, not only due to greater divergence in growth rates between countries, but also among social groups within countries, raising concerns about long-term social stability. Although globalisation has the potential to bring tremendous benefits, there is a fear that many countries and groups of citizens would not only lag behind, but would essentially be left out of any such benefits. While globalisation over the years has been primarily associated with convergence and catching-up, it is now being blamed as the culprit behind growing disparities. In this situation, it is becoming imperative to grasp not only the potential for higher growth, but also for the widespread benefits from this process, and how they can best be gained.

There are other reasons for this renewed interest in growth. With the arrival of new technologies, rapid quality changes and an increasingly service-oriented economy, productivity growth is becoming more difficult to measure. These difficulties are amplified by a lack of comparable measurement methodologies in different countries. Recent revisions of productivity growth in selected services in the United States, for instance, indicate that official figures fail to capture some of the upturn in growth, meaning that the performance of the 1990s, and especially the latter part of the decade, was most likely even more impressive than that recorded so far (Fixler and Zieschang, 1999). Furthermore, the OECD countries are confronted with major economic and social transformations associated with the rapid ageing of their populations. In addition, there are concerns over environmental degradation, and a demand for economic growth that is sustainable in the long term from both a social and an environmental perspective.

Figure 2.4. **Trends in international transactions,[1] by component**

OECD,[2] index: 1985 = 100



1. Average imports plus exports or average assets plus liabilities.
2. OECD excludes Luxembourg, Czech Republic, Hungary, Poland and Slovak Republic for 1985-92; Greece for 1998-99.

Source: OECD (2001*c*), based on ADB database, May 2001, and IMF, Balance of Payments Statistics.

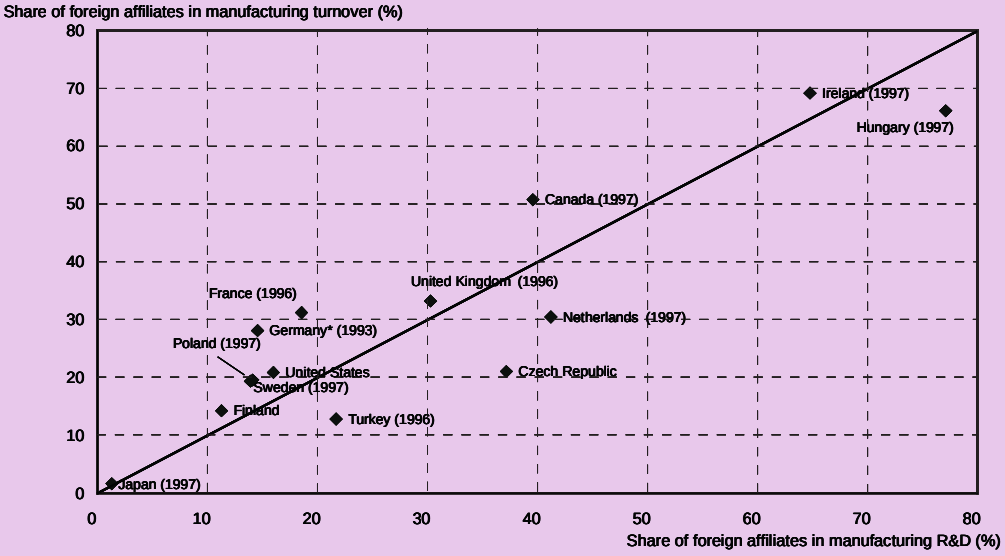
Decomposing the differences in growth

Before examining specific aspects of growth performance across countries, it is essential to decompose the nature of the observed differences. In a growth-accounting framework, economic growth depends on a number of factors, namely increased use and/or improved quality (skills) of labour, more and/or better capital in the production process, and greater overall efficiency in the combination of these factors of production, *i.e.* multifactor productivity (MFP).[2] MFP reflects many types of efficiency improvements, such as better managerial practices, organisational changes and, more generally, innovative ways of producing goods and services. Empirical analysis shows that these factors go some way to explaining cross-country differences in growth performance. Those countries that registered an increase in GDP per capita in the 1990s have generally drawn more people into employment, accumulated more capital equipment (particularly in information and communication technologies – ICT), improved the average quality of their workforce, and, in many cases, improved MFP (OECD, 2000*b*).

The quantity and quality of labour. In general, the quality of labour, as measured by the educational attainment of workers, has risen steadily, albeit slowly, across the OECD by between half a year and a whole year each decade since 1970. Regression estimates suggest that the long-run effect of each additional year of education could raise per capita incomes on average between 4% to 7% (OECD, 2000*c*). While many European countries have displayed quality improvements, these have generally been accompanied by sluggish employment growth. In 1999, the unemployment rate for the European Union was more than double that of the United States. France, Italy, Belgium and the Netherlands have high labour productivity, but their lower employment rates and shorter working hours nevertheless account for an income gap with the United States (OECD, 2000*b*; 2000*c*). Put another way, US workers are

Figure 2.5. **Share of foreign affiliates in manufacturing R&D and turnover**

1998 or latest available year



Source: OECD, AFA database.

less productive than workers in some countries but this may be because a greater portion of the population works, especially the young and low-skilled who tend to be less productive. The end result is more income on average for the population as a whole.

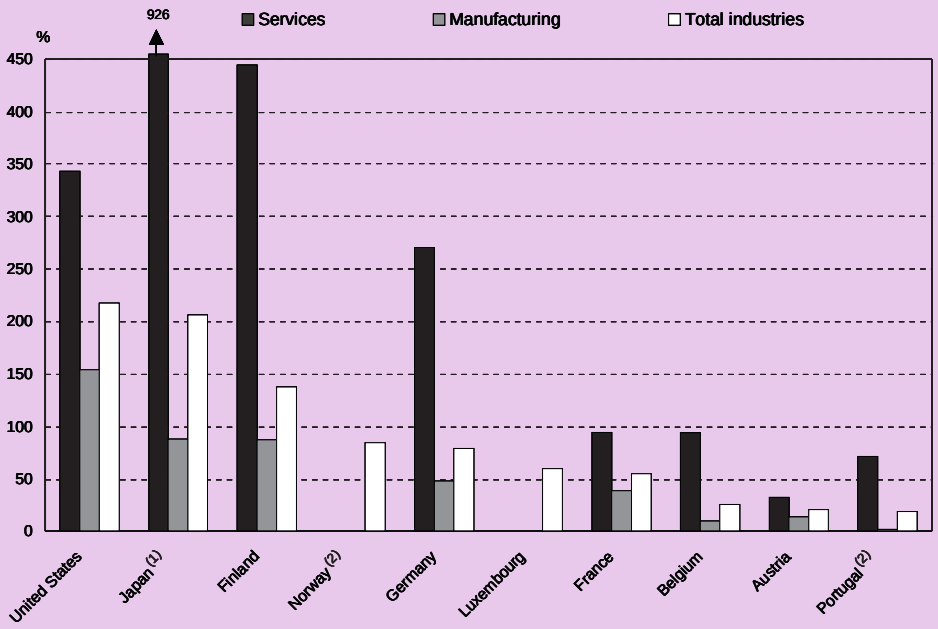
The productivity of labour. Whether or not countries grow rapidly, a large part of growth in per capita income is due to changes in labour productivity (Figure 2.4). Some of these gains may fit the "catch-up" hypothesis which postulates that countries with initially low-income levels should grow faster because they are able to catch up through transfers of technology and know-how. This hypothesis seems to hold true for Ireland, Korea, Portugal and Turkey (Scarpetta *et al.*, 2000). Along the same lines, Switzerland's slow output growth per capita would be predicted by its above-average initial income levels. However, this is not universally a factor for explaining growth. Most prominently, the US expansion accelerated over an extended period, despite the United States being the country with the highest income per capita and one of the highest levels of output per hour worked. Similarly, for Denmark, Finland, Norway and Sweden, the catch-up hypothesis provides few insights – the drivers of strong growth have to be sought elsewhere. Moreover, some countries, such as Mexico, had comparatively low per capita income and labour productivity, but did not catch up.

The role of physical capital. To a large degree, improving labour productivity depends on the rate of capital deepening, *i.e.* the services provided by capital equipment to each worker, and on multifactor productivity. The faster the capital deepening, the more rapid the growth of labour productivity, *i.e.* output per worker. The rate of capital investment tends to vary over time and across countries, with long-run averages of business sector investment accounting for between 10% and 20% of GDP. Since 1991, the United States has been the only major OECD economy to increase its rate of business investment every year. While the US take-off occurred from a relatively low level, the rate of increase has been exceptional, as shown in Figure 2.5, with double-digit increases recorded from 1995 to 1999. A 1% increase in business investment boosts annual growth rates by as much as 0.2% to 0.3%, generating a long-term increase in income per capita of about 1.3% to 1.5% (OECD, 2000*c*).

As in the case of labour, what matters is not only the quantity of physical capital, but also the quality. Technological improvements are important for raising the quality of business investment. In contrast to

Figure 2.6. **Outward investment**

Turnover of affiliates of national firms located abroad compared with national exports, 1998



1. 1994.
2. 1997.

Source: OECD, FATS database, January 2001.

the 1980s, investment in ICT during the 1990s has been the most dynamic component of business investment, representing up to half of all new investment in some countries. The sharp fall in ICT prices has encouraged investment, and investors have substituted ICT for investment in other assets. Chapter 3 analyses in greater detail the impact of ICT on the quality of investment and on output growth.

Multifactor productivity. The final factor that accounts for changes in GDP growth is accelerating MFP growth. MFP rose considerably in several OECD countries over the 1990s, notably in Australia, Canada, Finland, Ireland and Sweden, but also in Norway, the United States and New Zealand (Figure 2.6). In the second half of the 1990s, trend MFP improved further in several countries, including Canada, Finland and the United States. MFP growth is measured as a residual factor, after the contributions of increased labour and capital have been accounted for, which makes it difficult to examine all of the factors that influence it. Nevertheless, this report takes an in-depth look at several areas that are widely thought to have influenced MFP during the last decade. The technologies that many suspect may have spill-over effects that boost MFP are information and communication technologies, which are the focus of Chapter 3. The development and diffusion of knowledge such as that emanating from R&D, and the use of new technology which generates benefits that exceed the cost of purchasing the equipment (so-called technology "spillovers"), are addressed in Chapter 4. Finally, conditions for organisational change, one aspect of which is entrepreneurship, addressed in Chapter 5, is an important enabling factor.

Addressing the new factors in growth

It is against this background that Ministers requested the OECD to study the causes of growth disparities, and identify new factors and policies which could strengthen long-term growth performance.

Since then, in late 2000 and early 2001, there has been a dramatic reversal of fortunes. US GDP growth has slowed, and highly valued US equity prices have declined steeply, especially in the technology sector. This has been accompanied by plunging equity prices worldwide, and less sanguine growth prospects in other countries as well. Although the duration and severity of this downturn, and possible recession, remains uncertain at present, this cyclical swing does not diminish the importance of understanding the nature and sources of the evolving growth dynamics observed in the 1990s. In fact, there is likely to be a certain relationship in that the swiftness of the recent decline may have been influenced by over-investment or exuberance in financial markets during the heyday of the technology boom of the late 1990s. This might be considered as a "negative pay-back" from, or darker side of, the growth record studied in the ensuing chapters of this report. On the other hand, it is very difficult to say whether or to what extent there would be a "bubble" at any given point in time, and it is just as likely that future opportunities are being underestimated during the present gloom as that they were overestimated during the earlier euphoria. At any rate, the present report is not about the upturns and the downturns of the cycle. It aims to examine and unravel the extent to which significant, long-term change is altering the fundamental underpinnings of growth. Indeed, it appears clear that technological and organisational processes are under way, the limits and ultimate consequences of which are unlikely to be reached for some time to come. These basic results remain unaffected by the present downturn.

It should be emphasised that we are only able to judge the impacts of technologies such as ICT and, even more so, biotechnology, over a very short period. Nevertheless, it is important to strive to improve our understanding of the possible fundamental changes they bring, and the associated policy implications, at this early stage, so that we do not unduly diminish or distort their future potential. This special edition of the Science, Technology and Industry Outlook complements other work undertaken in the OECD Growth Project and related activities by providing an integrated, in-depth review of the role of ICT, technology and entrepreneurship in growth, how developments in these areas have contributed to shaping recent changes and disparities between countries in growth, and the associated implications for policy in different countries.

NOTES

1. These developments were explored in detail in the first year of the Growth Project, as reported in the interim report (OECD, 2000*a*). The underlying work was undertaken in close co-operation with the OECD Economics Department, and supporting tables and further detail can be found elsewhere (Scarpetta *et al.*, 2000). In what follows, growth is measured as GDP and as GDP per capita, the most widely accepted indicators. It is clear that these measures are not synonymous with welfare and are not suited to catching all the dimensions of economic growth, such as environmental or social concerns. However, consumption possibilities are an important aspect of welfare, and income growth usually raises sensitivity to environmental and social issues and the means allocated to deal with them.
2. Multifactor productivity is also referred to as total factor productivity. Reflecting the overall efficiency with which labour and capital are used, MFP is affected by a host of factors, including innovation, technological change and its diffusion, managerial practices, organisational change and, more generally, improved ways of producing goods and services.

Chapter 3

ICT AND GROWTH

Introduction

ICT is the latest example of a major technology that is transforming activity across the whole economy, just as the steam engine, railways and electricity did in the past. ICT has already had important economic impacts. It has contributed significantly to aggregate growth in several OECD countries in the past few years. More importantly, it has brought new competition and has been the catalyst of change in business, partly responsible for a major restructuring of firms, a change in work organisation, and enabling firms to reorganise transactions, reduce routine transaction costs and rationalise and restructure supply chains. Manufacturing has become more efficient, inventories and overheads have been reduced as co-ordination costs along supply chains have dropped, design and production have become integrated, and ICT applications have been part of innovation in services. Moreover, ICT has spawned value-generating networks between producers and consumers. On the other hand, there are also transition costs and losers. Capturing the benefits cannot be treated as a given but will depend on complementary investments and actions by private and public actors.

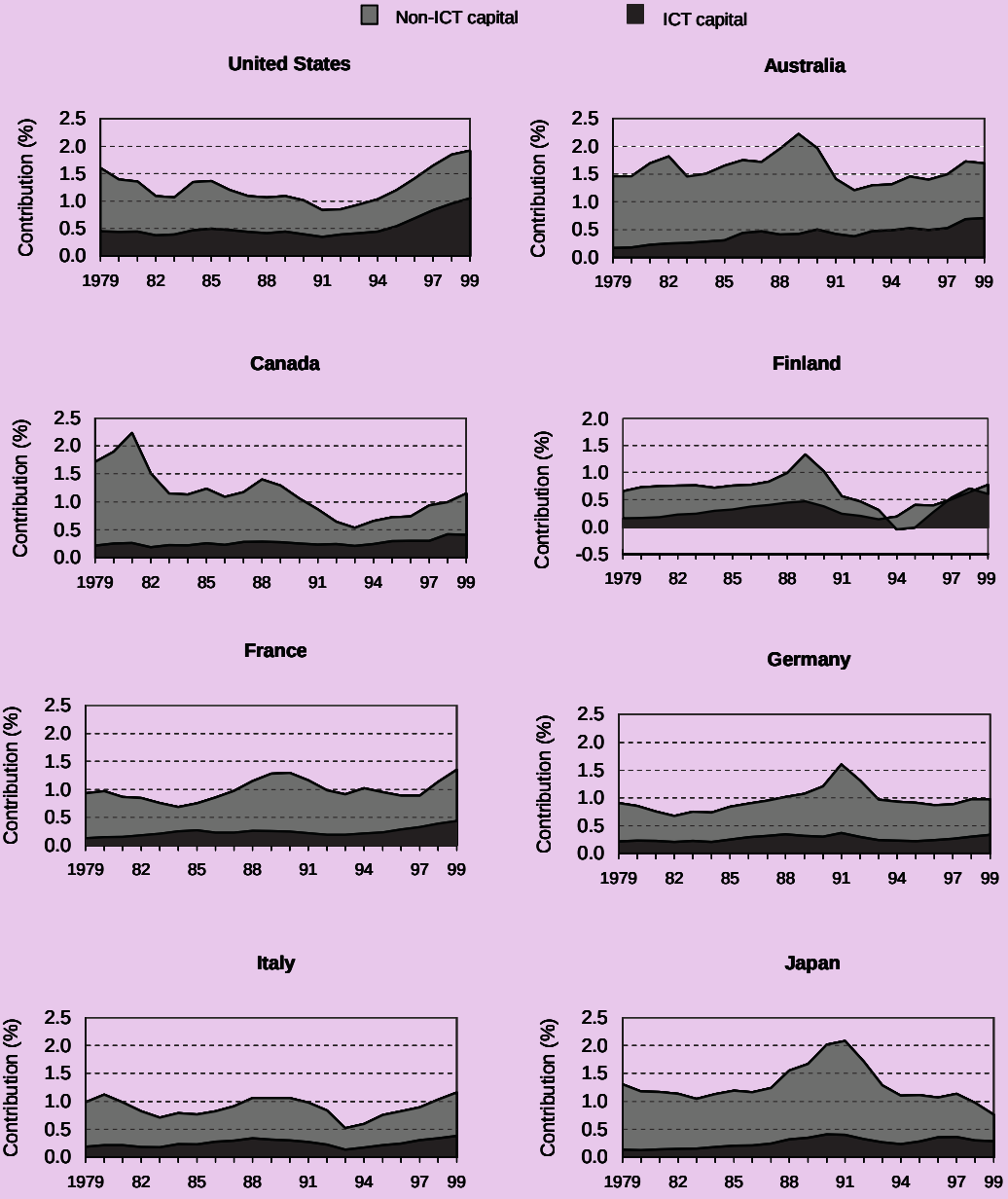
It is too early to say how important ICT will prove to be compared with previous new technologies. The benefits are often long-term, and will continue to develop, even if investment in ICT currently tapers off with the economic downturn. What is important is that ICT appears to be a major transformational technology, and governments have to ensure that appropriate policies are in place to seize the benefits of ICT, as well as limit any negative effects. Technologies based on networks such as telecommunications and the Internet, bring the benefits of networked economies – the more people that use them, the greater the benefits they generate for all users. The development of ICT partly resulted from policy efforts in some OECD countries to create a more innovative economy. Governments should build an environment that is conducive to innovation, removes barriers to diffusion and is adaptable to future technological breakthroughs; such policies are discussed more generally later in this report.

Contribution of ICT investment to growth

Investment in physical capital plays an important role in growth. It expands and renews the existing capital stock and enables new technologies to enter the production process. While some countries have experienced an overall increase in the contribution of capital to growth over the past decade, ICT has typically been the most dynamic area of investment. This section focuses on this component, with its potentially very large implications for growth, rather than on non-ICT investment. The dynamism of ICT investment reflects rapid technological progress and strong competitive pressure in the production of ICT goods and services leading to steep declines in prices. The US (hedonic) producer price index for computers, for instance, fell by over 14% annually between December 1990 and December 2000 (United States Bureau of Labor Statistics, 2001). This decline, together with the growing applications of ICT, has encouraged investment in ICT away from other assets (Figure 3.1). The available data for OECD countries show that ICT investment rose from less than 15% of total non-residential investment in the business sector in the early 1980s, to between 15% and 35% in 1999. Investment in hardware has typically increased at the most rapid rate, while software investment has also experienced fast growth, although from a small base (Colecchia, 2001).

Figure 3.1. **The United States is not alone in experiencing the growth effects of ICT**

Contribution of ICT capital to output growth (%)



Source: Preliminary version of Colecchia (2001).

While ICT investment accelerated in most OECD countries, the pace and its impact on growth differed widely. ICT investment accounted for between 0.2 and 0.5 percentage points of growth in GDP per capita over the 1980-95 period. Over the 1995-99 period, this contribution increased to between 0.3 and 0.9 percentage points a year, with the United States, Australia and Finland receiving the largest boost (Table 3.1). The contribution of ICT investment to GDP per capita in Japan, Germany, France and Italy has increased only marginally, and accounted for a mere 0.3 percentage points of total growth in the 1995-99 period.

Table 3.1. **ICT capital has boosted GDP growth**

Percentage points contribution to annual average GDP growth, business sector

		United States	Japan	Germany	France	Italy	Canada	Australia	Finland
IT and communications equipment	1990-95	0.3	0.2	0.2	0.2	0.2	0.3	0.3	0.2
	1995-99	0.6	0.3	0.2	0.2	0.2	0.4	0.4	0.4
Software	1990-95	0.1	0.1	0.1	0.0	0.0	n.a.	0.1	0.1
	1995-99	0.3	0.0	0.1	0.1	0.1	n.a.	0.2	0.2
Total ICT	1990-95	0.4	0.3	0.3	0.2	0.2	n.a.	0.5	0.2
	1995-99	0.9	0.3	0.3	0.4	0.3	n.a.	0.6	0.6

Note: The table compares the contribution of ICT capital to GDP growth for eight countries, differentiating between the role of ICT hardware and software. It shows that ICT contributed 0.9 percentage points to US GDP growth, three times more than in Japan, Germany and Italy. Australia and Finland also received large contributions of ICT investment in GDP growth. The estimates are based on a harmonised deflator for ICT investment, adjusting for cross-country differences in methods. The estimates are not adjusted for the business cycle.

Source: Preliminary results, Colecchia (2001).

In the 1995-99 period, software capital accumulation accounted for a third of the overall contribution of ICT capital to output growth (Box 3.1). This holds across all OECD countries for which software data are available, with the exception of Japan.[1] The United States provides the most striking example since the average percentage contribution of software in 1995-99 is up by a factor of four from its 1980-85 value. Nevertheless, these observations demonstrate that the United States is not alone in experiencing the "growth" effects of ICT.

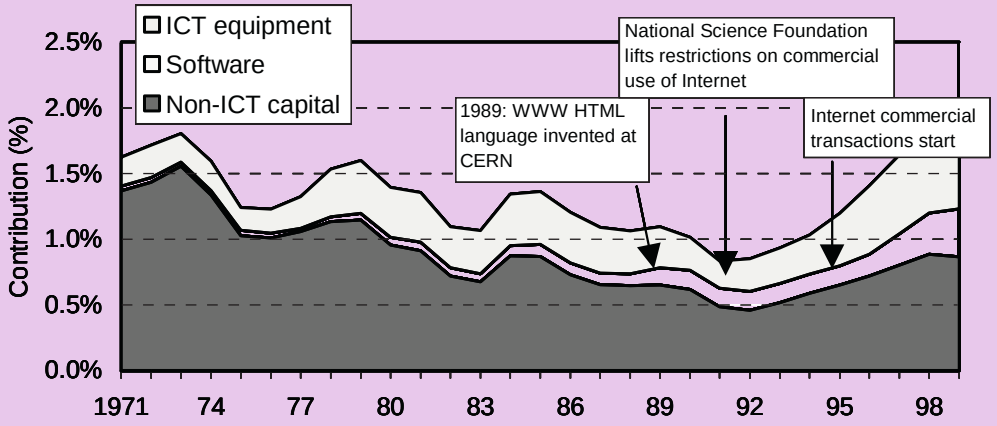
Box 3.1. **Software capital accumulation and the Internet**

One explanation for the surge in the contribution of software investment is the emergence and rapid diffusion of new general-purpose technologies such as the Internet. What is new compared to other technologies is that the Internet provides an infrastructure for new forms of electronic business. The development of the Internet hence entails various waves of complementary and self-reinforcing investment. Following the first wave of investing in communication infrastructure, there is a second wave in investment in applications (software) and then a third wave characterised by the development of on-line activities. In turn, the growth of online activities generates demand for new technology infrastructure and applications. For instance, new multimedia applications require continuous improvements in circuit technology and innovative software, enabling the use of video, speech, animation and music. Figure 3.2 shows the contribution of software capital to output growth in the United States and the timing of major Internet developments.

The shift in investment towards ICT has also led to a change in the composition of the capital stock in OECD countries towards assets with higher "marginal" productivity, *i.e.* an improvement in the overall quality of the capital stock (Schreyer, 2000*a*). The improvement in quality implies that investment in ICT has had larger effects on GDP growth than would have been achieved by similar levels of investment in other assets. In the United States, over the 1995-99 period, increased quality is estimated to account for over 0.5 percentage points of the total contribution of capital to GDP growth (1.7 percentage points). In Australia, about one-quarter of the 1.6 percentage point contribution of capital to GDP growth over 1990-99 is estimated to be due to improved quality.

Despite the emerging benefits of ICT, some OECD countries have seen only a slow increase in its use. Barriers to competition may be an important factor. Globalisation is an important component of this process since it opens new avenues for market entry and knowledge transfers and forces firms to look more and more to innovation and technology to help them restructure and thrive (see Chapter 2).

Figure 3.2. **The rising contribution of software to the US economy**

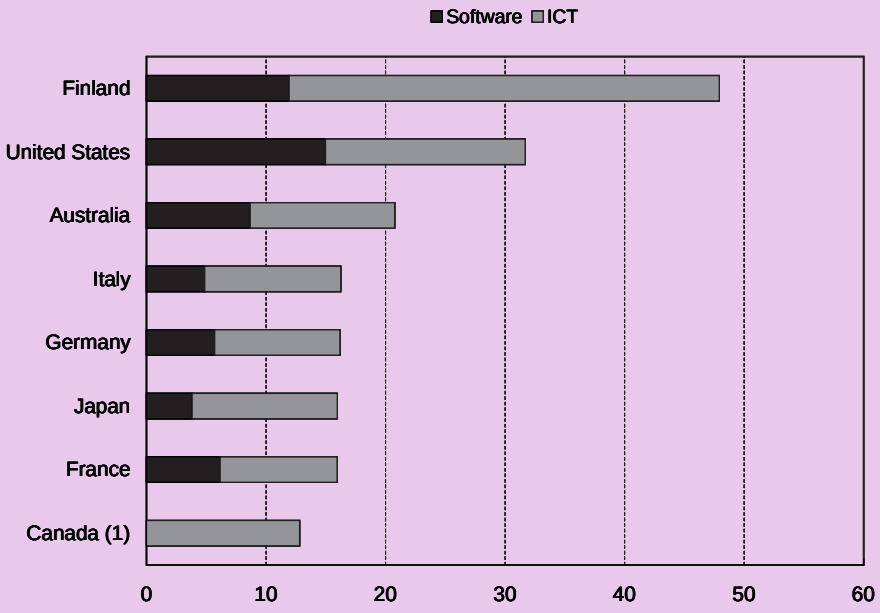


Source: Colecchia (2001).

Firms in the United States and Canada have enjoyed considerably lower costs of ICT investment goods in the 1990s than firms in most European countries and Japan (Figure 3.4). Low costs have undoubtedly helped to stimulate investment. Barriers to trade, in particular non-tariff barriers related

Figure 3.3. **ICT accounts for a large share of all investment**

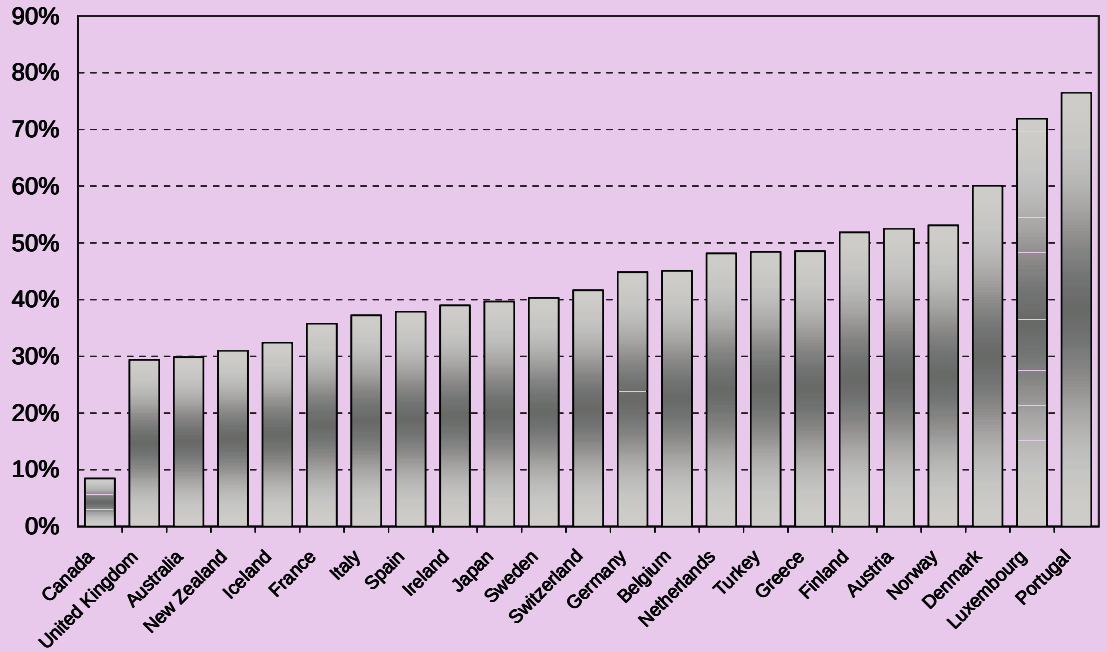
ICT as a % of non-residential GFCF, 1999



Note: ICT equipment is defined here as computer and office equipment and communications equipment; software includes both purchased and own account software.
1. Estimates for Canada exclude software.
Source: Colecchia (2001).

Figure 3.4. **The price of ICT investment**

Price differentials with the United States, average of estimates for 1993 and 1996



Note: Relative price differences in office and data processing machinery (here, on the basis of detailed purchasing power parities for 1993 and 1996) in the mid-1990s may help explain some of the discrepancy in ICT diffusion between OECD countries. US prices were the lowest by far, while prices in Japan and Germany were some 40% higher than in the United States. However, prices were higher still in Finland, which is nonetheless often considered a "new economy" country. Differences in value-added taxation play some role, but other factors, such as competition, also come into play.

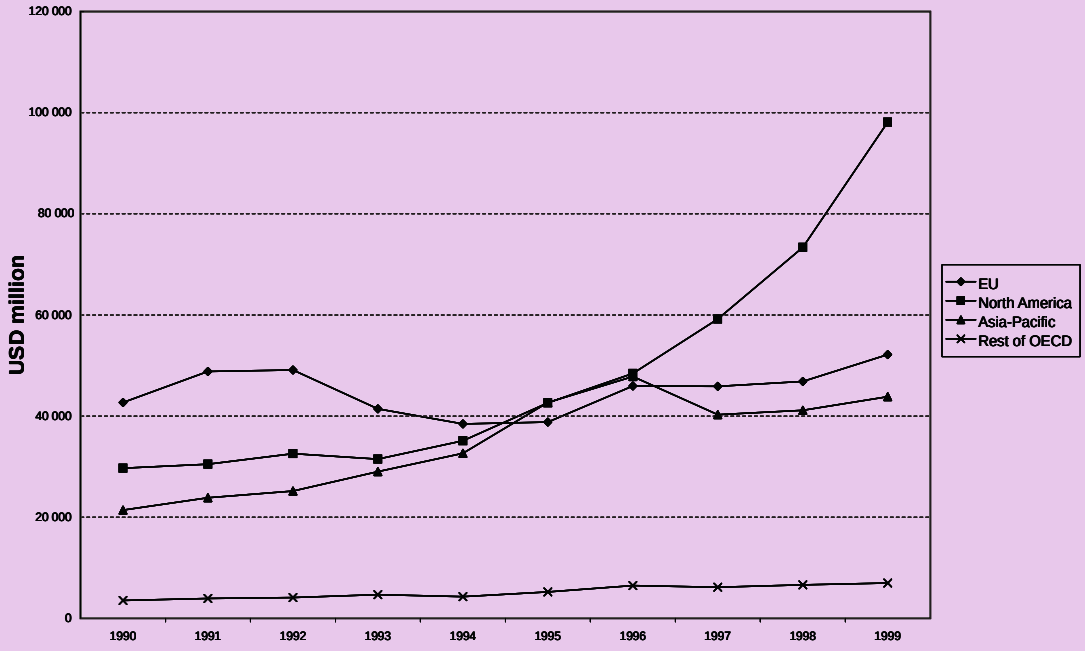
Source: OECD (1995; 2000*d*).

to standards, import licensing and government procurement, as well as the level of competition within countries,[2] explain an important part of the cost differentials. Over time, however, international trade and competition erodes cross-country price differences. The evidence suggests that in 1996 the prices of ICT investment goods in other countries were already much closer to those in the United States than they were in 1993; since then they have come down further across the OECD. Policies play an important role in influencing the process, both domestically and internationally, through measures such as the WTO Information Technology Agreement and liberalisation of trade in IT-related services.

The investment and diffusion of ICT depends not just on the cost of the investment goods themselves, but also on the associated costs of communication and use once the hardware is linked to a network. Regulatory reform of the telecommunications industry has been of particular importance in driving down these costs. It has led to more entrants, greater technology diffusion, improved quality and a higher rate of innovation. This has benefited the industry, as well as the economy as a whole. Countries that moved early to liberalise their telecommunications industry now have much lower communications costs and, consequently, a wider usage and diffusion of ICT technologies than those that followed later.

Investment in communication networks increased considerably during the second half of the 1990s (Figure 3.5). In 1999, telecommunication carriers had capital expenditures of USD 200 billion. The major contributing factors were new market entry, rising levels of investment in Internet backbones, expansion and digitalisation of wireless networks and large increases in investment in local access infrastructures. The United States was responsible for much of the increase in communication investment during this

Figure 3.5. **Telecommunications investment by region, 1990-99**



Source: OECD (2001*c*).

period, partly as a result of the 1996 Telecommunications Act which opened local markets to competition. European investment started to increase towards the end of the decade, partly as a result of the 1998 opening of European Union markets to competition. By way of contrast, after a sharp increase in investment during the middle of the decade, this figure has since declined in Japan.

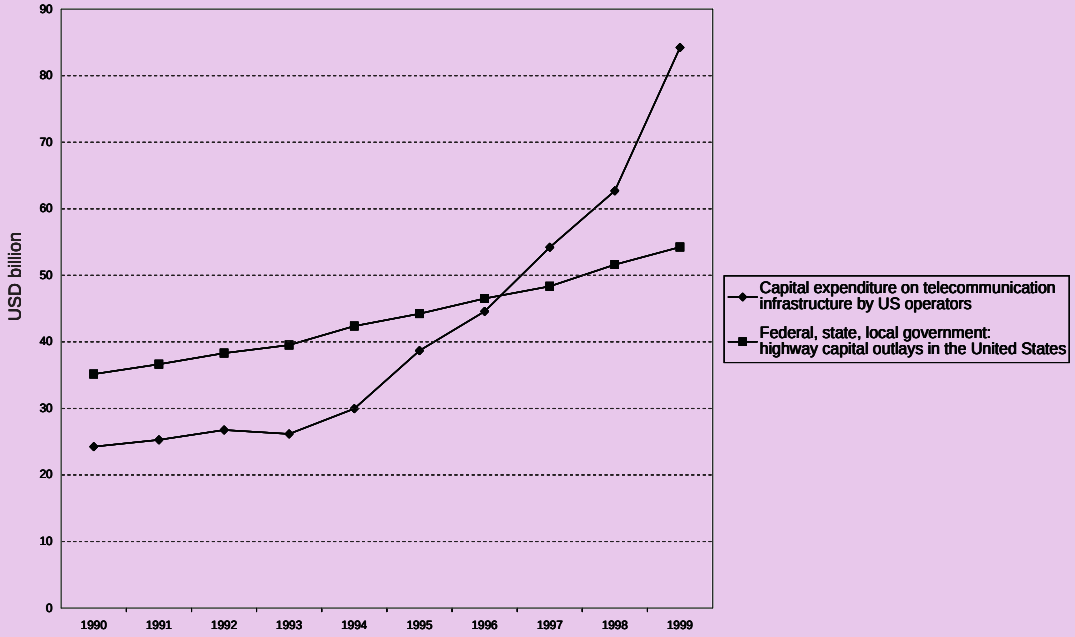
Investment and use of ICT is likely to be greatly encouraged by the growth in the market for mobile communications. That growth is based on competition and its impact on commercial and technological innovation in areas ranging from pre-paid cards to lightweight terminals. Some of the first data services are also emerging, including content provision, but at relatively low access speeds. In Japan, NTT Docomo's "I-Mode" service is a prominent example of pioneering first steps in wireless Internet access. In March 2001, two years after its launch, the service had over 35 million subscribers. A wide range of services provided by numerous enterprises are emerging and this is helping to create a market for mobile electronic commerce.

Just as the Minitel pioneered electronic commerce over fixed networks in France, new platforms continue to emerge. In the case of mobile communications, the next generation of wireless services will deliver levels of performance more in line with current access using a PC and a fixed network connection. Fixed communication networks will, of course, continue to evolve, and will provide much higher access speeds than are commonly used today. Although expenditure on communication networks may currently have steadied, telecommunication carriers have announced major new investment in access networks using optical fibre, "fixed wireless" and DSL (Digital Subscriber Line) technologies.

ICT industries

There has been continuing debate regarding the relative importance of the supply of ICTs *vs.* their use in contributing to growth. Effective diffusion and use of technology is a key factor in broad-based growth, particularly when combined with organisational change and effective human resource strategies involving education and training. Substantial evidence exists at firm level to show that ICTs can have

Box 3.2. **Investment in highway infrastructure and telecommunications infrastructure**



In the United States, since 1997, investment in information infrastructure has surpassed that in highways. While caution is needed in interpretation of this indicator, it is suggestive of the arrival of an information society based on an extensive information infrastructure, applications and use.

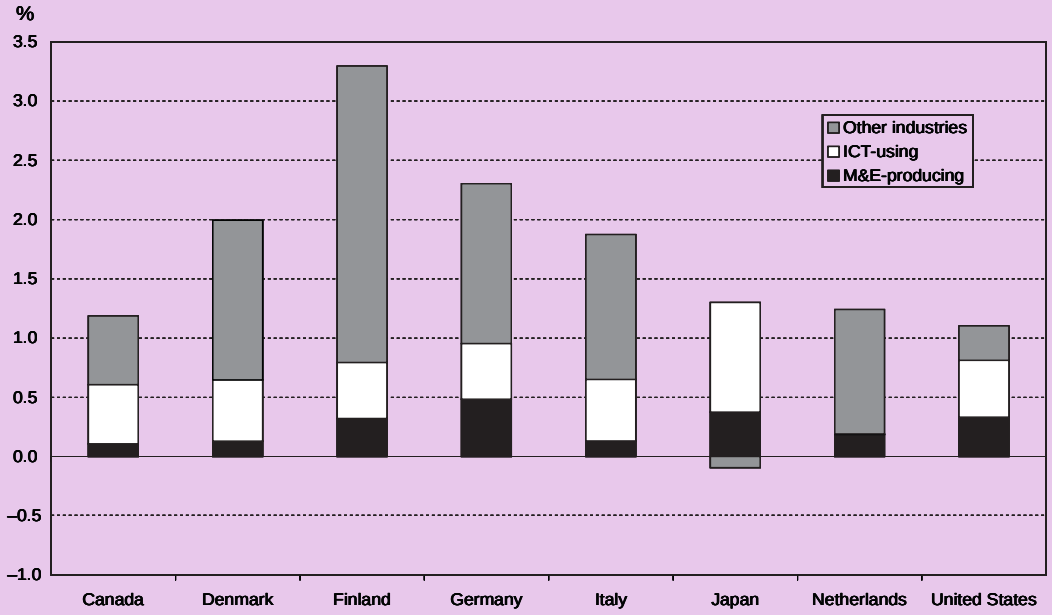
positive effects on firm performance, productivity, competitiveness, employment, etc. (see, for example, Gera *et al.*, 1999).[3] There is also increasing evidence that the effective use of ICT facilitates growth at sector level. For some countries (notably Finland and the United States), the role of ICT-using industries in labour productivity growth increased in the second half of the 1990s (Figure 3.6).

Meanwhile, ICT industries themselves contribute an important share of business sector value added and business sector employment. Their shares in value added and employment vary considerably across countries, but their relatively high growth rates in most countries have contributed positively to aggregate growth performance (Figure 3.7). Being able to trigger or respond to high growth in demand for their goods and services outputs, they have made important contributions to overall economic growth in those countries where they are significant.

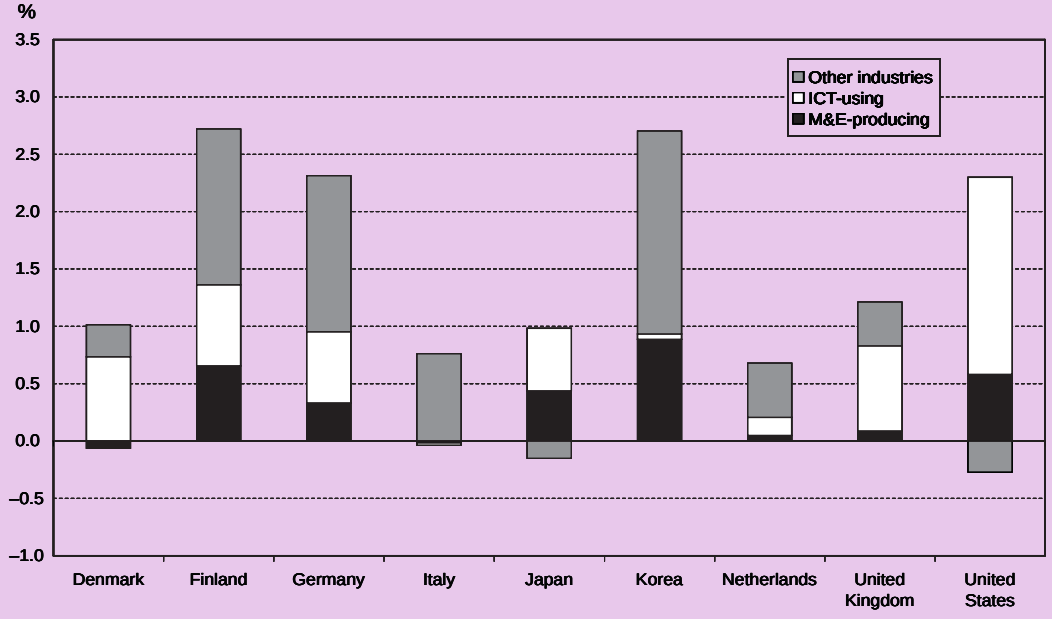
In terms of the broader growth picture across the whole economy, few OECD economies – the United States, Canada, Australia, Ireland and Norway – have increased trend growth both in GDP per capita in the 1990s compared with the 1980s, and in adjusted multifactor productivity. Four of these countries have a relatively large share of ICT (manufacturing and services) in value added and employment; only Australia does not have a large ICT sector. In countries that have seen a slowdown in trend GDP and a deceleration in adjusted MFP growth, the picture is more mixed, with some countries having large ICT sectors, others not. For those countries that have both data sets, MFP growth in the most recent period (1995-99) is positively and weakly correlated with the share of the ICT sector in business value added, but the correlation is not significant. Similar patterns apply for ICT manufacturing, where Australia and Norway (and Denmark) have relatively small ICT sectors and relatively good adjusted MFP growth; the correlation is again positive but not significant (see Figure 3.8).[4]

Figure 3.6. **Breakdown of labour productivity growth, 1989-95 and 1995-99**

A. 1989-95



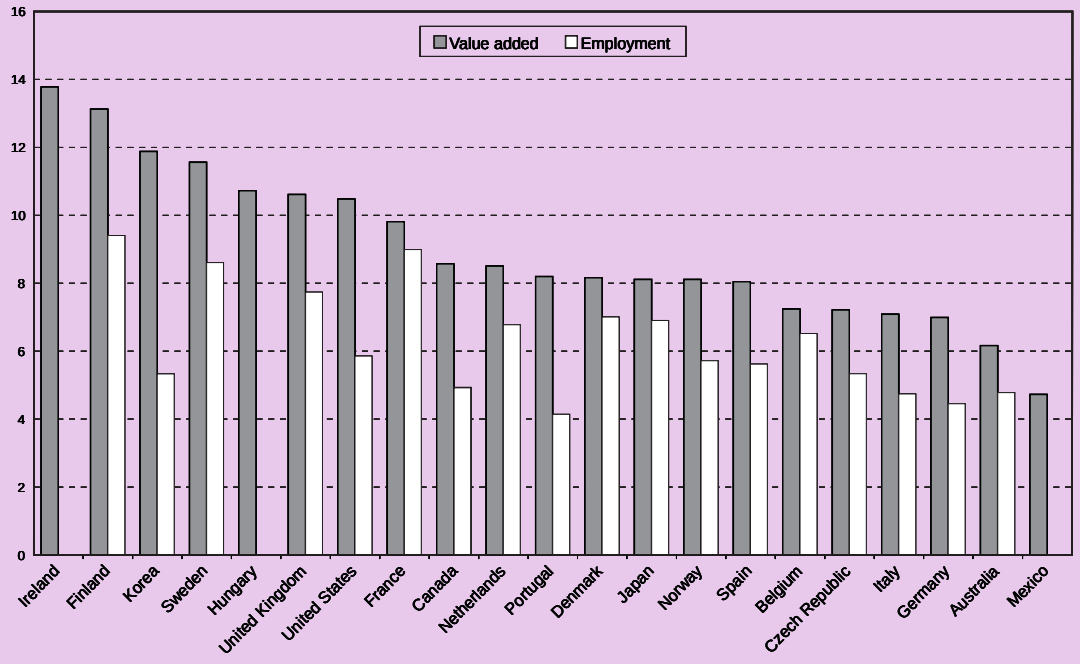
B. 1995-99



Note: 1991-95 and 1995-97 for Germany; 1989-95 and 1995-98 for Japan; M&E: Machinery and equipment.
Source: Pilat and Lee (2001).

Figure 3.7. **ICT industries account for a significant share of economic activity**

Percentage of business sector, 1998 or latest available year



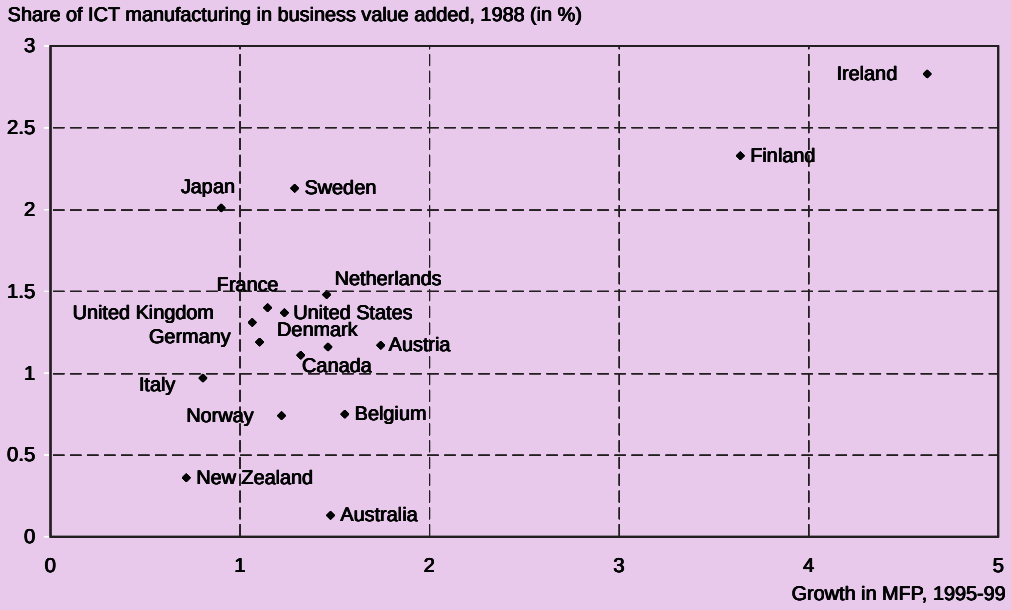
Source: OECD (2000*e*).

Having an ICT hardware sector is thus not a prerequisite for growth based on new technology. Geographical proximity to hardware producers may not be as important for ICT users as proximity to other specialised ICT sector services such as software and IT service providers, which are necessary when firms need local skills and advice to implement ICT-related changes which have large potential to raise MFP growth. Overall, the presence of a strong ICT sector is likely to help improve the ICT skill base and enhance diffusion through user-producer interactions. On the other hand, much of the production of ICT hardware is highly concentrated, because of its large economies of scale and high entry costs: establishing a new semiconductor plant cost some USD 100 million in the early 1980s, but as much as USD 1.2 billion in 1999 (United States Council of Economic Advisors, 2001), suggesting that for reasons of global efficiency such plants will be concentrated in a few countries.[5] All countries cannot compete in large-scale semiconductor production, even if they can all participate in specialised niche products. In fact, by removing trade barriers and by giving up ineffective hardware production, some countries, notably in the Nordic region, obtained an edge in software as hardware prices came down quickly because of relatively inexpensive imports compared with the costs of domestic hardware production.

Software industry

Because the ICT sector is a somewhat heterogeneous collection of hardware manufacturing, telecommunications services and software and IT services, it is useful to explore some of the components that make up the sector (OECD, 2001*f*). Software has been seen as one of the more dynamic parts of the ICT sector, and as a strong contributor to growth performance (Figure 3.9). Nevertheless as for the ICT sector as a whole, there is no simple relation between the relative size of the software sector, and improvements in adjusted MFP growth between the 1980s and the 1990s. Of countries with a relatively large software industry in business sector GDP or employment, only four out of seven had above the median adjusted MFP growth in the 1995-99 period (Sweden, Netherlands,

Figure 3.8. **The ICT hardware sector and MFP growth**



Note: MFP growth has been adjusted for hours worked. ICT manufacturing was almost 3% of business sector value added in Ireland and over 2% in Finland, both countries where MFP grew rapidly in the second half of the 1990s. However, Australia, Canada and Denmark experienced strong MFP growth, while having only a small ICT manufacturing sector. Japan, on the other hand, has a large ICT manufacturing sector, but had lower MFP growth over the 1995-99 period.
Source: MFP from OECD; OECD (2000*e*).

Denmark and Finland). Three had adjusted MFP growth increasing in the 1990s over the 1980s (United States, Sweden and Finland). Clearly, the software sector is associated with good overall performance in some countries, but this is not universally applicable.

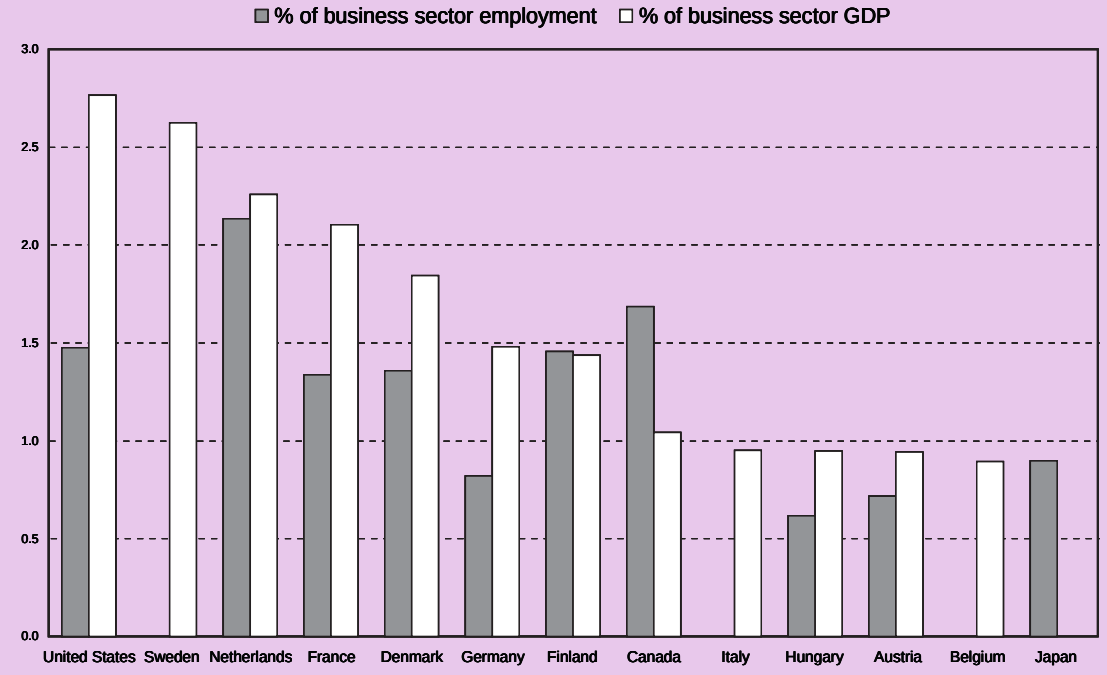
An important contribution to growth from the software sector comes via inputs from highly skilled workers and the use of their software products and services to improve efficiencies throughout the economy, for example through Internet and e-commerce applications (Box 3.3). The software sector is uniformly high skill across all countries for which data are available, and the sector employs a significantly greater share of highly educated workers compared with the share of tertiary educated employed across the whole economy (Figure 3.10).

Furthermore, software and related skills are not confined to the software or ICT sectors. They are spread widely across the whole economy, ensuring that ICT applications are developed and operate effectively, and make up a significant and growing share of total employment outside the ICT sectors (Figure 3.11). Data for the United States and France show that there are considerably more software and computer specialists working outside the "software sector" than within it. These employees are part of the wider phenomenon of the widespread diffusion and use and ubiquity of ICT throughout the economy.

Telecommunication networks

Access to telecommunication networks increased enormously during the second half of the 1990s. The total number of fixed network access channels and cellular mobile subscribers increased from 563 million in 1995 to more than 1 billion in 2000. Over the same period the number of Internet hosts grew

Figure 3.9. **The software sector is small but growing rapidly**



Source: OECD (2000e).

from 5 million at the beginning of 1995 to more than 110 million by February 2001. Nevertheless growth rates differ considerably among countries.

By the beginning of 2001, only four OECD countries (Turkey, Hungary, Poland and the Slovak Republic) still had monopolies in the provision of all or some fixed network services. In the wireless sector, the last monopoly was eliminated in 1998 (Figure 3.13). This does not imply that effective competition will immediately take hold. The ability of telecommunication operators to compete in long-distance markets has been more successful than in the local loop market. There are a number of reasons for this, including that it requires relatively less investment, often deals with customers who tend to be more price sensitive, and that the technology is available to allow customers to change service providers rapidly with little cost and even on a call-by-call basis. It is important for regulators, including competition authorities, to monitor the performance of markets and the development of competition by examining market shares, pricing and other competitive practices. Some regulators do not undertake this and, in a number of cases, regulators are unable to obtain the data necessary for evaluating how competition is developing.

In some countries, such as Finland, Germany, Japan the United Kingdom and the United States, new entrants had already taken more than 30% of the long-distance market in 1999. In other countries, like Australia, Italy, Korea and Spain, the incumbent firm still held on to more than 80% of the market in 1999, which could point to a lack of effective competition or more recent liberalisation. There is more to be done before competition in telecommunication markets takes hold in many OECD countries, although recent market-opening measures are increasing competition.

An example concerns the costs of leased lines. These lines are used to transport large volumes of information between firms and provide the building blocks for B2B electronic commerce. Liberalisation has significantly lowered the prices of leased lines in recent years, particularly following major communications reforms in Europe since 1998. For example, the price of a 2 Mbit/s line between London

Box 3.3. **The development of e-commerce**

While electronic commerce has grown rapidly in recent years, it still represents a relatively small value compared to total business activities. It is too small to explain improvements in aggregate productivity growth, *e.g.* in the United States. In the United States, for example, business-to-business commerce (B2B) accounted for around USD 600 billion in 1999, more than 90% of total e-commerce. Manufacturing led, with 1999 e-commerce shipments (value of goods and services sold on line over open networks such as the Internet and over proprietary networks running systems such as Electronic Data Interchange) accounting for 12.0% (USD 485 billion) of the total value of manufacturing shipments. Merchant wholesalers were second, with e-commerce sales representing 5.3% (USD 134 billion) of total sales. Selected service industries e-commerce revenues accounted for 0.6% (USD 25 billion) of revenues for these industries. Retail trade, the focus of much e-commerce attention, had e-commerce sales in 1999 of 0.5% (USD 15 billion) of total retail sales. Retail e-commerce sales in the United States in 2000 (data from a different survey) accounted for about USD 25.8 billion, or about 0.8% of total retail sales. In Denmark, electronic commerce accounted for about 1% of business sales in 2000 with the major part (87%) being business to business. It appears smaller in other OECD countries for which data are becoming available. In Australia, around 0.4% of all orders were received *via* the Internet in 1999/2000. In Canada, around 0.4% of all customer orders were received over the Internet in 2000.

E-commerce has major potential to modify business strategies and structures in the longer term, particularly in B2B. Preliminary results are available from the OECD electronic commerce business impacts project (EBIP) which uses a common analytical framework and methodology to undertake firm-level case studies in different sectors in ten countries. This work shows that the Internet (*www* and e-mail) is used very extensively with customers for advertising and information services and with suppliers for information services. However, core business transactions in ordering, billing, payment and delivery with customers and suppliers are still more frequently carried out over secure proprietary electronic data interchange (EDI) systems. Ordering, billing and payment are migrating from EDI systems towards the *www*, and also towards closed systems such as EDI over the Internet and extranets. Firms expected and experienced impacts of e-commerce largely in business functions such as catalogues, ordering and information capture. Innovation impacts were in enhanced product diversification, in process co-ordination and logistics and increased inter-organisational trust. Overall the study suggests that e-commerce strategies enable firms to present a broader range of products, reduce costs of production and distribution of goods and services, manage their supply chains more effectively, and improve communications and relations with customers and suppliers. But little quantitative information on impacts is yet available (OECD, 2001*g*).

E-commerce may provide considerable market advantages to those firms and networks of firms which successfully adopt new organisational methods. An example is the optical networking industry in Canada, where inventories declined from 30-40 days a few years ago to 9-12 days today. In "old economy" areas, e-commerce and related ICT applications have improved product development, procurement and supply. Car producers are able to reduce some of the costs of intermediation, reorganising production and the interface with customers and improving the through flow of production and customer information. The savings could be substantial in many areas. Korean car producers expect that the cost of procurement of maintenance, repair and operating supplies will decrease by 20% following the adoption of e-commerce.

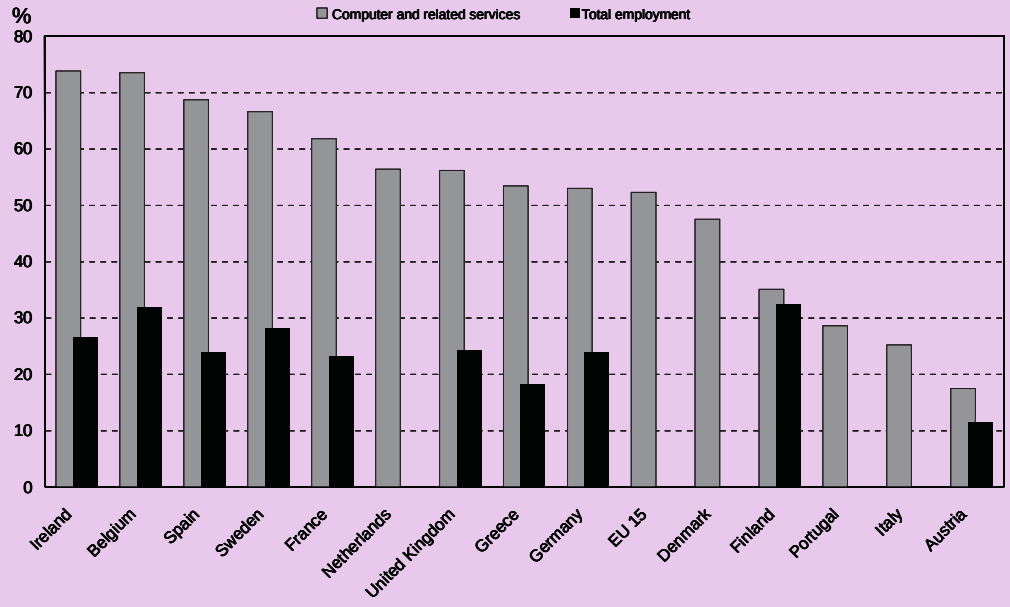
Barriers to further use of e-commerce were perceived to be related to lack of staff training and skills as well as regulatory factors (transaction security, legal structures, authentication mechanisms, and intellectual property protection). Government policies generally were not seen as a major barrier to adoption, but were sometimes seen as not sufficiently facilitating e-commerce, particularly in education and training, but also in other areas (OECD, 2001*g*).

and Paris was reduced by 92.4% between 1998 and 2000 (Figure 3.14). Over the same time, a 2 Mbit/s line between New York and Frankfurt had fallen by 83.3%. Nevertheless, prices continue to differ substantially between OECD countries on routes where there is less competition and for local connections. The prices for leased lines in many countries, such as the economies in transition, are considerably higher than in the Nordic region (Figure 3.15).

The price of leased lines, along with factors such as quality and availability, is among the key factors influencing the rate of Internet development for users. In the absence of competitive alternatives, experience has shown that telecommunication carriers with significant market power will exercise that

Figure 3.10. **The software sector employs highly educated workers**

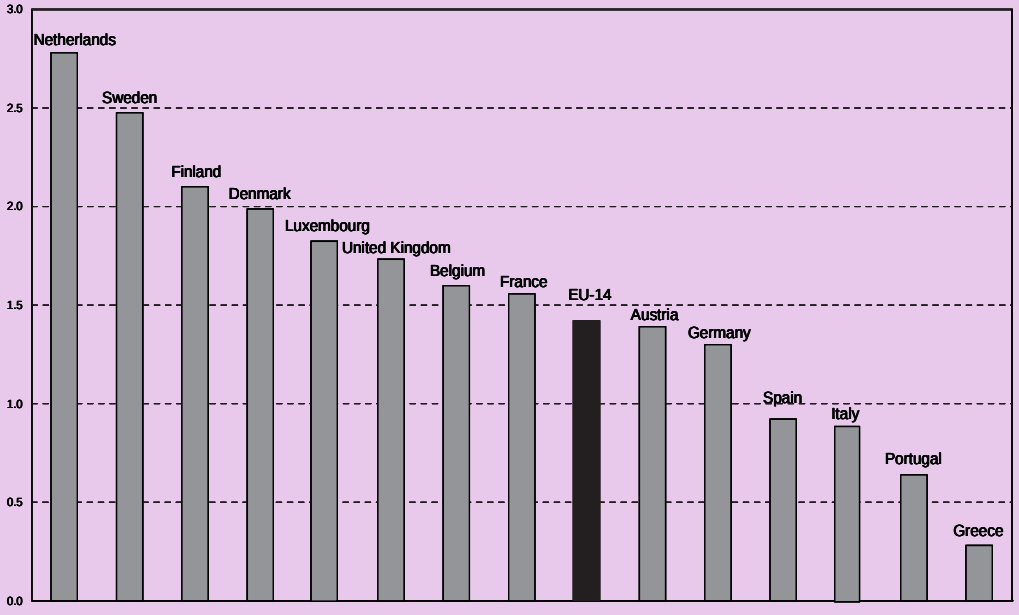
Percentage of workers with tertiary education, 1997



Source: OECD.

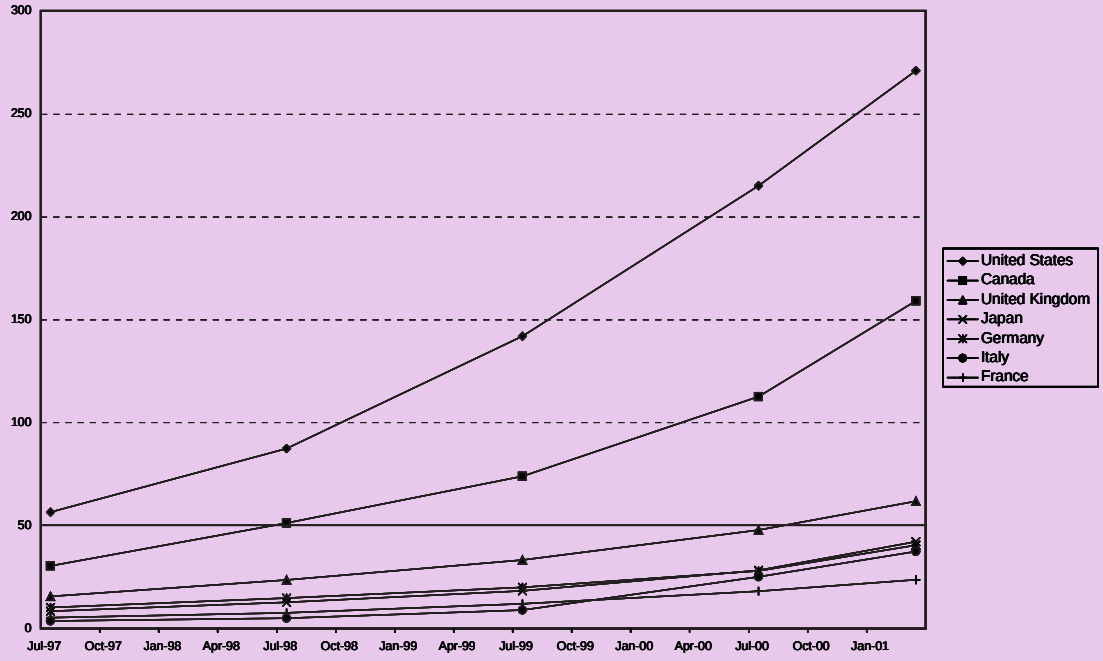
Figure 3.11. **Computer workers**

Percentage of total employment in 1999



Source: OECD, based on the Eurostat Labour Force Survey.

Figure 3.12. **Growth of Internet hosts per 1 000 inhabitants in the G7 countries**



Source: Netsizer (*www.netsizer.com*).

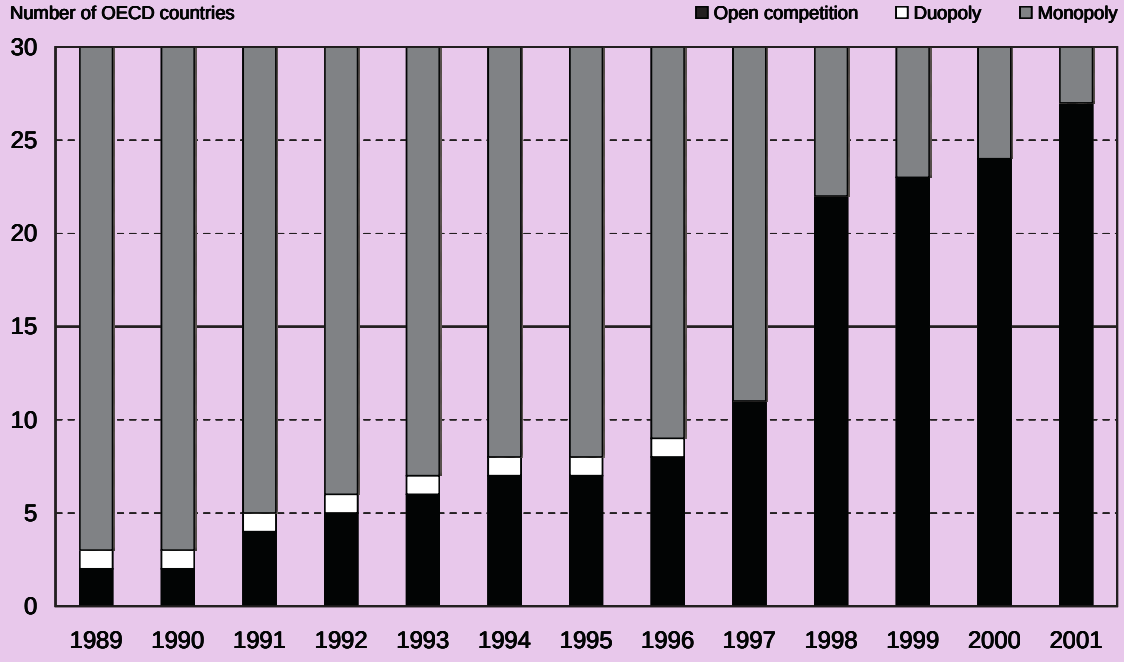
power to the detriment of Internet development. This may not always be fully captured in the advertised price of a leased line. For example, if the provision of a new connection is not made available in a timely fashion or if the level of service quality is poor, this can impact on users' ability to develop Internet services. In Western Europe, countries with relatively low leased line pricing tend to have a significantly higher number of leased line connections to the Internet (Figure 3.16). At the same time, competition is beginning to address remaining price and quality barriers, particularly where alternative infrastructure is now being rolled out. Prices are now starting to decrease in high-cost countries, such as Spain, but there is room for further reductions.

Another example concerns the costs of Internet access for consumers. The prices charged to consumers by Internet Service Providers (ISPs) are directly affected by the cost of capacity from backbone networks. The level of prices differs considerably from country to country due to the fixed and variable telephone charges set by telecommunications firms (Figure 3.17). Such cost differences also seem to affect the uptake of the Internet; countries with lower access costs typically have a greater number of Internet hosts (Figure 3.18). The rate of Internet demand and the development of infrastructure supporting electronic commerce in different countries are undoubtedly influenced by many factors. This includes not only the level of pricing but also the structure, *e.g.* as regards metered *vs.* unmetered, as well as the quality and speed of the network. Not least for electronic commerce, factors such as security, trust, user confidence and skills are also fundamental determinants.

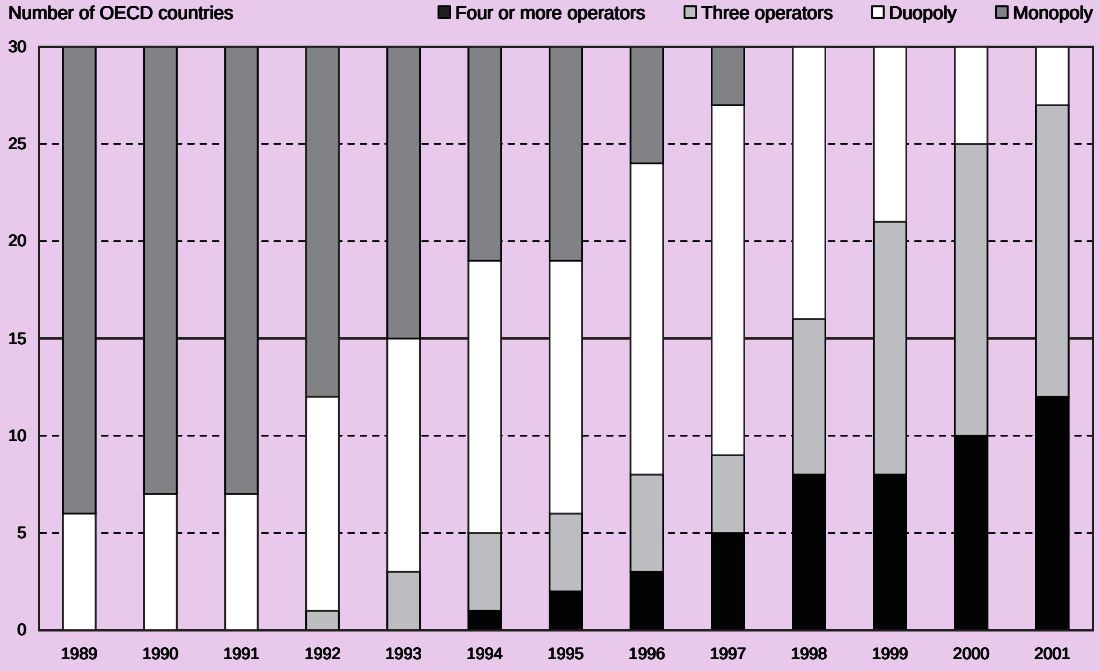
The development of fully-fledged competition at the local level is a major challenge. In 1999, new entrants had only a very small share of local markets in virtually all OECD countries; only in the United Kingdom did new entrants have an important share of local markets (OECD, 2001*h*). More competition in the local loop would drive prices down further and would help to change the pricing structure of the Internet. Consider, for example, unmetered access to the Internet (*i.e.* rather than paying by the minute, users pay either a flat fee or no fee for unlimited Internet access). Australia,

Figure 3.13. **Competition in OECD telecommunications markets is increasing**

A. Competition in fixed network infrastructure

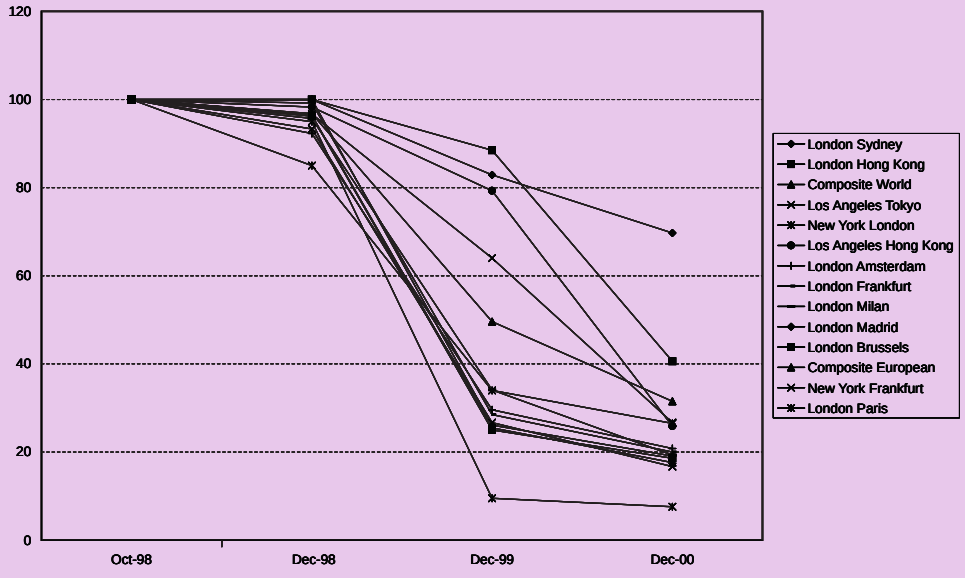


B. Competition in cellular mobile infrastructure



Note: There are no longer any monopolies in the wireless telecommunications sector, and the share of the market with four or more operators is rising. In the fixed-line area, open competition has spread fast, with only three monopolies remaining in 2001.
Source: OECD (2001*h*).

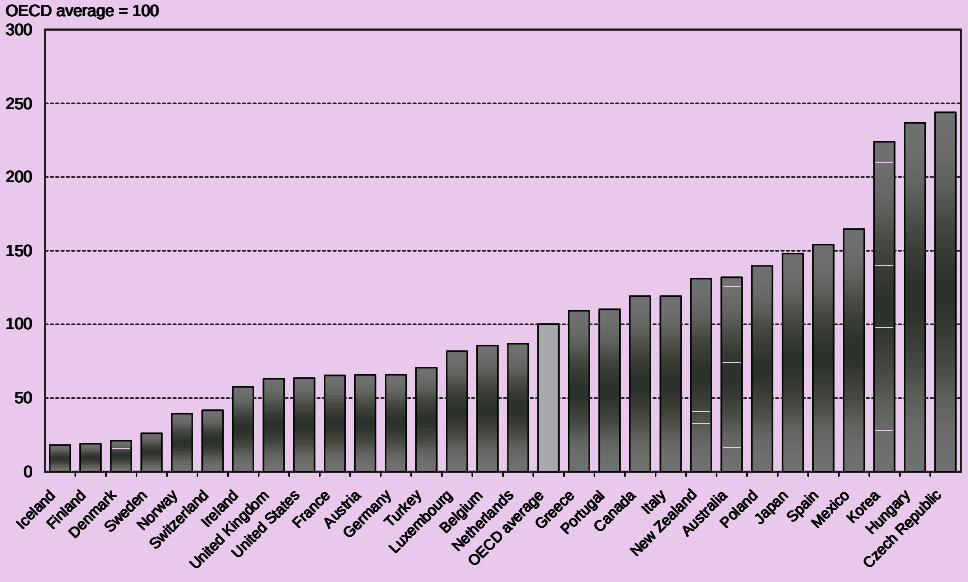
Figure 3.14. **Band-X Bandwidth Price Index (2 Mbit/s)**



Source: Band-X (*www.band-x.com*).

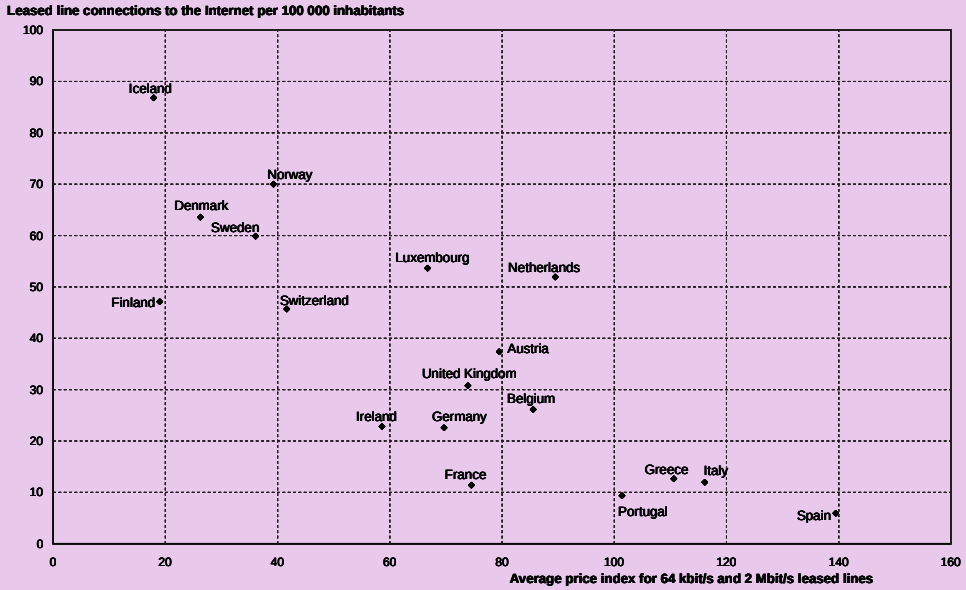
Figure 3.15. **The cost of leased lines in the OECD, August 2000**

Charges for a basket of national leased lines of 2 Megabits per second, OECD average = 100



Source: OECD (2001*h*).

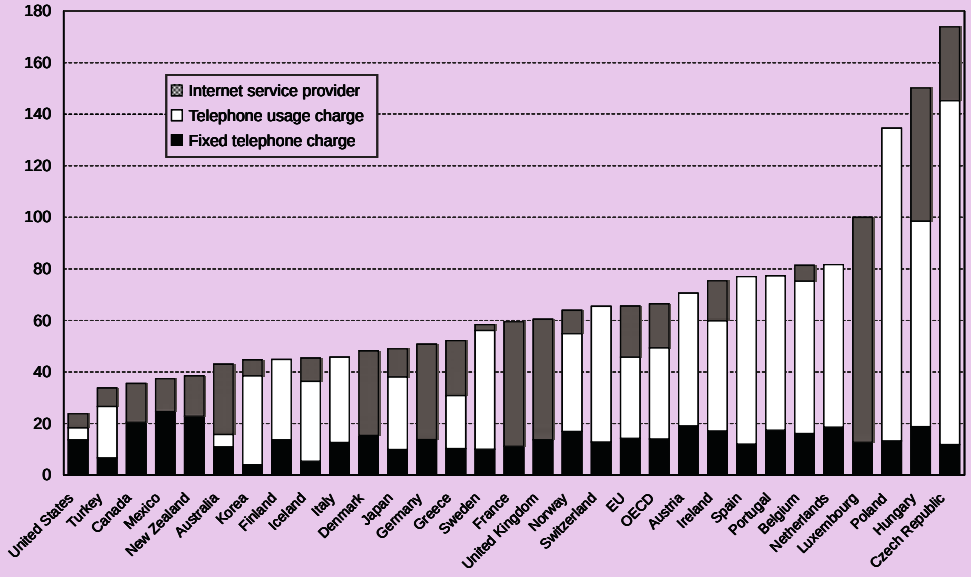
Figure 3.16. **Leased line costs and Internet development in Western Europe**



Note: The graph shows the total charges (excluding taxes) within each country for a basket of national leased lines that can carry 2 megabits of information per second. It shows that the Nordic countries have the lowest charges for such lines. Hungary and the Czech Republic have the highest charges.
Source: OECD *(2001h).*

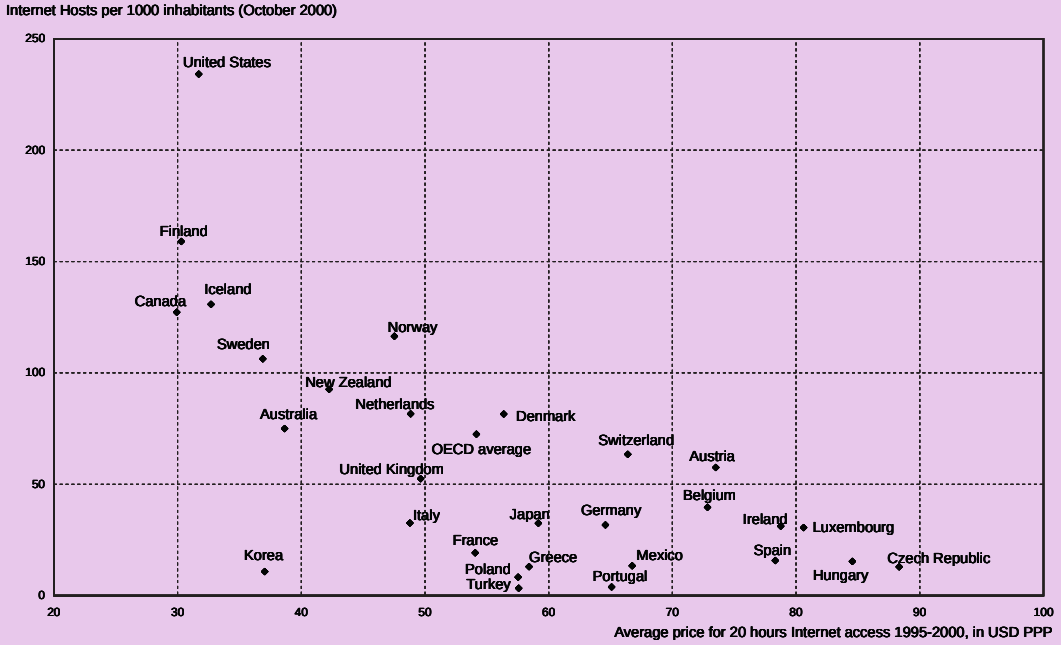
Figure 3.17. **Access costs for the Internet in OECD countries differ considerably**

Costs for 40 hours of Internet use at peak times, September 2000, in USD PPP



Note: Internet access costs differ substantially across OECD countries, primarily due to differences in variable telephone charges and the costs of Internet service providers. Previous OECD studies show that these differences are primarily due to the state of competition in different Member countries.
Source: OECD (2001*h*).

Figure 3.18. **Countries with low access costs have a greater diffusion of the Internet**



Note: Countries with low average access costs over the 1995-2000 period, such as Canada, Finland and the United States, typically have more Internet hosts – a computer system connected to the Internet – than countries with high average costs. Other factors matter though; Korea now has low average access costs but still a low penetration of the Internet. Access costs include VAT, and cover both peak and off-peak periods.

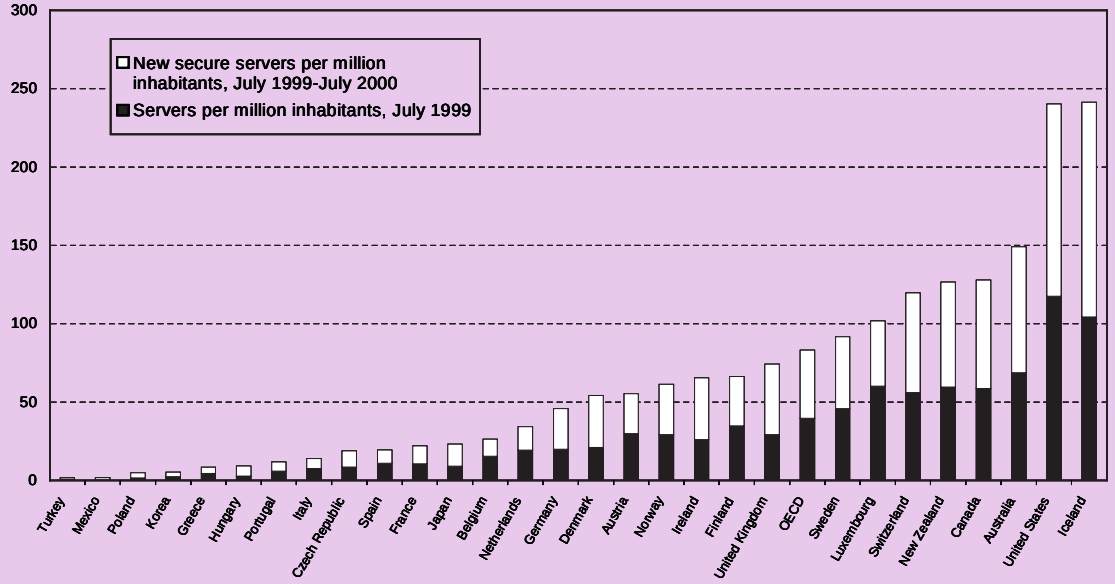
Source: OECD (*www.oecd.org/dsti/sti/it/cm*) and Telcordia Technologies (*www.netsizer.com*).

Canada, Mexico, New Zealand and the United States have had such systems in place for some time. That has led to more time spent on line. This is good for B2C electronic commerce, whose development depends on users becoming accustomed to the Internet and feeling secure enough to take the time "to shop around". Countries with unmetered access typically have more secure servers – which are needed for secure transactions on line – and more rapid growth in secure servers (Figure 3.19).

Unmetered access was available from the leading telecommunication carrier in twelve OECD countries by the beginning of 2001, up from five at the beginning of 2000 (OECD, 2001*h*). Countries where unmetered offers have been introduced include Finland, Hungary, Japan, Portugal, Spain and the United Kingdom. This number is expected to increase in 2001 as new interconnection frameworks become available, designed to enable unmetered offers for users. For those countries which have not yet done so, an important step is to implement a specific interconnection framework which enables a flat rate Internet access option to be available to Internet Service Providers (ISPs) to allow for unmetered charges to consumers.

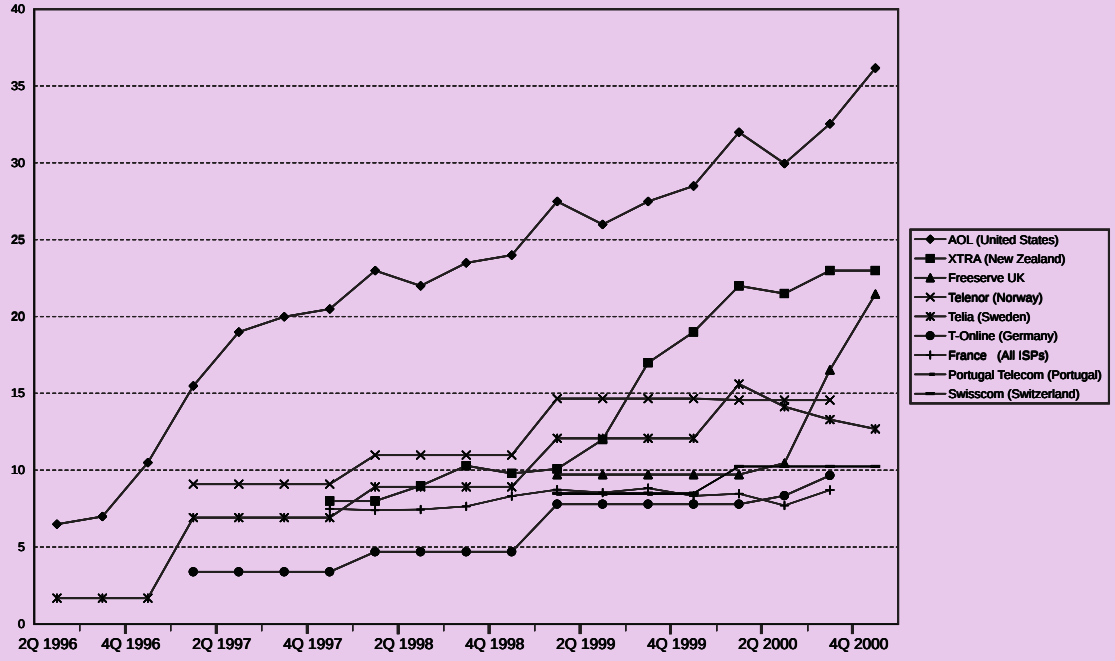
The trend towards flat rate options being available to users is already having an impact on the amount of time users are spending on line. Freeserve, one of the leading ISPs in the United Kingdom, reported that average usage per subscriber had increased to 22 hours per month by the end of 2000 (Figure 3.20). The sharp increase corresponds to the availability of flat rate tariffs in the United Kingdom during the second half of 2000. Only AOL in the United States (36 hours) and Telecom New Zealand's XTRA (23 hours) report more online time per subscriber – with flat rates having been available in both countries for a longer period.

Figure 3.19. **Electronic commerce has developed rapidly in countries with unmetered access**



Note: Countries with the highest rate of diffusion of secure servers in July 1999 have seen a greater increase in new secure servers than countries that had a low penetration rate. Countries with unmetered access (Australia, Canada, New Zealand and the United States) are among those with the highest penetration of secure servers, implying a greater diffusion of electronic commerce.
Source: OECD and Netcraft (*www.netcraft.com*).

Figure 3.20. **Hours spent on line (average per month per subscriber)**



Source: OECD (2001*h*).

The introduction of competition in local networks usually involves "unbundling", the separation of the local network and infrastructure from the services provided over that network. In other words, the local network operator should not have to be the same as the phone service provider. Unbundling enables new entrants to offer such services as unmetered Internet access to their customers should they so wish. However, it is not a simple process; it requires regulatory reform to promote fair competition and to create the conditions for future investment by new entrants. Such measures include "shared access" which is already implemented in Japan and the United States.[6] Most OECD countries have started to consider unbundling as a policy option, and the European Union has mandated unbundling of the local loop for its member states as of the beginning of 2001. Other countries need to take steps to ensure effective unbundling policies at cost-based prices to enhance competition and enable competitive DSL provision.

Another important policy challenge is to promote greater competition among different networks, *e.g.* fixed networks, cable television networks, satellites and wireless networks, so that users can choose. Such competition is likely to be more intense if these potentially competing networks are owned by different companies, especially if there will only be a single fixed or cable television network operating in a market. Both unbundling and competition between different networks will help stimulate the development of high-speed access options, *e.g.* broadband technologies such as optical fibre and very high-speed digital subscriber lines (VDSL) that enable access to multimedia applications. The competitive development and diffusion of these technologies would also help to spur e-commerce. In many countries, movements in this direction have come very recently. By the end of 2000, there were 22 countries with commercial high-speed digital subscriber line services – up from just seven in 1999. High-speed Internet access *via* cable modems was available in 21 OECD countries. In the most advanced countries this is beginning to change the access landscape. For example, although Korea has had a low penetration rate for some Internet indicators, its broadband penetration rate increased from 0.6 per 100 inhabitants at the end of 1999 to 10.3 at the end of February 2001. Only two other countries – Canada (4.54) and the United States (2.25) – had exceeded two broadband subscribers per 100 inhabitants by the end of 2000 (Figure 3.21). Competition between firms using different broadband, or competing with the same technology, is a feature of each of these three countries. This underlines the continued need for surveillance of market openness to facilitate competition between different high-speed access technologies. It also raises the need to review feasibility to allow for non-discriminatory access by ISPs to cable television (CATV) networks.

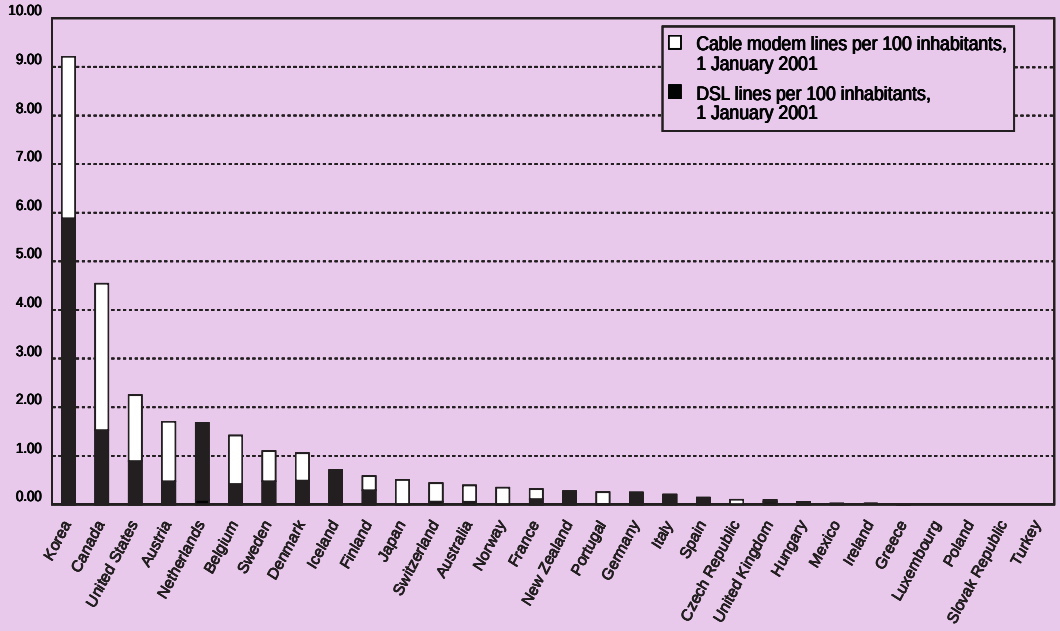
ICT use among different social groups: harnessing digital opportunities

The preceding sections examined the differences in access to and use of ICTs and the ICT supply across OECD countries. It is argued that competition in ICT markets (notably telecommunications), combined with pricing strategies to increase use of networks and the Internet, explain a large part of the differences in PC and Internet access and use across OECD countries. This section examines factors within OECD countries that explain differences in uptake and use. The previous sections can be described as having a technology-centred focus, in that they largely examine how the cost of producing and using the technology influences the extent of its use. In this section, the focus is on socio-economic factors, although price and cost factors continue to matter. If the cost of Internet access is halved, for instance, it will come within affordable reach of a much larger number of individuals, households and businesses.

ICT *use by income*

There are significant differences in ownership, access and use of new ICTs across various socio-economic characteristics of the population [see, for example, Statistics Finland (1998, 2000), United Kingdom National Statistics (2000), US Department of Commerce (2000)]. Individual or household income is a very strong determinant of the presence of PCs and Internet access in homes, with higher income groups acquiring ICTs early and leading uptake. In all countries for which information is available, there are very large differences in PC and Internet access by household income brackets, with the highest having large multiples of the lowest (Figure 3.22). Internet access is more recent, and levels of access are somewhat lower, albeit growing faster. Although most countries use different income brackets, distribution patterns are very similar in those countries for which they are comparable.

Figure 3.21. **Broadband penetration rates in OECD countries**



Source: OECD, Telecommunications Database, June 2001.

The pattern of diffusion can be described in terms of the shapes of logistic diffusion curves. The annual percentage point change in penetration tends to be higher for the highest income groups as penetration reaches around one-half of these households in the middle stages of new technology diffusion, and penetration is now very high in these groups. On the other hand, on their diffusion curves, the lowest income groups have higher rates of increase, even though percentage point differences between the lowest and highest income groups are widening. For Internet access, for example, in the United States, in 2000 access for the highest income bracket reached 78% compared to only 13% for the lowest income bracket. Nonetheless, the growth of the penetration rate over 1998-2000 for the highest income bracket was equal to only 29%, compared to 79% for that of the lowest income bracket. The Netherlands was the only country with higher Internet access growth in the highest income group.

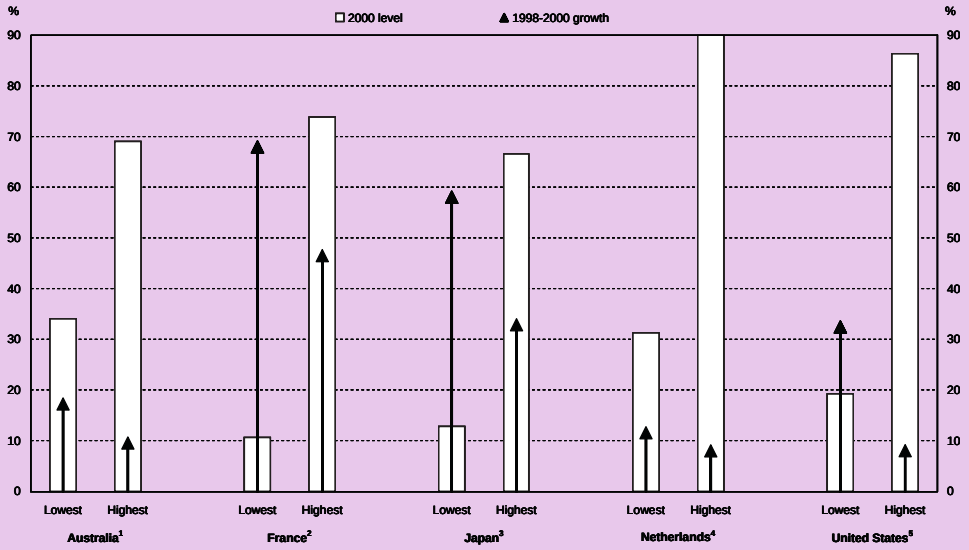
There are larger relative differences between income groups for Internet access compared with the differences for PCs. This suggests that in early stages of new technology diffusion, income distribution is a more important determinant of the pattern of diffusion. For all countries the annual percentage point change in penetration is higher for the highest income groups than for lower income groups. The lowest income groups have larger rates of increase in access in most but not all countries, possibly because of country-specific factors determining rates of uptake across income groups in the earlier stage of diffusion of the Internet.

ICT *use by educational attainment*

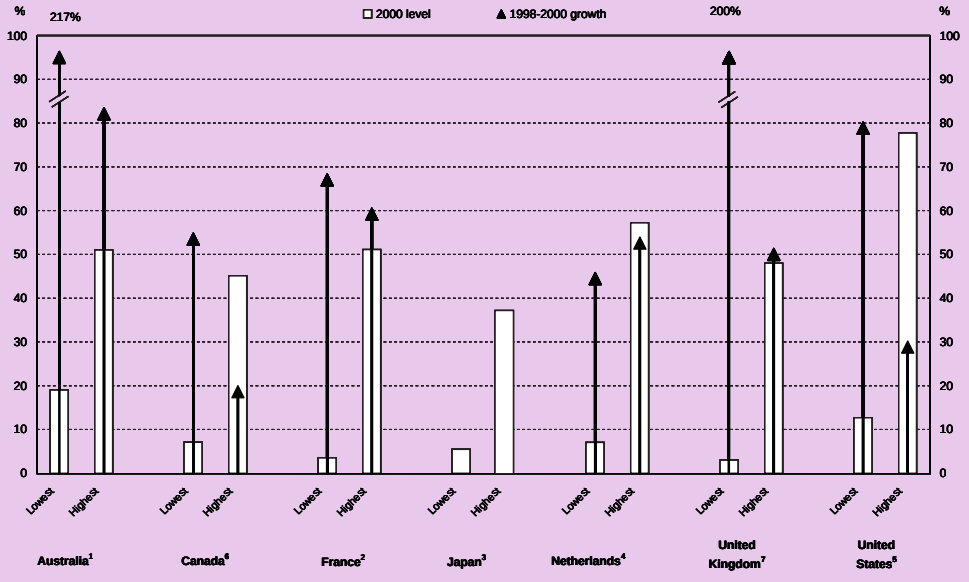
Educational attainment helps to explain differences in access to ICTs. In general, the higher the level of education, the more likely individuals are to have access to and use ICTs in both the home and the workplace. Educational attainment and income are strongly related, and education is a differentiating factor, largely through its effects on income. However, education also has some independent explanatory power; some groups with high levels of educational attainment and relatively low income (*e.g.* teachers, some public sector workers) have high levels of ICT use.

Figure 3.22. **Income is an important determinant of access**

PC penetration by household income, selected OECD countries



Internet access by household income, selected OECD countries

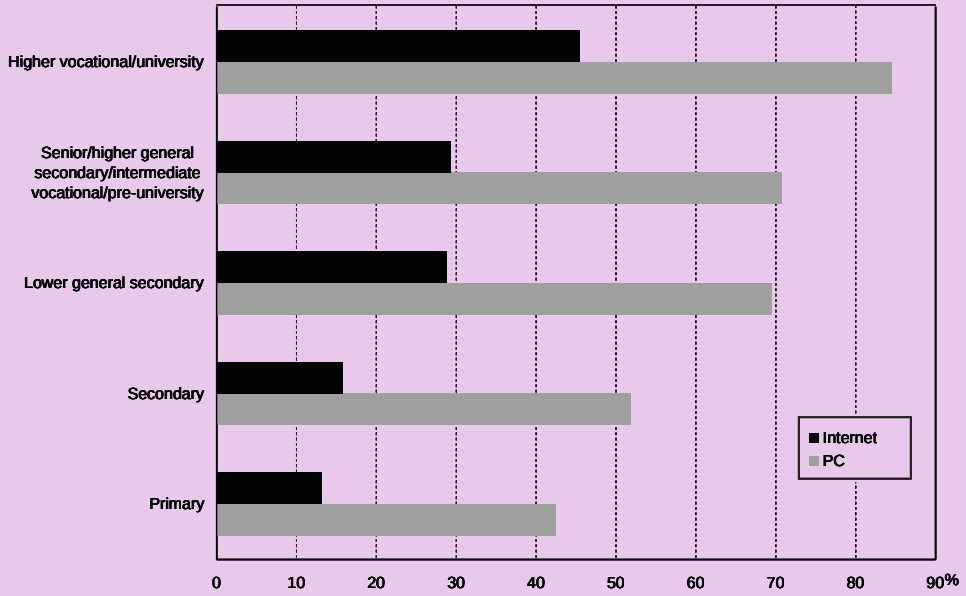


1. Lowest income bracket: less than AUD 50 000; highest income bracket: more than AUD 50 000.
2. Lowest: less than FRF 80 000; highest: more than FRF 450 000. 1999-2000 growth for Internet.
3. Lowest: less than JPY 3 million; highest: more than JPY 12 million. For Internet, year 2000 only.
4. Lowest: second decile; highest: tenth decile. 1999 level. 1998-99 growth.
5. Lowest: less than USD 15 000; highest: more than USD 75 000.
6. Lowest: first quartile of income; highest: fourth income quartile. 1999 level: percentage of households using a computer regularly from home. 1998-99 growth.
7. 1998/99 and 1999/2000 instead of 1998 and 2000. Lowest: second decile; highest: tenth decile.

Source: OECD (2001*i*), based on data from Australian Bureau of Statistics, Statistics Canada, INSEE, Ministry of Post and Telecommunications of Japan, Statistics Netherlands, Office of National Statistics of the United Kingdom, and US Bureau of the Census.

Figure 3.23. **Educational attainment helps to explain differences in access to ICTs**

PC and Internet access by educational level in the Netherlands, 1999 (%)



Source: OECD from national sources.

The large differences in PC penetration and Internet access between those with tertiary education and those at the lowest educational attainment levels are illustrated in the Netherlands in Figure 3.23. The magnitude of these differences varies across countries. For PCs, they are about a factor of six in the United States, compared to about two in the Netherlands. Although these differences have persisted over time, particularly in terms of percentage points, access by the less-educated groups is growing at more rapid rates, albeit from a low base.

Internet access is also higher for those with higher educational attainment. However, due to its earlier stage of diffusion, percentage point differences are greater for Internet access and the newer technology for different educational attainment groups. They vary by a factor of over nine in the United States, to about a factor of three in the Netherlands.

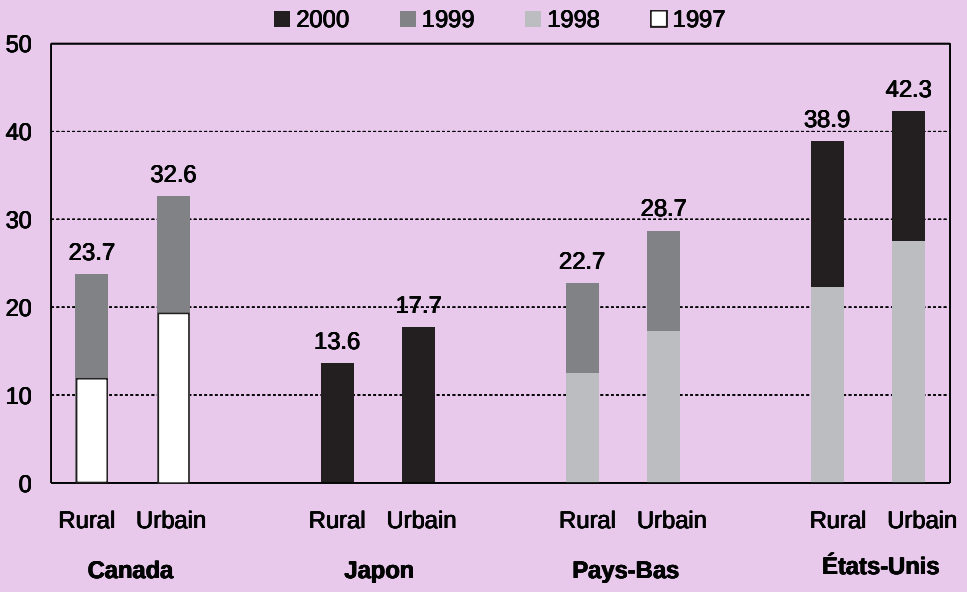
ICT *use by different social groups*

Age and gender also play their role in household and individual access patterns. PC penetration and Internet access are generally lower for older people than for younger age groups. The 35-45 year age group appears to be the highest users, and usage has tended to grow faster in younger age groups. Age patterns are similar across countries; only in Australia and the United Kingdom do the youngest surveyed age groups have the highest rates of Internet access. Differences in the use of the new technologies based on gender appear substantial in some cases, although there is a considerable variation across countries. In the United States (August 2000), Internet use rates by men and women were statistically identical. However, women users tended to be in younger age groups, while men were in older groups. For Iceland, which has high rates of ICT access, the picture is similar. On the other hand, in Sweden, recent data suggest that men may be outpacing women in use of the Internet. In Japan, men access the Internet from home at about twice the rate of women, although women are catching up. In the United Kingdom, 52% of men accessed the Internet in July 2000 but only 39% of women.

Turning to differences in access and use by geographical areas, there is considerable variation in ICT use across geographical areas within OECD countries. Internet access in urban areas is everywhere greater

Figure 3.24. **Urban homes are more connected than rural ones**

Internet access among rural and urban households



Note: For the Netherlands, "rural" is defined as a low degree of urbanisation, and "urban" a high degree. For Japan, "rural" is defined as "villages and towns" and "urban" as "cities".
Source: OECD, based on national statistical sources.

than in rural areas (Figure 3.24). Two reasons are usually advanced for these differences: *i*) costs tend to be higher and quality of access lower in rural areas, despite considerable efforts in some countries to ensure standardised pricing and quality; and *ii*) incomes tend to be lower in rural areas and ICT costs are relatively higher for low-income groups. In addition, members of households in urban areas are more likely to have occupations where computers and the Internet are part of their everyday work environment.

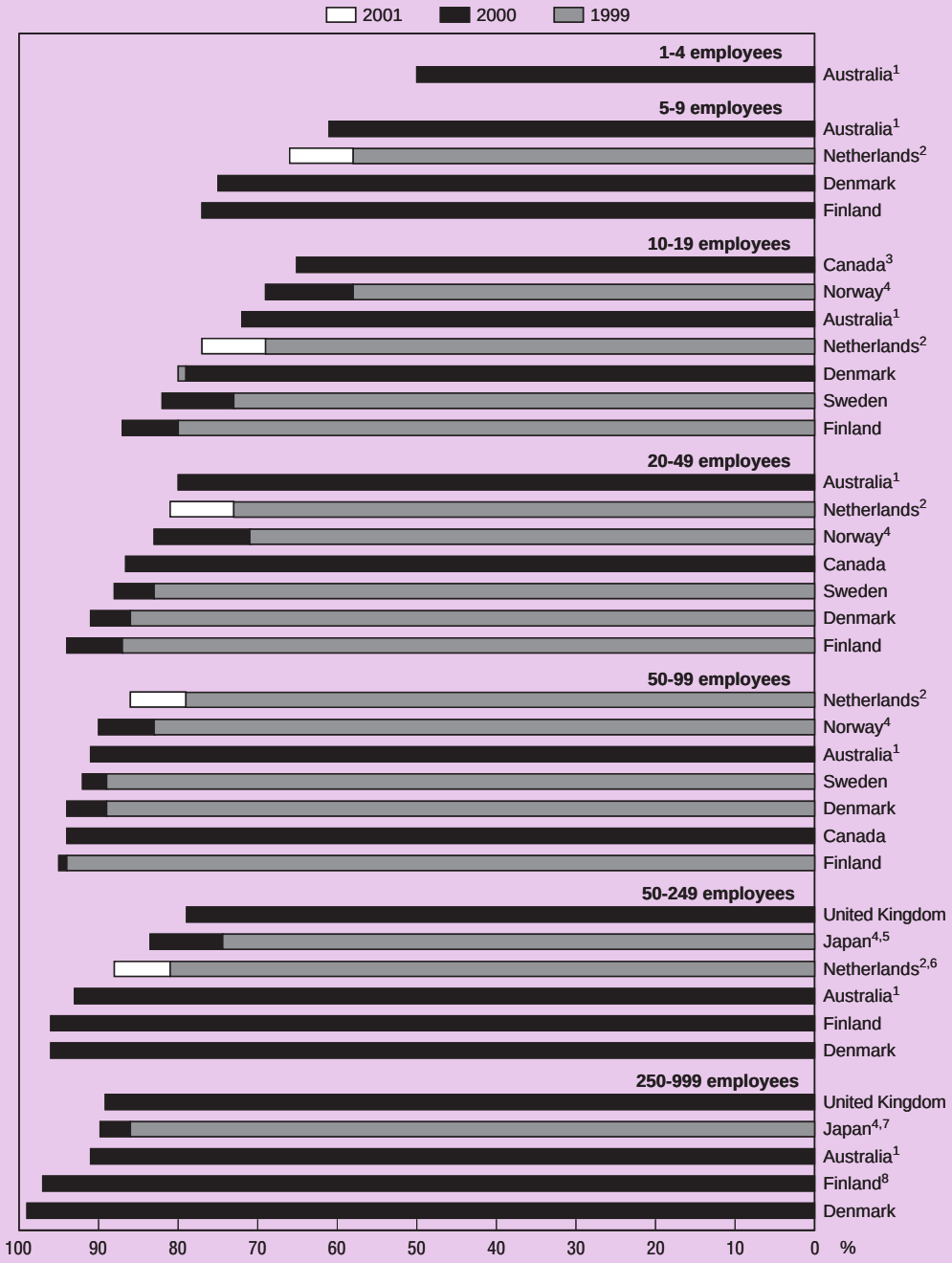
There appear to be strong links between ICT ownership and use in the workplace and in the home (see, for example, US Department of Commerce, 2000). Access and usage of ICTs at work are linked with educational attainment, occupation, and income, and these have a significant influence on the level of ownership and usage pattern of ICTs at home as well (for France, see Cezard and Vinck, 1998).

ICT *use by firms*

Considerable differences exist among firms in their use of ICTs and the Internet. These occur by industry (traditional industries use them less than more R&D-, skill- and technology-intensive industries), by size (small firms are less likely to use them than large ones), and by region (rural regions trail in ICT use in general, and some much more than others). There is considerable variation in the use of new ICTs across the business sector. Most firms are now equipped with PCs, so the pattern of access to the newer technology, the Internet, gives a better picture of how new technologies diffuse. The size and structure of enterprise divides are described extensively elsewhere.[7]

One particular issue capturing continuing policy attention is the access by SMEs to information networks and SME use of ICTs. The population of SMEs is highly heterogeneous, and some SMEs are at the forefront in innovative use of ICT, partly as small size may give firms a high degree of flexibility to develop new applications. Nevertheless, in all OECD countries for which data are available, smaller firms are on average slower to adopt and use ICTs and fewer of them have access to the network infrastructure. Figure 3.25 shows that small firms are catching up, but SMEs are still an estimated 30% to 50% behind large firms in their use of ICT. In addition to differences in levels of application, there are

Figure 3.25. **Internet access in the business sector by firm size**



1. 1999-2000.
2. The figure refers to the Internet and other computer mediated networks. Reference period, 1st quarter of 2001.
3. 1-19 employees.
4. Expectations for 2000.
5. 100-299 employees.
6. 50-199 employees.
7. 300-499 employees.
8. 250 and more employees.

Source: OECD, *Science, Technology and Industry Scoreboard: Towards a Knowledge-Based Economy*, Paris, 2001.

also indications that SMEs use ICT less strategically than larger firms (Australian Bureau of Statistics, 2000; UK DTI, 2000*a*). Relatively little official data exists to date on ICT and e-commerce use and impacts by firm size; the OECD is undertaking extensive work to improve the availability and international comparability of statistics and information.

There is considerable scope for further improving the connectivity of SMEs to global information networks, as well as their capacity to use ICT effectively. However, SMEs are likely to lag behind large firms in this area for a long time to come. This will serve to prolong significant disadvantages for SMEs in terms of access to global markets, public procurement and financing, with continued implications for operational efficiency and competitiveness. The situation is paradoxical since ICT offers new opportunities for SMEs to access information at low cost and to gain network externalities, *e.g.* through joining clusters which can become much more effective through appropriate use of ICT (see further Chapter 5).

Approaches taken to harness digital opportunities

Overall, policies aimed at overcoming some of these differences in the distribution of access by individuals, households and businesses within OECD countries are an important complement to regulatory initiatives to enhance competition in network infrastructure and the supply of ICTs, and basic infrastructure development and broadband infrastructure development. All OECD countries have complementary policies in areas such as:

- D*iffusion to individuals and households*: access through schools and other public institutions.
- D*iffusion to businesses*: ICT support and training for small businesses and information diffusion.
- E*ducation and training*: ICT education and training in schools, vocational training, teacher training.
- G*overnment projects*: government services on line, government procurement.

Given the potential of ICTs to contribute to growth and the importance of network effects flowing from the wider diffusion and use of ICTs, such policies may have important leverage effects. So far, relatively little evaluation of diffusion policies is available, but in general they are seen to have positive information and demonstration effects. For education and training policies, where governments are major players, the long-term positive individual benefits and large social externalities are more clear.[8]

Building confidence in using ICTs

Policies to increase competition and encourage the diffusion of ICT and the use of e-commerce need to be complemented with an appropriate regulatory and legal environment, particularly in the areas of privacy, security and consumer protection. Greater confidence is needed among consumers, business providers and government. Progress is being made, but concerns remain, for example, over divulging sensitive private information, such as customer databases, over the Internet, or ensuring that transactions across the Internet are safe from fraud, malicious hacking and other criminal acts. Authentication and certification mechanisms are being developed to help identify users and safeguard business transactions. If e-commerce is to be an important way of doing business in the future, it will have to be reliable, secure and safe to use under all conditions. Electronic commerce and ICT also create challenges to traditional consumer laws and practices, consumer rights in the event of receiving non-conforming goods, and in such areas as levying taxation on goods and services, where OECD is leading international work (Box 3.4).[9]

Some of this reluctance to do business (personal or otherwise) has to do with attitudes. Governments can influence these by using ICT applications themselves. Tendering public services, information, collecting taxes or procuring goods and services on line can help increase government efficiency while having the additional benefit of building public confidence. In many countries, not only is public information increasingly on line, but income tax declarations are being filed on line, greatly facilitating the processing of these forms and their transfer to other parties.

The benefits of ICT will not be fully exploited if progress is not matched in other sectors of the economy such as logistics. Consumers have often complained about the slowness of physical delivery of products due to inefficiency of the logistic industry and custom clearance. In a number of countries, there is a need for governments to strengthen transport infrastructure, reduce or eliminate public

Box 3.4. **New policy challenges**

Every period of radical technological change brings its new challenges, and adjusting to ICT is no exception. Economic and social changes are likely to continue in the years ahead as new technologies come on stream, and regulations and policies will have to be kept flexible to adjust to new circumstances. It is too early to tell precisely what impact ICT will have on competition, competition policy and intellectual property rights (IPR), for example. Nevertheless, informed judgements can be made.

ICT could have pro-competitive effects by improving information and market transparency, and by helping to create a truly global marketplace. On the other hand, the Web might lead some producers to collude in such a way as to limit competition (OECD, 2001*n*). Moreover, greater customisation of products and services could lead to higher rather than lower prices, with single firms establishing temporary monopolies over certain lines of business. This is not necessarily a problem for the long term as in markets with a very high rate of innovation, it is normal for firms to expect and sometimes achieve a high rate of return for their investments over a limited period of time. Provided that customer network effects are not reinforced with high switching costs, the market should eventually break such temporary monopolies as new innovations arrive or as consumer tastes shift. There are, however, considerable challenges in working out how to regulate the networks which are the basis for the Internet economy. Consideration needs to be given to how to reap economies of scale while at the same time encouraging interoperability in national and global networks so as to reduce the probability of creating durable monopolies. Competition authorities and network regulators need to be vigilant in removing anti-competitive practices that might be used to prolong monopolies.

Governments have a key role to play in the protection of intellectual property rights (IPR) (see also Chapter 4). The Internet makes it possible to copy and distribute any type of digital information, such as books, music, video and software, immediately and at zero or very low marginal costs. These possibilities call for a rethinking of existing IPR regimes, as there are new balances to be struck between rewarding inventors and innovators with temporary monopolies, and encouraging widespread diffusion and use of inventions and innovations. Many creators of digital information and content are seeking stronger legislation and enforcement of IPR. For a start, stronger legislation might limit the spread of information to libraries with weak purchasing power for instance. And it is not clear to what extent these companies actually suffer from the infringement on copyright. In any case, the main problem may not be new legislation, but rather about enforceability; each computer linked to the Internet has the potential to distribute unlawful copies. On the other hand, technology and the market may provide self-regulating answers, such as CD-ROMs that are more difficult to copy.

support of some forms of transport where these are ineffective and/or distort competition, and to undertake further regulatory reform in support of innovative logistics solutions. Developments in logistics and e-commerce have pushed ahead a modal approach to transport policy, whereby shippers view the whole transport supply chain in serving their business-to-business as well as business-to-consumer requirements. However, there is a need to remove remaining barriers to logistics chains which transcend the boundaries of different transport modes as well as national borders. These challenges are particularly important in Europe because of the fragmented institutional set-up, but are highly applicable in other regions as well (Andersson, 2000; OECD, 2001*m*; OECD, 2001*t*).

Apart from the significance of ICT as a major growth factor, questions are being raised not only about the distribution effects but also the health effects of ICT. First, some, such as the International Labor Organization, have argued that the introduction of the Internet and ICTs into the workplace and other areas of human action and interaction, raises the risk of stress and stress-related disorders, especially as the distinction between the workplace and home becomes more blurred. On the other hand, there are also positive effects, *e.g.* ICTs reduce physical and mental stress by allowing at least some workers to telecommute or reorganise work-related processes. Additional research is needed to understand the ways in which ICT can be most effectively integrated into the workplace to boost productivity as well as worker satisfaction. Second, electromagnetic radiation emanating from cathode ray tubes (*e.g.* computer displays) and wireless communication devices has been alleged to cause a range of negative effects on human physiology. The scientific and medical data continue to be reviewed and will require further analysis before firm conclusions can be made. Finally, the use of ICTs – the Internet, in particular – in health-care delivery and administration has raised concerns regarding privacy and security.

Although the benefits of such applications in improving the quality of care, expanding its reach and reducing its costs appear significant, greater assurances will be needed that personal health data can be effectively protected from unintended release and misuse (CSTB, 2000). There are concerns over the privacy and security of genetic information that require special attention.

Concluding policy implications

ICT is an enabling technology with wide-ranging applications that are most productive when diffused and used in conjunction with organisational change and training and education. Although new technologies may lead to exaggerated expectations with respect to their short-term impacts, their potential for long-term structural change and wealth creation should not be under-estimated. Governments should ensure that policies are technology-neutral to avoid technology lock-in, and that there are broad pro-competitive frameworks in place which allow the potential for network externalities to be exploited and adverse social implications to be mitigated.

There are considerable differences across OECD countries in terms of their level of development and recent growth trajectories. Although the following policies are generic rather than specific, there are differences in terms of timing, sequencing and phasing in selecting and prioritising appropriate policy mixes. Furthermore, there are systemic factors to be taken into account when devising policies which affect ICT development, diffusion and use. Broad national and international frameworks for innovation, entrepreneurship and skill formation, interacting with specific policies for ICTs in areas such as improving access and use by individuals and businesses, are needed to overcome issues of digital divide.

Finally, there are a number of areas that present joint challenges which will need to be met by all OECD countries, and in some cases by the entire global community, and where international co-operation needs to play an important ongoing role. This is notable in the areas of: *i*) work to improve data and measurement in order to better understand market developments and policy challenges; *ii*) liberalisation and competition in the development of network infrastructure; *iii*) the establishment of an effective framework for confidence and trust in new systems, for example in the use of the Internet and online transactions; *iv*) the establishment of a comprehensive framework for business transactions in areas such as taxation.

Within this broad framework for ICT development and use, policy approaches to the ICT sector, ICT diffusion and e-commerce comprise:

- ***Implementing enabling policies to increase access and use.*** Pro-competitive market liberalisation policies need to be pursued, particularly in the communications area to enable the rapid diffusion and widespread use of new and dynamic technologies to the vast majority of users. Policies may need to be implemented to ensure that all segments of the population and geographic areas have access to these technologies.
- ***Enhancing the development of high-speed communication networks and services and their diffusion throughout society.*** This will require improving the conditions of access to local communication infrastructures through effective policies or regulating unbundling and shared access to the local loop and interconnection frameworks:
  - Review feasibility to allow for non-discriminatory access by ISPs to CATV networks, as a platform for Internet access, where cable operators have significant market power.
  - Continued surveillance of market openness to ensure technology-neutral policies to enhance competition between different high-speed access technologies.
  - Implement a specific interconnection framework that enables a flat rate Internet access option to be available to ISPs to allow for unmetered charges to consumers.
- ***Building confidence in the use of* ICT *for business and consumers.*** Governments need to continue to work with business and civil society, and provide guidance, and to establish flexible frameworks for privacy, security and consumer protection to strengthen trust and build confidence in electronic commerce.

- **Focusing policy efforts on diffusing and using new technology.** The network benefits of using ICTs expand as the number of users increases. Government policy needs to focus on improving diffusion mechanisms and enhancing the conditions for uptake (*e.g.* through focused policies for trailing sectors and regions, ICT training – generic and professional – and the development of e-learning and lifelong learning strategies)[10] and contribute to productivity growth and innovation.
  - **Producer-user interactions.** The ICT supply side is an important factor in growth performance and business dynamism, and interactions between ICT users and producers are major sources of innovation and entrepreneurship within national and global networks. General government policies to support basic R&D and provide a broad framework for ICT business sector innovation, technology development and service provision are important factors in spreading ICT uptake and use more widely.
  - **ICT training and education.** Many initiatives have been undertaken to increase the supply of professional ICT skills and to improve the level and spread of basic generic ICT skills. Short-term initiatives need to be business- and market-led, but there are important inputs from government in the long-term development of a flexible and adequately trained workforce in the broader policy context of encouraging lifelong learning and professional education, and adapting the content of education and training to new demands and the development of ICT.[11]
  - **Small businesses.** SMEs generally face information and resource gaps compared with larger enterprises. These are usually more pronounced in new technologies, including ICTs. Private and public efforts to improve information flows to smaller and lagging firms may help overcome these externalities and provide positive network benefits. Network infrastructure, transaction security and regulatory issues may also need addressing to the extent that they give disincentives to small firms, and training and skill development strategies are a crucial component of government policies affecting the small-firm sector.
  - **Digital divide issues.** Policies aimed at overcoming differences in the distribution of access to ICTs within OECD countries are an important complement to regulatory initiatives to enhance competition in network infrastructure and the supply of ICTs. To the extent that such distributional differences persist, country-specific initiatives may be needed, focusing on measures aimed at: *i*) improving diffusion to individuals and households *via* access through schools and other public institutions; *ii*) improving diffusion to businesses *via* ICT training and information diffusion for small businesses; *iii*) IT education and training in schools, vocational training, teacher training; and *iv*) judicious use of government services on line, and government procurement to provide demonstration effects.[12]
- **Stimulating e-commerce through e-government and government use of ICTs to improve efficiency, extend reach and demonstrate large-scale applications.** Online government information and services and online government procurement as part of broad government knowledge management strategies[13] will improve internal government efficiency and increase government external reach to citizens and businesses in an increasingly knowledge-intensive economy, while at the same time providing important public demonstration and diffusion effects. Governments should expand their provision of information and public services on line, procure goods on line, and undertake other activities, such as collecting taxes on line, to increase government efficiency and provide demonstrations of the development and use of Internet and e-commerce strategies.
- **Ensuring that the benefits of ICT reach all groups of society.** The policies described above should promote the benefits of ICT for all citizens, without undermining incentives for restructuring and re-skilling. They also need to take into account concerns regarding privacy, health and organisational issues which increasingly intrude on the lives and work of families and individuals. The task requires a policy approach that is comprehensive in terms of coverage of relevant areas including regulatory, technological, educational and economic issues.

NOTES

1. This is partly due to the fact that software investment in Japan is underestimated.
2. While not necessarily demonstrating a causal relationship, countries with a high relative price level of ICT investment tend to have a lower degree of competition, as measured by indicators of the level of economic regulation (Nicoletti *et al.*, 1999). Statistical tests suggest that the relationship is significant: correlation coefficient = 0.57, t-statistic = 3.07.
3. See Gera *et al.* (1999). See also the extensive work of Brynjolffson.
4. There seems to be no correlation between the share of ICT services in total business value added and adjusted MFP growth in 1995-99. The ICT services data set comprises IT and software services (computer and related activities), telecommunications services, and wholesaling and renting of IT and related equipment (OECD, ICCP work in progress).
5. Those parts of ICT hardware production that can easily be set up, such as the assembly of PCs, are likely to have less technological spin-offs than indigenous high-tech capabilities in the development and production of semiconductors, or the building of more labour-intensive software capabilities that are necessary for an increasingly wide range of products and processes.
6. Shared access or line sharing is where carriers in dominant positions enable part of their subscriber lines' band to be used by new entrants, so that, for example, a new entrant could provide a digital subscriber line (DSL) service while the incumbent carrier continues to provide telephony.
7. See OECD (2001*j*); OECD (2001*i*); Joint WPIE/TISP Workshop, 7 December 2000; "The Digital Divide: Enhancing Access to ICTs", at *www.oecd.org/dsti/sti/it/infosoc/act/digital_divide/digital_divide.htm*
8. See, for example, OECD (2001*k*). For the benefits of improving human capital see OECD (2000*c*), OECD E*conomic* O*utlook*, Chapter 4, "Links between economic policy and growth"; and OECD (2001*l*).
9. OECD work covers many of these issues. See *www.oecd.org/subject/e_commerce/*
10. See also OECD work on lifelong learning and e-learning summarised in papers for the OECD Meeting of the Education Committee at Ministerial Level, "Investing in Competencies for All", Paris, 2-4 April 2001, *www.oecd.org/els/Ministerial/*
11. OECD, Meeting of the Education Committee at Ministerial Level, "Investing in Competencies for All", Paris, 2-4 April 2001, *www.oecd.org/els/Ministerial/*
12. An inventory of best policy practices to reduce the digital divide is in preparation. See OECD (2001*j*) and Joint WPIE/TISP Workshop, 7 December 2000, "The Digital Divide: Enhancing Access to ICTs", *www.oecd.org/dsti/sti/it/infosoc/act/digital_divide/digital_divide.htm*
13. For a discussion of the development of e-government in the broader context of knowledge management in government, see OECD (2001*o*).

Chapter 4

SCIENCE, TECHNOLOGY AND INNOVATION: IMPLICATIONS FOR GROWTH

Introduction

By any number of measures, scientific advances, technological change, and innovation have become key drivers of economic performance. Some of the recent features of this transformation are the growing impact of information and communication technologies (ICT) on the economy and society; the increasing interactions between science and industry, leading to a more rapid development of new products and processes and a shift to more knowledge-intensive industries and services; faster technology diffusion; and rising skill requirements. The ability to harness the potential of new scientific and technical knowledge and to diffuse such knowledge widely has become a major source of competitive advantage, wealth creation and improvements in the quality of life. In order to reap the benefits from these changes, governments will have to put the right policies in place and, in particular, will need to address the following important questions: What can be learned from the most successful countries on how government S&T policies can best contribute to increased innovation performance? What are the implications in two specific areas of S&T policy: public funding of R&D and management of the public research sector?

This chapter responds to these questions by investigating the contribution of technological innovation to economic growth. It does not attempt an exhaustive analysis of the processes of innovation and technology diffusion, or of related government policies; it concentrates rather on those developments and issues that appear most important in explaining recent growth patterns across the OECD.[1] The chapter reviews available evidence on the growing linkages between innovation and growth and, through econometric and cross-country analyses, identifies the characteristics of national innovation systems that seem most closely linked to strong innovative performance. Particular attention is paid to the management and allocation of R&D funding and to the sharing of knowledge among innovating organisations. The chapter provides recommendations to governments for increasing the returns from public financing of R&D, for improving the economic contributions of public research institutions (*i.e.* government laboratories and universities), and for strengthening national innovation systems through increased openness to international flows of knowledge. Public R&D funding and research institutions account for a sizeable share of R&D resources in OECD countries and can be directly influenced by changes in government policy. As the chapter notes, however, mutually reinforcing changes in public policies and private sector R&D strategies are necessary to create national (and international) innovation systems that are more capable of sustaining economic growth over the long term, without depleting the human, intellectual and natural resources upon which growth and social well-being ultimately depend.[2]

Innovation and economic growth: establishing the links

Defined as the development, deployment and economic utilisation of new products, processes and services, *innovation* is a major driver of economic growth. Innovation influences growth at both the microeconomic and macroeconomic levels. At the microeconomic level, innovation enables firms to respond to more sophisticated consumer demand and stay ahead of their competitors, both domestically and internationally. Innovation surveys for 12 European countries indicate that more than 30% of annual

revenues in the manufacturing sector derive from new or improved products, *i.e.* the result of innovation (DTI, 1999). Innovation is also important in the service sector, although innovation in services appears to draw less on formal R&D than is the case in manufacturing. Service sector firms are making greater use of new technology, especially ICT, in their work processes and service offerings (CSTB, 2000).

At the macroeconomic level, innovation contributes to the three drivers of output growth: capital, labour and multifactor productivity (MFP).[3] Countries that registered above-average growth performance in the 1990s generally drew more people into employment; accumulated more capital; improved the quality of their workforces; and, in many cases, improved MFP (OECD, 2000*g*). The contribution of innovation to MFP growth has long been recognised: increased MFP reflects greater overall efficiency in the use of labour and capital and is driven by technological and non-technological innovation – improved management practices, organisational changes, and improved ways of producing goods and services in response to evolving consumer and societal needs. However, innovation also creates new products that become part of the capital stock used by firms in generating their own economic output. ICTs, which have been the most dynamic component of business investment and have made significant contributions to economic growth in many fast-growing economies (OECD, 2001*p*), have experienced extremely high rates of technological innovation in the past decade. Similarly, improvements in the quality of the workforce are often a response to the needs of firms that were innovative in the development and/or adoption of new technologies.

The importance of innovation in driving growth can be seen in comparisons of various indicators of innovation's contribution to growth rates. Countries that experienced accelerated rates of growth in MFP between the 1980s and 1990s (Australia, Canada, Denmark, Finland, Ireland, New Zealand, Norway, Sweden, the United States) tended to have above-average rates of growth in patenting (Figure 4.1). This held true even for the United States, which had a high patenting rate even at the beginning of the 1990s and might have been expected to face greater difficulties in increasing its rate of patenting and its rate of growth (Figure A4.1 in Annex). Of course, patents do not measure innovation directly, but by sampling an important fraction of inventive activity they can provide useful insight into innovative performance.[4] The growing rate of patenting and the rising share of high-technology goods in trade among OECD countries further suggest that innovation plays an increasingly important role in economic growth.

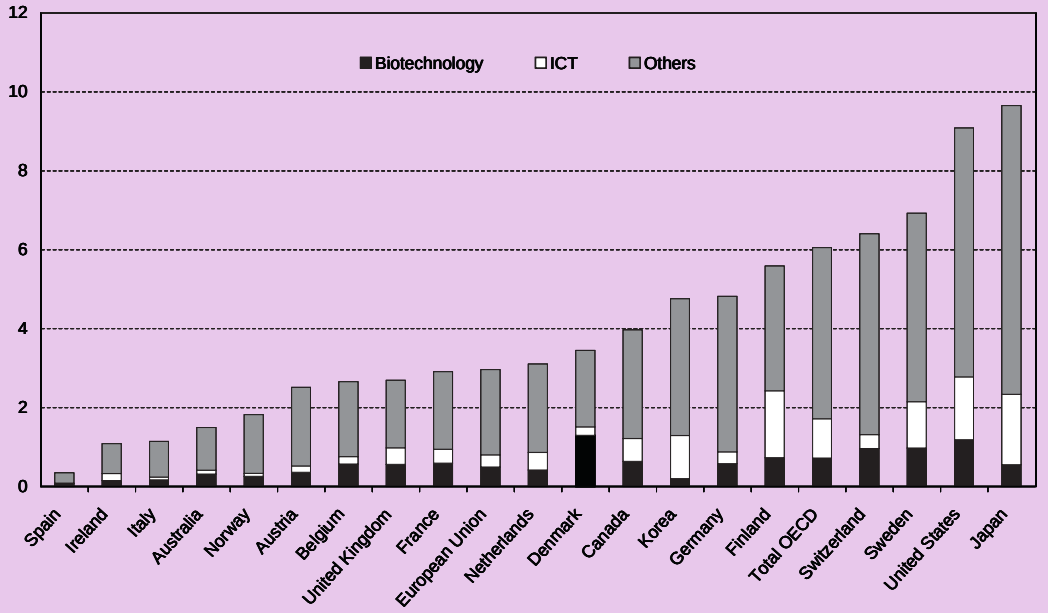
Arguably, a country's innovative capacity is more important to its economic growth – and to its ability to sustain growth over the long term – than is any particular technological breakthrough or industrial sector. While development and adoption of ICT appears to have been a key driver of growth in the 1990s, other technologies – biotechnology, nanotechnology, or something entirely different – may create new industries and reinvigorate established industries in the future. Countries that experience the highest levels of growth are likely to be those that can most rapidly develop new products, processes and services based on these new technologies and apply them most efficiently to other sectors of the economy. Radical innovation by a few organisations, together with incremental technological and organisational innovation by an increasingly large number of firms and working teams, will therefore remain essential to ensuring the *sustainability* of economic growth over the long term. It will also be important for ensuring *sustainable* economic growth – that is, growth that preserves the environment and natural resources – and to a host of other social objectives, such as improved health (OECD, 2001*b*, 2000*f*).

Increasing economic returns from science and technology: lessons from leading countries

The growing importance of innovation in driving growth suggests that countries that are more effective in acquiring, exploiting and disseminating knowledge will reap greater economic rewards in the long run. But how can innovative effectiveness be increased? A variety of factors appear to influence the effectiveness of innovation, including macroeconomic policies aimed at ensuring a stable business environment and access to capital and protection of intellectual property rights (IPRs). Additional evidence from cross-country comparisons suggests that government S&T policies wield considerable influence. The levels and nature of support for R&D and the degree of interaction and knowledge transactions in national innovation systems can both be influenced by government policy and are important in establishing an effective framework for innovation. The private sector also plays an

Figure 4.1. **Growth in patenting, 1992-99**

Annual average growth of patents granted at the US Patent and Trademark Office, by country of inventor



Source: OECD, based on data from the US Patent and Trademark Office.

important role in both these areas, and government policy will need to reflect changing patterns of industrial innovation and provide the needed incentives to spur business investments. Increasing economic returns from science and technology will require further efforts by governments to adjust their policies to such changing patterns, especially: globalisation of business research and innovation strategies, and the increasing role of demand as a driver of technological innovation and diffusion.

Raising the returns from R&D

Innovation can take many forms, ranging from radical innovations that create wholly new products, processes and services to incremental innovations that improve upon existing offerings in a more modest way. Although attention often focuses on the initial introduction of new products, processes or services, incremental innovation and technology diffusion – which improves upon initial innovations and spreads them throughout the economy – provide equally important economic benefits over the long term. The sources of new ideas that drive innovation are also varied: innovation may stem from new science and technology or from new forms of organisation, new skills, new forms of marketing and ways in which demand manifests itself in the marketplace. Most successful innovation involves a combination of these factors, with specific patterns reflecting characteristics of different industries, their customers and the means by which firms can protect and appropriate the returns from their innovative efforts (Table A4.1 in Annex).

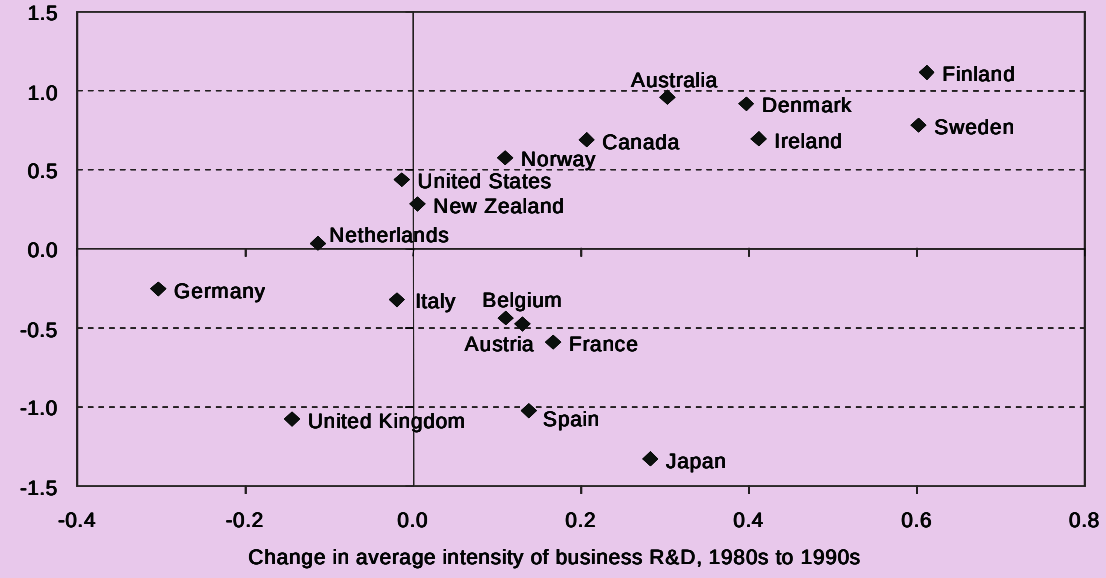
Successful innovation depends either directly or indirectly on sustained investment in R&D, complemented by investments in manufacturing capacity, marketing and human resource development (HM Treasury, 2001). Over the past decade, new science and technology have increased their role as drivers of innovation, both stimulating development of new industry sectors, such as ICT and biotechnology, and rejuvenating more mature industries in the manufacturing and service sectors.

Formal R&D is the source of much new scientific and technological information, although other activities such as engineering, design and learning-by-doing – which are not categorised as formal R&D and therefore not included in standard R&D statistics – make a significant contribution. Meanwhile, with the improved means of communication and associated organisational change, both within and between firms and organisations, the linkages from research right through to marketing and market research have evolved in both directions, enabling stronger complementarity between different functions and the development of more market-driven innovation.

A cursory comparison illustrates that a strong correlation exists between GDP per capita and formal R&D. Analyses of the link between *increases* in business expenditures for R&D (BERD) and *increases* in MFP show a similar relationship (Figure 4.2): OECD countries in which business expenditure on R&D relative to GDP grew most rapidly from the 1980s to the 1990s typically experienced the largest increase in rates of MFP growth. However, importantly, not all countries with increased expenditure on business R&D saw an improvement in MFP. Some experienced marked declines in MFP despite growing levels of BERD. This distinction emphasises the fact that increases in R&D funding are, by themselves, insufficient to drive improvements in MFP and economic growth. The way in which R&D funds are allocated (*e.g.* the institutions to which they are directed, the fields of science and industry to which they are related, and the kinds of mechanisms used to finance R&D) and the processes for commercialising and disseminating knowledge, matter crucially. There are multiple channels for commercialising and diffusing technology, and these processes are influenced by a number of factors and activities apart from R&D.

Cross-country comparisons of growth patterns provide additional insight into the elements that underlie differences in R&D efficiency across the OECD. Recent econometric analysis of 16 OECD countries reaffirms that increases in private sector, public sector and foreign R&D all contribute to increases in MFP. The work further indicates that the relative balance among these sources of R&D funding strongly influences the overall contribution to MFP growth. In particular, the analysis shows that:

Figure 4.2. **Change in MFP and in average intensity of business R&D**



Source: OECD, based on data for the *OECD Economic Outlook,* No. 68 and *Main Science and Technology Indicators* 2000-II.

i) the contribution of business expenditures on R&D (BERD) to MFP growth is smallest in countries that have a larger share of BERD funded by governments; *ii*) the contribution of public R&D funding to MFP growth is higher where the share of universities is larger compared to government labs; and *iii*) the contribution of all forms of R&D is higher in more R&D-intensive countries (Box 4.1). These results must be interpreted with caution due to the limitations inherent in such economic modelling, but they do provide evidence that differences in the relative levels of business, government and foreign R&D funding, as well as in the mix of institutions supported by such expenditures (Figure A4.4), contribute significantly to differences in economic growth.

Box 4.1. **R&D and productivity growth: an econometric analysis**

An econometric analysis was conducted on a panel of 16 OECD Member countries to determine the contribution of R&D performed by the business sector, the public sector (*i.e.* government laboratories and institutions of higher education), and foreign businesses to MFP growth between 1980-98.[1] To ensure the robustness of the results, the analysis was conducted on different panels of countries and over different time periods.[2] The results of the analysis are summarised below. All results are averages over countries and time; little can be said about results for specific countries or time periods.

- E*ffects of business* R&D *on productivity*. On average, a 1% increase in business R&D coincided with a 0.13% increase in MFP. The effect increased after 1980 and was larger in more R&D-intensive countries. The effect of business R&D on MFP was lower where the share of government in funding was larger, most likely because government expenditures on defence R&D made a smaller contribution to MFP.
- E*ffect of foreign* R&D *on productivity*. A 1% increase in foreign R&D coincided with a 0.44% increase in MFP. This effect was essentially stable since 1980 and was larger in R&D-intensive countries, suggesting that the size of the domestic R&D base influences the rate of technology adoption from abroad.[3] The impact was somewhat larger the smaller the size of an economy.
- E*ffect of public* R&D *on productivity*. A 1% increase in public R&D coincided with a 0.17% increase in MFP. The effect decreased after 1980 and was larger in countries in which the share of universities (as opposed to government labs) was higher. The effect was also larger in countries with lower shares of defence R&D and higher levels of R&D intensity.

These statistics measure the effect of R&D on MFP only – not on total GDP. Hence, they capture the spillover effects of private, public and foreign R&D rather than the total effect. This is especially important in interpreting the results for business R&D investments. If the social return of R&D is equal to its private return, and if the private return to R&D is equal to its output share,[4] then the elasticity of MFP with respect to domestic business R&D should equal zero. A positive elasticity signals the existence of spillovers. The model captures, in principle, most of the effect of public and foreign R&D, but only the spillover effect of business R&D. Having a spillover effect of public R&D higher than the spillover effect of business R&D reflects the fact that public R&D tends to be conducted in areas in which appropriability is weakest, or the social return far exceeds the private return (Cameron, 1998).

1. The model on which the estimated equation is based is a simple Cobb-Douglas production function. The model was estimated in a logarithmic form and as an "error correction model" (ECM), which allows to differentiate the long-term impact from the short-term impact. The estimation method is SUR (seemingly unrelated regression), which allows to control for simultaneous shocks affecting the countries. Additional details of the analysis are contained in Guellec and van Pottelsberghe (2001).
2. Data sources are OECD MFP indexes and R&D data from MSTI.
3. Foreign business R&D measures private R&D expenditures carried out in other countries and does not include those carried out by foreign affiliates located in the country. The relatively high level of correlation reflects the importance of international spillovers effects on MFP, especially for smaller countries.
4. The assumptions underlying the calculation of MFP must also hold true for this analysis to be valid: notably perfect competition and constant returns to scale at the aggregate level. A further caveat is that the assumptions used for calculating MFP may not hold completely: increasing returns to scale and imperfect competition are often associated with R&D (*e.g.* Romer, 1990).

Source: Guellec and van Pottelsberghe (2001).

Strengthening inter-organisational linkages and knowledge exchange

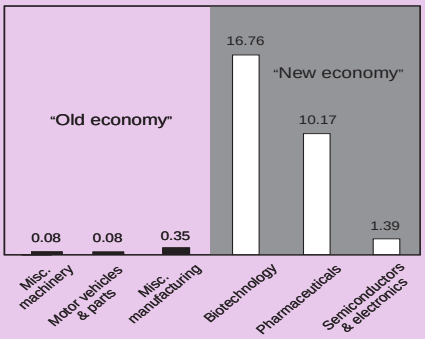
Empirical research has provided ample evidence to show that innovative economies are characterised by high levels of interaction among different innovating organisations and high levels of formal and informal exchanges of knowledge. These interactions reflect the fact that many types of external sources of knowledge are important in driving innovation within individual firms (Table A4.2 in Annex). More efficient national innovation systems boast strong complementarities between private and public investments in R&D, greater experimentation by a larger number of actors, and public/private co-operation on projects with potentially high social returns but that are too risky for private investors alone (OECD, 1999*a*). Such properties shorten the time between discovery of new scientific and technical principles and their application in products, processes and services; and ensure adequate feedback of information from industrial innovators to a research community that is responsive to economic opportunities.

Indicators developed by the OECD shed additional light on the factors that drive innovation performance (OECD, 2000*g*, 2001*c*). Together, these indicators suggest that uneven growth performance, especially among high-income countries, is influenced by differences in the way R&D expenditures are allocated and managed, but also by differences in the structure of national innovation systems and the linkages among innovating organisations. The factors highlighted by these indicators determine the *effectiveness* with which R&D funding and innovative activity can be converted into economic growth:

- A*n increasingly diversified base of* R&D *performers*. Both the number and variety of R&D-performing organisations have increased in high-growth countries. Small firms are playing an increasing role in performing R&D (Figure A4.2 in Annex), as are firms in the service sector (Figure A4.3 in Annex). While these trends reflect, in part, improvements in the ability to measure R&D in small businesses and service sector organisations, they nevertheless indicate growth in the participation of small firms and service sector firms in the R&D process.
- S*trong and growing linkages between science and industry*. Citations to the academic literature in patent applications have increased dramatically in the past decade – especially among higher-growth countries (Figures 4.3 and 4.4). This increase is seen not only in the most science-intensive industries (pharmaceuticals and biotechnology), but in many other industry sectors as well, highlighting the growing importance of science to innovation throughout growing economies (Figures 4.5 and 4.6). Measures of joint authorship of research papers indicate similar growth in linkages between science and industry.
- R*ising levels of networking among* R&D*-performing institutions*. Linkages have increased not only between industry and the science sector, but also among R&D-performing organisations themselves. Horizontal and vertical strategic alliances among firms have increased rapidly, especially in the ICT and biotechnology sectors, as has the cross-licensing of intellectual property. These forms of networking allow firms to share technology, collaborate on R&D projects and gain access to other complementary assets needed for successful innovation, such as manufacturing capacity or marketing channels (OECD, 2000*h*).
- I*ncreased internationalisation*. With the exception of the United States, which has an exceptionally large and decentralised innovation system, most of the faster-growing countries are small economies that have developed efficient schemes of supporting a strong and generally specialised science base that is well-integrated with the national innovation system and international scientific networks (Table 4.1).

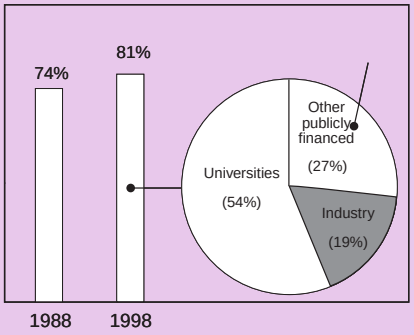
These changes have led to an improved division of labour in R&D tasks and increased competition in matching technological and market opportunities. They have widened the scope for open exchanges of knowledge, through *market-based transactions* of both embodied (*e.g.* mobility of qualified labour, acquisition of technology-based firms) and disembodied knowledge (*e.g.* licences). In several advanced countries, large firms have been able to *reorganise their* R&D *efforts* to concentrate on projects more closely linked to strategic business needs and to their particular competencies. To ensure access to complementary technologies and to a broader swath of technological innovation, they have increased

Figure 4.3. **Average number of scientific articles cited in US-issued patents, 1998**



Source: Sara, based on Narin *et al.* (2000).

Figure 4.4. **Publications of US public research as % of all citations in US-invented patents**



Source: Hicks (2000).

The "new economy" is dependent on basic scientific research that is carried out mostly in publicly financed organisations

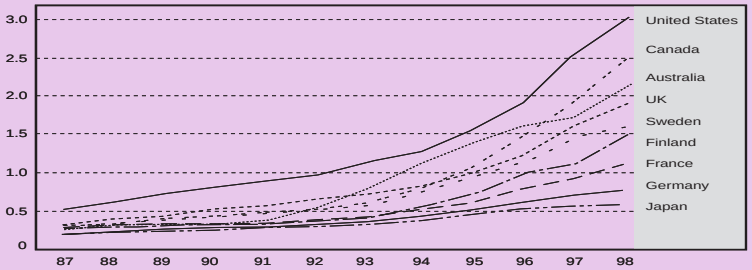
Table 4.1. **Citations from national sources in US-issued patents, 1990-97**

Country of citing patent inventor	Australia	Canada	Finland	Netherlands	Sweden	United Kingdom	United States
% share of national scientific sources	21.3	18.4	15.7	13.9	18.9	24.4	63.7
% share of the country in world publications	2.0	4.3	0.6	2.0	1.6	7.6	35.4

* Share of national scientific sources divided by share of the country in world publications.
Source: Narin *et al.* (2000).

The linkage between technology and science has a strong national component, even for small countries

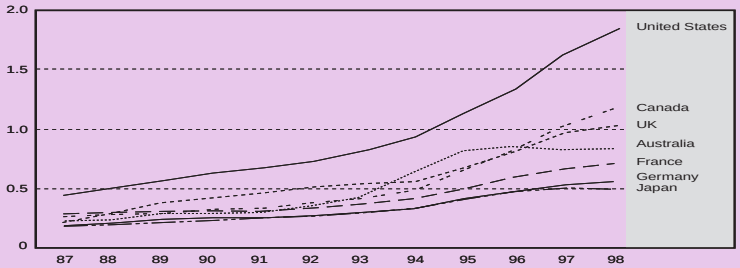
Figure 4.5. **Science linkage in selected countries, for all patents**
Measured by the average number of scientific papers cited in US-issued patents



Source: CHI Research.

International divergence in the intensity of linkage between technology and science…

Figure 4.6. **Science linkage, excluding patents in pharmaceuticals and biotechnology**
Measured by the average number of scientific papers cited in US-issued patents



Source: CHI Research.

… does not only reflect relative specialisation in the most "science-intensive" fast growing industries

Note: Part of the recent increase in the average number of scientific papers cited in US-issued patents reflects changed processing of patent applications, the increasing ease of locating scientific articles, and greater incentives to cite them. Comparable data based on European or Japanese-issued patents are not available.

their links to other firms and public research institutes: funding R&D in these organisations and making venture capital investments to stimulate technology development; and licensing technology or acquiring firms in order to access promising technologies. The public sector has become increasingly active in this booming market for knowledge, helping to foster three main channels: spin-offs, patenting and co-operative research (Figures 4.7, 4.8 and 4.9).

Boosting innovative efficiency across the OECD

Significant opportunities exist for other countries to follow the lead of the most advanced ones in improving their innovative performance. Several developments have expanded the opportunities for improvement:

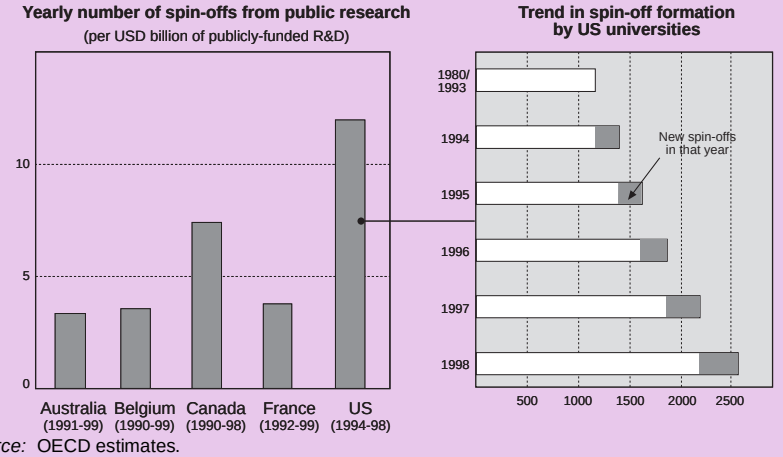
- *The development and diffusion of* ICT, has simplified and reduced the cost of codifying and diffusing knowledge. ICT has facilitated greater co-operation among researchers and research organisations, increasing the effectiveness of research work (OECD, 1999*b*, 2001*q*).[5] ICT has also reduced barriers to entry in some R&D activities (Pavitt, 2000).
- *The lowering of cultural and administrative barriers to entrepreneurship*, has facilitated the creation of technology-based firms (OECD, 1998*a*, 2001*r*).
- *Greater availability of private* R&D *funding*. The development of venture capital and the spread of specialised stock markets (such as the NASDAQ, *Neue Market*, *Nouveau Marché*, and Euro-NM) has expanded financing opportunities for small technology-based firms (Narin, 1999). The restructuring of R&D in large firms has increase their reliance on external sources of R&D, prompting many of them to finance small firms and increase R&D support to universities.
- *Changing government missions*. Reductions in government spending on defence have favoured a reallocation of S&T resources towards areas with greater market opportunities, such as the life sciences, ICT, and the new sciences resulting from the convergence of several disciplines (*e.g.* bioinformatics).

Nevertheless, determined actions are called for in many countries to catch up with the leaders, as the risk and cost of falling behind in technological innovation are increasing. Growing international mobility of human resources, globalisation of business strategies, and the winner-takes-all aspects of innovation-based competition in some emerging industries can widen the gap in economic performance among countries with differing levels of technological capability. Mobility allows more successful countries to attract talent from those that offer less attractive opportunities to highly qualified labour. Globalisation enables firms to more easily identify and access the best sources of knowledge in the world, which can also work to the advantage of innovation leaders. Winner-takes-all competition implies that first-mover advantages can create a sustained and widening gap between leaders and followers in many of the fastest growing new industries.

Leading countries must also make concerted efforts to improve their own R&D performance and that of other countries. The primary challenge for those countries that are forging ahead is to resolve new issues that emerge at the interface between public and private research. At the same time, they must help narrow international differences in innovation performance across OECD countries. Sustained large differences in innovative performance could, for example, accelerate the migration of talented scientists and engineers from low-performance to high-performance innovators (*i.e.* brain drain). If left unaddressed, this pattern could ultimately reduce incentives for all countries to invest in education as sending countries reap fewer benefits from their investments and receiving countries become reliant on foreign education systems. Narrowing the performance gap could, in contrast, bring emigration and immigration into closer balance, improving the circulation of scientists and engineers among countries. Greater circulation could both accelerate the pace of technical change (by increasing the rate of information sharing) and reward continued investments in education (Box 4.2).

Priorities for government S&T policies will of course vary across countries. For the least advanced Member countries (characterised by the weak innovation and R&D capabilities of most firms) the top priority is clearly to improve educational attainments (Table A4.3 in Annex) at all levels – from basic

Figure 4.7. **Spin-off formation in the 1990s**

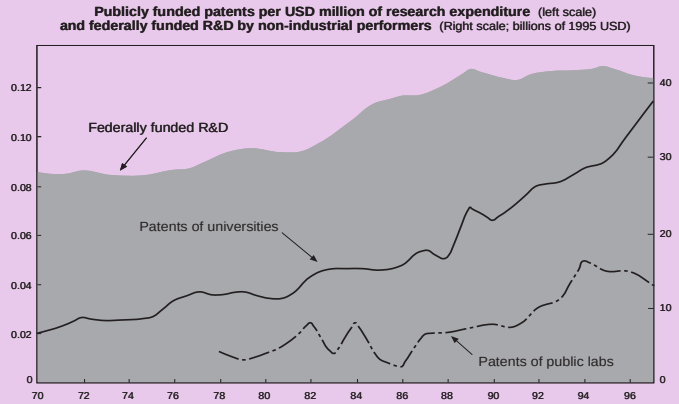


Source: OECD estimates.

Three routes for commercialising the results of public research are gaining in importance:

the entrepreneurial route…

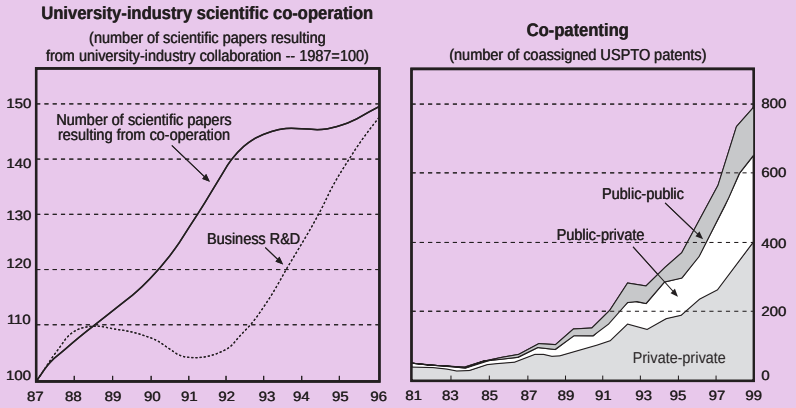
Figure 4.8. **The growing patenting activities of publicy-funded research organisations in the United States**



Source: OECD, based on Jaffe and Lerner (1999).

… the patenting route…

Figure 4.9. **The growing public-private co-operation in the United States**



Source: OECD, based on Hicks (2000).

… the co-operative route.

Box 4.2. **International mobility of S&T personnel: an emerging issue**

International mobility of researchers, scientists, and highly skilled workers is not a new phenomenon but, concurrent with globalisation, the upskilling of overall employment and increasing demand for scientific and technological skills in innovative firms and sectors, it has emerged as a major policy issue on the agenda of OECD countries.

International mobility favours contact between researchers of different backgrounds, which is a key source of new findings. As researchers tend to move to regions that offer better conditions for scientific and technical work (*e.g.* more interesting projects, better wages), international mobility tends to accelerate rates of technological change. The benefits of mobility are therefore generally positive, but their distribution across countries can be problematic.

Although difficult to measure, the migration of highly skilled workers in science and technology appears to be small in comparison to overall migration, although it is increasing with regard to both permanent and temporary flows. Much of the migration, which originates principally from Asia, is directed towards large countries such as the United States, Canada, and to a lesser extent some European OECD countries. Still, the migration of human resources in S&T, whether students, researchers and entrepreneurs, can have a disproportionate impact on a country's research capacities and its potential for innovation and economic performance, in at least three ways:

- First, foreign scientists and researchers enhance the circulation of knowledge, especially tacit know-how, and contribute to the stock of scientific potential in the receiving country. This has been especially true in the United States, for example, where in 1997 some 26% of PhD recipients in science and engineering were foreign-born.
- Second, highly skilled immigrants, and immigrants in general, are a source of entrepreneurship. Immigrants from China and India created around 30% of Silicon Valley start-ups in 1995-98.
- Third, access to talent from abroad may reduce wage pressures in sectors where high skills are at a premium and contribute to the firm's research and business development. In several OECD countries, including the United States, Germany and the United Kingdom, foreign skilled workers are being courted in order to meet temporary shortages of talent in specific fields, notably in information technology.

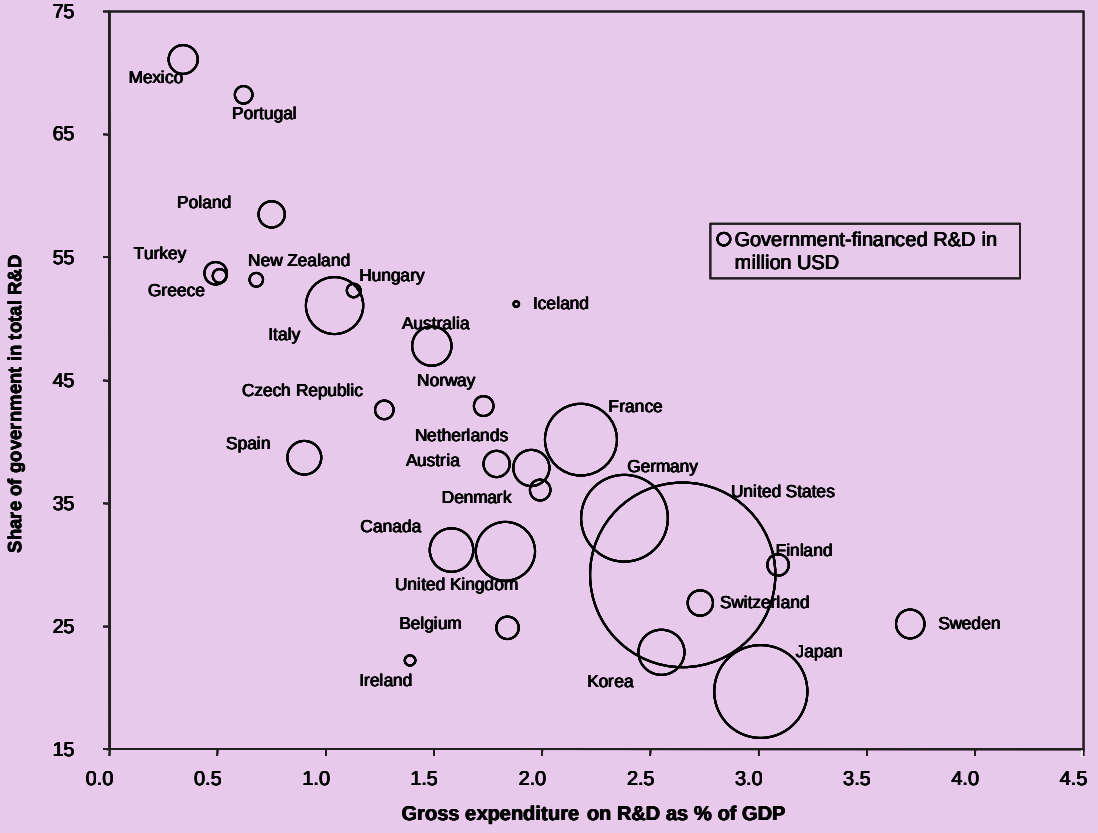
The drivers of migration are many and include employment conditions in both receiving and sending countries as well as immigration policies in receiving countries, which are increasingly selective and skills-based. It is clear, however, that the push and pull factors for human resources in science and technology relate more to opportunities for higher education and research in receiving countries compared to those available in sending countries and to improved conditions for entrepreneurship. Public research institutions, which contribute more to business innovation today than in the past, increasingly rely on attracting and recruiting top students and researchers from a global talent pool. Indeed, evidence shows that much of the international migration of scientists and engineers is localised around knowledge-intensive clusters or centres of excellence. New programmes to repatriate scientists and engineers from abroad have helped some countries increase return migration and retain talented workers, although additional efforts may be needed.

education to more specialised training of technicians, engineers, top-level scientists – while stimulating innovation in the private sector through improved framework conditions. Such countries must also build or consolidate the sets of institutions that have proved effective in enhancing private innovation in more advanced economies. For the latter, enhancing the performance of the R&D and innovation system will require different tasks reflecting country size, varying starting points and diverse institutional features (Figure 4.10). These tasks must be inspired by common principles and best practices learned from the experiences of the last decade.

Government policy can affect a country's innovation system in three primary ways: *i*) reforming policies and practices for financing R&D; *ii*) altering the structure, financing and decision-making processes of public research institutions; and *iii*) improving conditions for innovation by, for example, modifying rules and regulations related to IPR protection, licensing of public research, competition policy and human resource mobility. The discussion below focuses primarily on the first two of these mechanisms which exert a direct influence on significant portions of the innovation system. Governments finance approximately one-third of all R&D investments in OECD countries through both

Figure 4.10. **Government's role in R&D differs considerably across the OECD**

As a % of GDP, 2000



Source: OECD based on data from OECD *Main Science and Technology Indicators* 2000-II.

direct funding (which totalled more than USD 150 billion in 1999) and indirect financial incentives (*e.g.* tax incentives, which amounted to several billion dollars more) (OECD, 2001*s*). Government laboratories and universities conduct approximately 30% of all R&D in the OECD area – much of which is directed towards basic and applied research – and they received approximately 75% of government total R&D funding in 1999. Some framework conditions for innovation are also examined, but only insofar as they relate to issues of technology transfer between the public and private sectors.[6]

Increasing the returns from government investments in R&D

Improving the effectiveness of public R&D funding in stimulating economic growth requires a variety of steps related to government funding of R&D conducted in the business, higher education, and government sectors. Investments in each sector can contribute directly or indirectly to growth by supporting the creation of the scientific and technical knowledge that underpins much of innovation or by directly financing business innovation. Most government R&D funding is not intended to contribute directly to economic growth and productivity enhancements but is instead spent in support of various other government missions (*e.g.* national defence, health, environmental protection, scientific advancement). Nevertheless, opportunities exist for increasing their potential economic returns. Steps can be taken to make public financing of business R&D more effective and to increase the economic spillovers from other mission-oriented R&D.

Support for basic and long-term research

Ensuring adequate government support of basic research (as opposed to applied research or development) is especially important for stimulating industrial innovation.[7] Basic research produces scientific and technological knowledge that businesses can use to innovate. It is an especially important source of innovative ideas in high-technology industries, such as ICT and biotechnology, and may be playing a more important role in other industries as well as they become more knowledge-intensive. What industry expects most from the public sector is improved access to qualified labour and the results from high-quality and relevant – but not necessarily more applied – public research (Pavitt, 2000).

The need for government to support basic research is on the rise. Even though business R&D expenditures grew rapidly between 1985 and 1999 (while government R&D funding stagnated – see Figure A4.5 in Annex – industry funds relatively little basic research. In the United States, for example, only 8% of industry-funded R&D was allocated to basic research in 1998, compared to 23% of government R&D funds. Similarly, the share of university research financed by industry, while growing, remains small. Universities are the primary performer of basic research, and over 70% of university R&D funding in the OECD area comes from governments. Closer ties between industry and universities have increased the contribution of public research to economic development, but such relations have not reduced the need for continued public financing of basic research.

Changes in the nature of business R&D may have further limited the ability of firms to directly support basic and long-term research. As competition and the pressure to introduce new products, processes and services more quickly increased during the 1990s, many large, multinational corporations restructured their R&D operations to link research programmes more closely with product development activities.[8] Although this trend was somewhat counteracted by the establishment and growth of central research labs in several other firms (*e.g.* Intel, Microsoft, Motorola, and NEC), industry research appears, in general, to have become more focused on areas that are directly relevant to business concerns. More broad-based inquiries into fundamental science appear to have been scaled back in many firms. Other changes in business innovation, most notably the increasing linkages among firms and between industry and public research institutions, may serve to increase the economic returns to government from government investments in research by facilitating the diffusion of knowledge. In areas attracting significant industry interest and increasing amounts of business R&D, government investments in basic research stand a better chance of being converted into new products, processes and services.

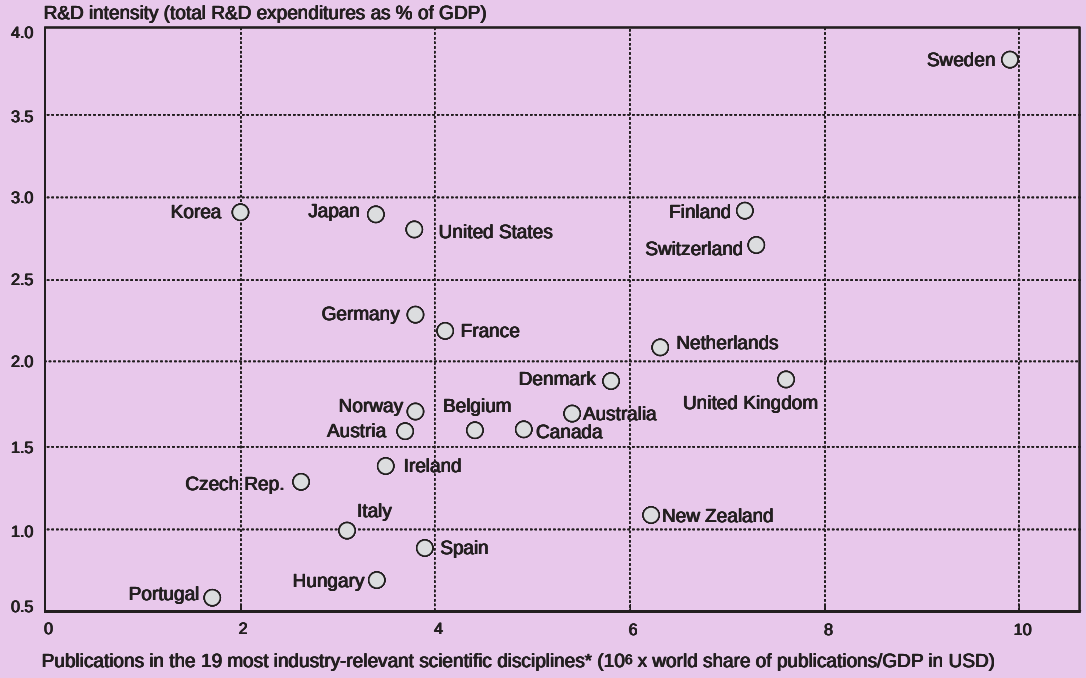
Furthermore, the increasing globalisation of R&D and the more widespread sharing of knowledge among researchers and businesses in different countries do not appear to have diminished the importance of a strong domestic knowledge base – or of the role of government in helping to create it. Free-riding on R&D conducted by other countries is not a viable option. As stated by Pavitt (2000), the knowledge that results from basic research may have attributes of a public good, but it is not a free good. The ability to understand and make use of the results of basic research performed in other countries requires strong domestic R&D capabilities. Just as *companies* must maintain R&D programmes in order to develop an absorptive capacity for outside innovation (Cohen and Levinthal, 1994), *countries* must develop their internal scientific capabilities in order to understand and use new knowledge developed elsewhere. The success of this approach is evidenced by the Nordic countries which, despite their small size and use of foreign technology (as indicated by, e.g., patenting rates of foreign companies in Nordic countries), have among the highest levels of investment in R&D (measured by R&D intensity), scientific output (measured by citations), inventiveness (measured by resident patent applications per capita) and MFP growth in the OECD (Figure 4.11). In their patent applications, the Nordic countries, along with other highly innovative countries, continue to cite domestic scientific literature at a much higher rate than international literature (see Table 4.1).

Stimulating business R&D *and innovation*

Government financing of fundamental research is an important means of expanding the base of scientific and technical knowledge that firms can exploit in the innovation process, but it is not the sole

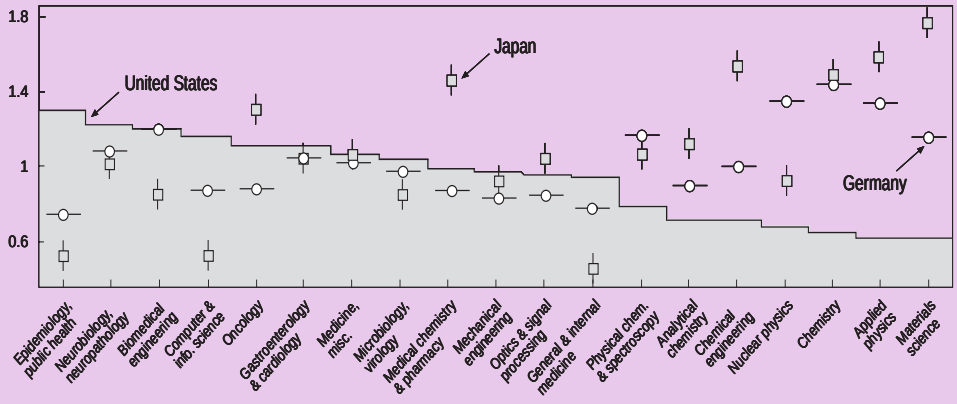
Figure 4.11. **R&D intensity and scientific output**

1998 or latest year available



Source: OECD, partly based on data from OST.

Figure 4.12. **Profile of relative scientific specialisation of the three largest OECD economies**



Note: Relative specialisation is measured as the share of each discipline in one country's total publications divided by the share of this discipline In world publications.

Source: OECD, partly based on data from OST.

instrument for stimulating business innovation. Industry faces considerable risks in bringing new products, processes and services to market – especially those with significant scientific or technical content. While the promise of increased market share and profits provides significant motivation for firms to invest in R&D and other innovative activities, the associated costs and risks, combined with the difficulties firms face in appropriating the benefits of their R&D investment (*e.g.* due to competitors making use of the results), typically result in lower levels of business R&D than are socially optimal. Improving framework conditions related to, *e.g.*, competition rules and protection of intellectual property rights (IPRs)[9] can be of great importance for boosting business innovation. Governments may nevertheless have a sound rationale to create additional incentives for business R&D expenditures, such as by funding business R&D directly or by implementing a range of indirect measures, such as tax incentives. Both these tools have been shown to boost business R&D expenditures (OECD, 2000*k*; OTA, 1995) – and consequently overall levels of R&D intensity;[10] however, the choice of policy instrument must be well-matched to the specific policy objective desired. Econometric analysis (Guellec and van Pottelsburghe, 1999) indicates that:

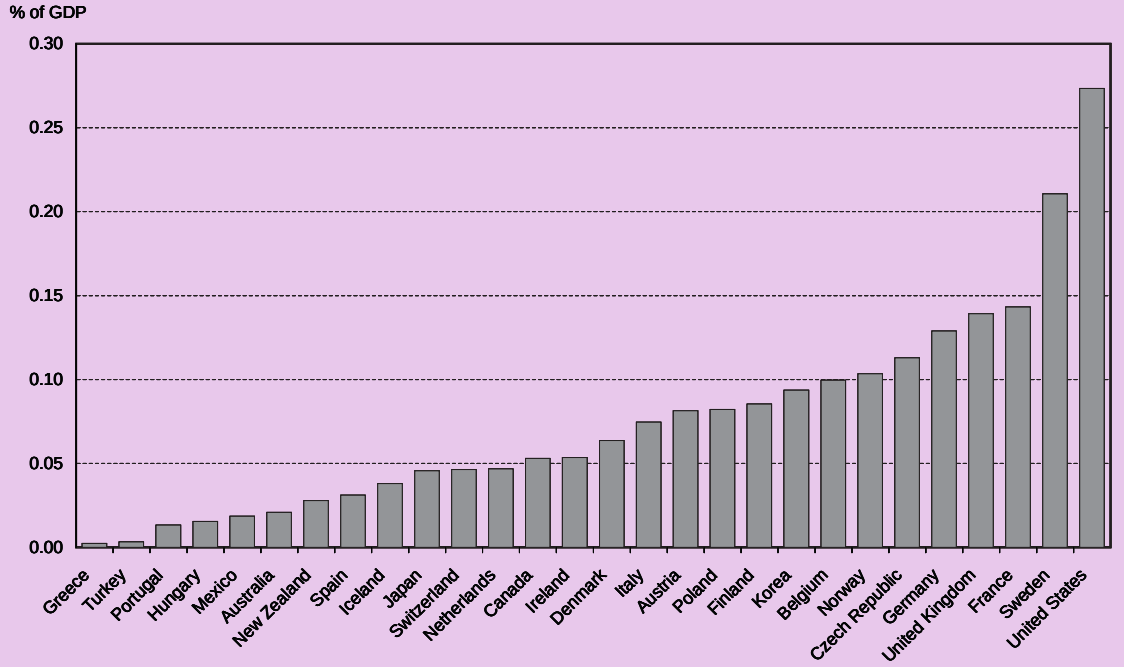
- Direct government funding of business R&D and tax incentives tend to be substitutes for each other; increases in one reduce the effectiveness of the other in stimulating R&D.
- The effect of tax incentives is short-lived and more effective when stable for a long period of time, thus allowing firms to integrate their value into longer-term planning.
- Increasing direct funding of R&D beyond a certain threshold (in this study, 13% of business expenditures on R&D) typically reduces its effectiveness.

Other characteristics of these mechanisms further influence the scope and optimal combination of effective government policies. Differences in the capabilities of direct and indirect financial measures imply that effective government support for industrial R&D should strike a balance between market-based incentives and direct funding of business R&D. Whereas market-based mechanisms, such as tax credits, can motivate increased levels of R&D throughout the business community, more direct forms of support (some of which is delivered via public/private partnerships) tend to be more effective in encouraging riskier ventures and directing industrial R&D towards areas with potentially large social and economic benefits.

In the case of *tax-based mechanisms*, individual firms determine how additional R&D resources will be spent, *i.e.* which technologies will be pursued and which firms will benefit. They apply, to differing degrees, to the full range of R&D-performing organisations. Largely for these reasons, tax incentives are an increasingly popular means of supporting industrial innovation.[11] Tax incentives appear, on average, to increase business R&D expenditures by an amount equal to the loss in tax revenue (Hall and Van Reenan, 2000), but their effectiveness is highly contingent on the precise nature of their design (HM Treasury, 2001). Whether they are based on a firm's total R&D expenditures or only the increment over a base level, and whether and not they contain provisions for firms without taxable revenues to carry forward credits to a future date can influence the size of the credit and the kinds of firms that benefit most. Tax incentives do not generally encourage established non-R&D performing firms to begin investing in R&D (European Commission, 2000), nor do they appear to influence corporate R&D strategies. Instead they act mainly as a financial tool to expand business R&D programmes at the margin (OTA, 1995). As a result, they are less likely to induce firms to pursue R&D projects that they would not otherwise support, than to hasten existing R&D projects. In particular, they do not induce firms to pursue R&D projects with higher social returns (*i.e.* technologies with significant spillovers or fundamental research).

In the case of *direct funding of industry research*, governments have greater influence over the work conducted. Hence this tool can be used to ensure that industry addresses important public missions that might not otherwise be addressed (and to maximise social returns to innovation) while relieving firms of the financial risk associated with more radical (and hence uncertain) technological pursuits. This approach, however, puts government in the position of selecting topics that receive attention and individual firms that receive government funds, raising the risk that governments may unduly interfere with market forces. If applied correctly, *public/private partnerships* can help mitigate the risk by allowing

Figure 4.13. **Direct government funding of business R&D as a percentage of GDP, 1999**



Note: The data indicate all government funding of business R&D, regardless of the mission for which it is intended. It includes defence-related R&D whose share in publicly financed business R&D is particularly high in the United States and, to a lesser extent, in the United Kingdom and France. It does not include the cost to government of indirect incentives for business R&D (such as tax credits).
Source: OECD.

industry and government to jointly identify and finance R&D projects. Involving multiple private sector participants in such partnerships can hasten the dissemination of results throughout the industrial community and encourage a focus on pre-competitive technology. As with other forms of direct government funding of business R&D, partnerships must be carefully managed to avoid capture by vested interests. Other risks involve diffusing programme objectives and dissuading firms from engaging their top researchers in the effort.

To the extent that governments provide direct funding for business R&D (Figure 4.13), they need effective mechanisms for selecting projects and partners. It can be expected that governments are better at assessing the needs of public missions (*e.g.* defence, health) than the commercial potential of innovations. Governments need to establish procedures and structures for soliciting needed information, whether through merit review panels or through the use of industry cost-sharing, to validate commercial potential and the spreading of risks. The use of more open, competitive processes for awarding funding can also ensure that individual stakeholders do not unduly influence government decisions or monopolise the results of publicly financed research. Balancing the objectives of knowledge diffusion with the legitimate rewards of appropriation expected by firms participating in public/private partnerships calls for policy guidelines relating to IPR management.

Exploiting mission-related R&D

Additional steps can be taken to tap the economic potential of government-funded R&D that is aimed at fulfilling other social objectives. In many OECD countries, the largest part of government funding of business-performed R&D is aimed at public missions that do not contribute directly to productivity as currently measured, such as defence, health, and environmental protection.

Government procurement of goods and services can provide an additional, indirect stimulus for mission-related business R&D. For instance, mission-oriented R&D can generate opportunities to develop generic technologies or advance fundamental research in the course of these other activities. This path has been productively pursued in the United States, where a significant amount of health-related R&D expenditures have been aimed at fundamental research, *e.g.* in the life sciences, that laid the groundwork for many biotechnology companies. The US Department of Defense has exerted similarly strong influence on the ICT industry by investing in R&D related to fundamental computing and communications technologies, such as packet switching (the basis of the Internet), human-computer interfaces (which produced the computer mouse and graphical user interface), and artificial intelligence. Much of this work has been supported by the Defense Advanced Research Projects Agency (DARPA), an organisation chartered to pursue new technologies with potentially far-reaching military applications, but not necessarily tied to ongoing weapons development programmes.

Further opportunities exist for pursuing dual-use technologies that meet both commercial and defence needs. The end of the Cold War, the rising cost of weapons systems, and the growing predominance of the civil sector in driving technological development, all call for major changes in the priorities and organisation of military research. Such changes can reduce the costs and improve the relevance and quality of military research while simultaneously contributing to increased economic spillovers. They may take any of several forms:

- Regulatory reforms, such as the Federal Acquisition Streamlining Act of 1994, which made it easier for the US Department of Defense to procure technology from commercial sources in the United States.
- Institutional reforms, such as the creation in 1995 of the Defence Evaluation and Research Agency in the United Kingdom, which oversees military R&D programmes, but with an explicit mandate to promote dual-use technology development.
- Specific incentive programmes to promote greater synergies between military and civilian research, such as the Dual-Use Applications Program in the United States.

Actions in each of these areas have helped to enhance the contribution of defence R&D expenditures to the commercial sector.

Re-evaluating small business R&D *programmes*

Programmes to support small and medium-sized enterprises (SMEs) can be tailored to match the changing environment in which SMEs operate. SMEs play an increasingly important role in national innovation systems, both conducting a growing share of R&D and helping mediate the interface between university research and industrial innovation (Pavitt, 2000). New technology-based firms are commercialising technology invented in universities, and frequently either blossoming into larger firms, or being acquired by them (see Chapter 5 on entrepreneurship). The importance of SMEs to the economy has resulted in the establishment of a range of government programmes specifically aimed at R&D in SMEs.[12] These programmes are typically justified by the social and economic benefits created by SMEs, as well as by the particular challenges these firms are perceived to face in the marketplace. The latter include difficulty in raising capital for R&D investments, a lack of complementary assets or intellectual property protection to help them appropriate the benefits of their innovations (Teece, 1987; Anton and Yao, 1994), and difficulties in competing for government R&D funding.

The situation facing small and medium-sized enterprises is changing in a number of respects. Not only are SMEs capturing a larger share of government R&D funding, but also their potential for creating value has been recognised by the venture capital community, resulting in a rapid influx of private funding in a number of OECD countries. The overwhelming majority of this private venture funding to date has flowed to firms in the ICT and biotechnology sectors, especially in the United States. Although venture capital does not aim at supporting R&D *per se*, its substantial emphasis on small, high-technology businesses has enabled markets to become considerably more capable of sustaining large, risky investments in R&D in early business stages, in some countries more than others. Considerable

differences remain in the size of country's venture capital markets and in the kinds of venture capital investments made in them. For example, while most venture capital investment in the United States is channelled into early-stage companies, venture capital in several other countries is oriented towards later-stage expansion and management buy-outs.

It is important that governments re-evaluate and revise their strategies for funding R&D in small companies to ensure that they better complement – and avoid crowding out – private investments. The influx of venture capital does not necessarily remove the rationale for government support for SMEs because significant discrepancies can still exist between private and social returns to R&D and innovation, even in sectors that receive considerable private capital. Recent research indicates that the most successful government-funded small-business projects have been in industry sectors that boast high levels of private venture capital (Gans and Stern, 2000).[13] This finding suggests that private venture capital signals the presence of significant technological opportunities in a field, and that government funding can stimulate additional exploitation of those opportunities. The key to ensuring that government funding does not crowd out private investment is to ensure that small firms have exhausted their opportunities for private support before seeking public support, such as by requiring recipients of government funds to secure matching funds from the private sector.

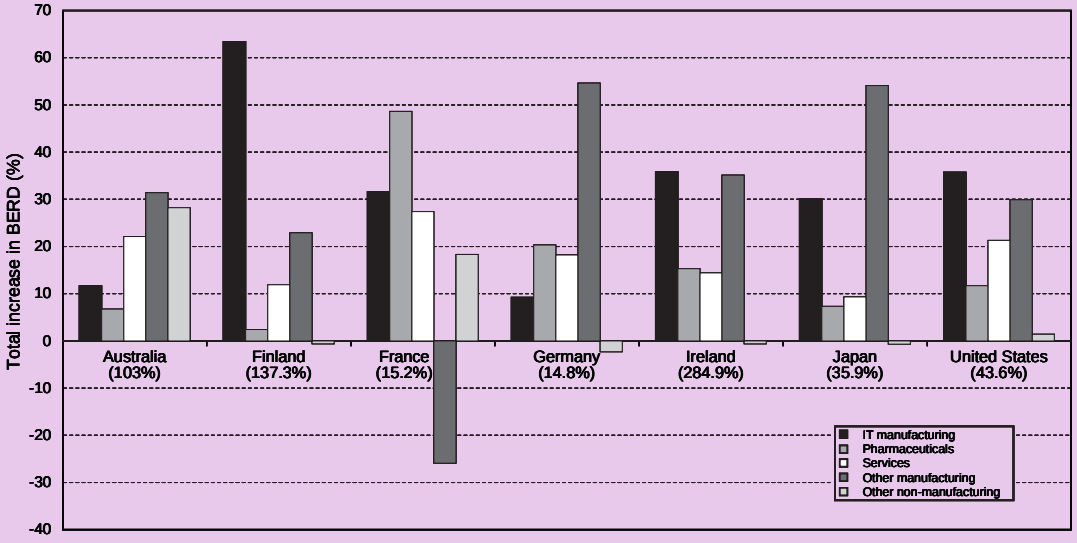
Increasing the flexibility of government financing

Flexibility is important to ensuring the effective use of public R&D funding. High levels of flexibility allow governments to appropriately shift R&D funds into areas of increasing social or economic importance. The scientific output of the United States, for example, is more highly specialised in fields related to ICT and life sciences than is that of Japan and Germany, and this may have contributed to its stronger economic performance in the 1990s (Figure 4.12 above). Future scientific discoveries or technological breakthroughs could open up new opportunities for industrial innovation and economic growth. Governments may want to ensure a match between their R&D investments – especially those in knowledge creation – and industrial R&D investments, which can signal industry's ability to capitalise on new knowledge and convert it into new products, processes or products.

While business R&D used to be stable compared to many other economic activities, it can now shift fairly rapidly across industry sectors, corresponding to the differential growth rates of different industries in OECD countries. In Finland, for example, where total business expenditures on R&D (BERD) more than doubled between 1990 and 1998, approximately three-quarters of the increase came from the ICT, pharmaceuticals and service sectors – 60% from ICT alone (Figure 4.14). Similarly, in the United States, which saw a 44% increase in BERD during this timeframe, more than 70% of the growth came from ICT, pharmaceuticals and services.[14] This situation contrasts to that in Germany and Japan, where more than 50% of the growth in BERD resulted from increases in more traditional manufacturing sectors such as transportation equipment and machinery. Australia also presents an interesting case, because it experienced significant growth in R&D – and significant growth in GDP and MFP (OECD, 2000*j*) – but almost 60% of the growth in BERD was in other manufacturing industries and in non-manufacturing areas other than services.

Shifts generally occur much more rapidly in business R&D than in government R&D, and countries exhibit significant differences in their ability to respond.[15] In the United States, for example, federal government funding for research in computer science grew faster than funding for any other major discipline, increasing at an average rate of 14% per year, from USD 671 million to USD 1.4 billion in constant dollars (CSTB, 2000). Growth in funding for medical research was second, increasing at 8.5% per year.[16] In contrast, federal R&D expenditures in Germany (which account for about half of Germany's total government R&D funding) declined in nominal terms from DEM 17 billion in 1991 to DEM 16.2 billion in 1998. Funding for information technology grew, but at a rate of only 1.8% annually. Funding for biotechnology grew much more quickly, at a pace of 7.6% a year (BMBF, 2000). The development of new market mechanisms for financing risky projects (venture capital) and increased global networking in R&D activities has also lagged activity in the private sector (OECD, 2000*i*; OECD, 1998*a*, Chapter 7).

Figure 4.14. **Distribution of the growth in business R&D by industry, 1990-98**



Note: Information technology manufacturing includes office, computing, and accounting machines, communications equipment, and electronic components. The decline in R&D in other manufacturing industries in France derives from steep reductions in defence expenditures (OST, 2000).
Source: OECD ANBERD Database, November 2000.

The flexibility of government R&D can be increased in three ways, each of which has inherent strengths and weaknesses:

- Governments can redirect public funds to those bodies that are most responsive to change. Industry is generally able to reorient resources more quickly than universities and government labs, but shifting government resources towards industrial R&D may place fundamental, long-term research at risk. Universities are potentially more flexible than government labs because they typically conduct research across a broader range of fields and respond to changing student interests, but their disciplinary structure can impede rapid redeployment of resources and the carrying out of interdisciplinary research.
- Governments can make greater use of funding instruments that permit them to more rapidly shift investments among fields of science and technology or among institutions. Short-term contracts and grants, for example, allow greater flexibility than broader-based institutional funding. An over-reliance on short-term funding mechanisms can, however, undermine the stability needed to allow R&D with long time horizons, suggesting the need for a balance between different kinds of funding instruments.
- Governments can attempt to increase the ability of public research organisations (*e.g.*, universities and government labs) to reorient their research programmes in response to emerging needs and opportunities. Reforms in the way such research institutions are organised, managed, funded and evaluated could help them become more agile and more capable of redirecting resources to fields of growing importance – without sacrificing their specific missions. Such reforms are discussed in the following section.

Enhancing the contributions of public research institutions

Increasing the social and economic returns from public research institutions often requires that changes in government financing of public R&D (as outlined above) be accompanied by compensatory

changes in the incentive structures and the capabilities of universities and government laboratories. Without such measures, financial pressures to redirect the strategies of public research institutions could prove ineffective and even counterproductive. Both the structure of public research institutions and the way in which they interact with industry often need reform. Although the kind of changes implemented in different countries will need to be tailored to the specific strengths and weaknesses of their existing institutions, the experiences of the leading countries can highlight the types of steps that may be most effective in increasing the contribution of public research institutions to economic growth.[17]

Of course, the ability of public research institutions to contribute to growth will be constrained by the fact that many of them will continue to serve other primary missions. Although the goals of such institutions differ from one OECD country to another, most public laboratories support specific government missions, such as health care, environmental protection, energy or defence, that contribute indirectly to economic growth. Universities will continue to emphasise education and training of high-skilled workers and the creation of fundamental scientific and technical knowledge (*i.e.* curiosity-driven investigations in universities). Attempts to boost the economic contributions of public research institutions could, if not properly managed, compromise their ability to fulfil their primary missions. Nevertheless, steps can be taken to improve the ability of such organisations to include economic growth as a secondary mission. In some cases, it may be appropriate for governments to shift R&D resources from other missions to innovation and economic growth.

Structural and organisational reforms

Experience from countries such as the United States, the United Kingdom and Australia shows that universities can make effective contributions to industrial innovation. The current strength of the US biotechnology industry, for example, derives largely from life-sciences research conducted in the university sector; similarly, the nation's booming ICT industry has benefited from a series of advances (in areas such as networking, computer graphics, and microprocessor design) pioneered in university labs (CSTB, 1999). The ability of universities to contribute to industrial innovation derives from their ability to produce fundamental knowledge in fields related to industry interests and seed future innovation. Universities also play an important role in developing the human resources that are needed to conduct innovation. Many scientists and engineers trained in universities move to private industry and help firms develop, transfer, absorb and exploit technology from other sources. They are increasingly involved in entrepreneurial ventures, such as spin-offs, that help bring new technologies to the marketplace.

Strengthening the contribution of universities to industrial innovation cannot be achieved by simply increasing funding for university-based research. Public funding for university research grew in many OECD countries during the 1990s, but universities achieved varying degrees of success in commercialising the results of their research. The reasons are varied, but centre around the ways research priorities are established, R&D funding is allocated, and resulting intellectual property rights are managed. Many universities, for example, lack strong research programmes in fields with significant economic implications. This shortfall can be addressed by building on existing strengths in individual institutions (and strengthening ties to industry), but additional efforts may be needed to develop new capabilities in under-represented, yet potentially important fields. Countries that rely on institutional models of funding university research (*i.e.* in which research funding is included with other core university funding and allocated across departments by the university itself) may face difficulties in making such changes, as their governments have limited ability to steer university research to areas of emerging societal importance. Requiring universities to compete for a portion of their government R&D funding would afford governments greater opportunity to influence research directions, but institutional funding would remain important in supporting fields with little immediate social or economic potential and in preserving the freedom of academic research.

Changes in the management and structure of public university systems could also improve the ability of universities to contribute to economic growth. Tight centralisation of university systems can limit the autonomy of individual institutions to respond rapidly to emerging scientific and technological

opportunities and enter into mutually advantageous partnerships with industry (OECD, 1998*b*). Some degree of centralisation is needed to establish general guidelines governing university-industry relations and to boost the overall quality of university systems. More decentralised systems, in which universities enjoy greater freedom in developing institutional policies governing research and relations with industry, are likely, however, to respond more effectively to emerging opportunities (OECD, 2000*k*). Further structural reforms may be needed to help universities overcome disciplinary boundaries that dominate their structure, management and administration. Universities will be increasingly challenged to find ways of ensuring that emerging interdisciplinary fields (*e.g.* sustainable development, nanotechnology and bioinformatics) receive sufficient attention from university researchers. New managerial structures for organising such research and for evaluating its results may be desirable.

Government laboratories face an even more daunting set of challenges. While government laboratories have made numerous contributions to industrial innovation and economic growth,[18] recent econometric analysis shows that the effects of publicly funded R&D on productivity growth are larger in countries that devote more of their public research budget to universities rather than government labs (Guellec and van Pottelsberghe, 2001). This result reflects the fact that in some countries the very nature of the R&D missions entrusted to government labs limits the generation of economic spillovers. But additional structural impediments also appear to be in place. Although their size and research portfolio are diverse (Table A4.4 in Annex), public labs in a number of countries face common problems related to ageing staff, blurred missions and relative isolation from the main streams of knowledge exchange and from the education system. Government labs do not generally participate in training students who can transfer knowledge to industry, and the disciplinary nature of many labs can impede their attempts to conduct research in emerging interdisciplinary areas.

Opportunities exist for increasing the ability of public laboratories to contribute to economic growth. A number of OECD countries, including the Netherlands and Norway, completed evaluations of their public laboratories and introduced reforms that resulted in clearer missions and a stronger market orientation. These reforms have changed institutional structures and funding models to create incentives for laboratories to work more closely with industry and to give industry a greater voice in shaping the research agenda of such institutions. Germany is also considering changes in its laboratory system to boost its effectiveness and economic contribution (Box 4.3). Experience to date suggests that attempts to overcome institutional barriers and broaden the strategic directions of public research organisations are most effective if they offer managers and staff of public research organisations significant potential benefits from entering the market for knowledge, such as opportunities for career development; new sources of funding; or new directions and expertise for research in some fields.

Governments can take additional steps to increase synergies among public research organisations, especially in countries where public labs are major players. One approach is to develop further ties between universities and public labs in order to strengthen the role of labs in training S&T workers (*e.g.* CNRS labs within universities in France). A second approach is to provide a stable meeting place for collaborative research (*e.g.* co-operative research centres in Australia and Austria). A third approach is to use catalytic programmes (*e.g.* thematic research networks or programmes in France, Japan, the Netherlands and the United States) to encourage public labs to collaborate on a set of linked projects. A fourth approach builds on existing "bridging" organisations (*e.g.* the Fraunhofer in Germany) that are chartered to operate at the interface between universities, government labs and industry.

Evaluation processes for publicly funded research must also evolve if universities and public laboratories are to engage in research that is more closely related to economic interests and in fields of growing importance. Strong evaluation processes at the government level will be especially important if universities are given greater autonomy in allocating resources, but great care must be taken to ensure that excessive evaluation does not impede the conduct of good science. Evaluation criteria will need to take into account both excellence in research and training of graduates and impact on society. The evaluation of researchers of many public institutions should also be reformed to include the impact of their research results on society, as well as on the advancement of their own discipline. At the institutional level, evaluation processes need to be revised to accommodate interdisciplinary research.

Box 4.3. **Reforming public laboratories in Norway and Germany**

Reforms in Norway

Public laboratories have traditionally played an important role in Norwegian R&D policy. In 1997, these institutes performed 26% of all R&D in Norway. Until the 1980s all publicly funded technological and industrial research was carried out in designated public labs owned by the Norwegian Research Council for technical-industrial research (NTNF). It became increasingly clear that the double function of priority setting for R&D support and management of a large number of research organisations was undesirable.

It was thus decided in the early 1980s to separate the two functions and to create a more decentralised system. The public labs were transformed into market-oriented research institutes that received a combination of basic institutional funding and programme funding.

In the late 1980s, the system of funding the institutes was changed. Only industrial firms could apply for project funding under the new model, called user-oriented management of R&D.

Since that time, the system for funding of research institutes has been further transformed and now consists of three parts, of which the first two account for 10%-20% of an institute's typical turnover: basic institutional funding; strategic, institute-level programmes; and competitive programme or project funding with industrial partners.

The successive changes over the past 20 years have led to a better division of tasks and responsibilities between the public agencies responsible for strategic task and priority setting and the labs.

Proposed reforms in Germany

Germany established 16 public labs* between 1956 and 1992. These labs employed a staff of 23 000 people in 2001, and received approximately DEM 3 billion a year in institutional funding – equivalent to 25% of all public R&D funding.

The laboratories have been criticised for the lack of co-operation between institutions and a lack of flexibility in their research approaches. A recent evaluation of these public labs showed that their potential and resources were not being used efficiently. A proposal has therefore been made to gradually move away from an institutional funding of these institutions to a programme-oriented funding, with the objective of allocating resources along the lines of thematic research programmes that cross institutional boundaries and on the basis of an external evaluation in line with international standards.

In the proposed system, the government would set priorities for the programmes to be funded after consultation with the science community, the business sector and the labs concerned. Programme portfolios, running over several years and defining clear interim milestones, as well as the share of work and budget of the institutions involved, would be established for individual research subjects. Research proposals submitted on this basis would be evaluated *ex ante* by an international evaluation team. The government anticipates that this reform would produce several benefits:

- More focused allocation of R&D funds with greater transparency in regard to priority setting, selection of research proposals, and allocation of funds.
- Improved planning security due to the fixed-term nature of the programmes.
- Greater competition for resource allocation tempered by increased networking between institutions and improved international collaboration.
- Strengthening of scientific excellence, promotion of interdisciplinary research and co-operative research approaches with industry.

* Public labs in Germany (*Grossforschungseinrichtungen*) are research institutions outside the universities (not including Fraunhofer or Max-Planck institutions) which are jointly funded by the Federal government (90%) and the *Länder* governments (10%).

The existing disciplinary structure of most universities and some public laboratories can impede work that spans multiple disciplines, in part because resulting evaluation criteria cannot accurately judge the intellectual merit of the work or its possible societal contributions.

Strengthening technology transfer mechanisms

In addition to structural and organisational changes, policy makers also need to take specific steps to strengthen the mechanisms for transferring technology from public research institutions to industry. Stronger technology transfer mechanisms can enable university and government researchers to better appreciate the technical problems faced by industrial enterprises and to more effectively transfer new knowledge to industry, whether through flows of people or technology. Without sufficient technology transfer, new knowledge created by the public sector research cannot be readily commercialised by the business sector, thus reducing the impact of public R&D funding. Greater attention must be paid to the interface between knowledge creation in public research institutes and the transfer of that knowledge to industry where it can be applied to new or improved products, processes and services.

Public research can be transferred to the business sector in three primary ways. First, public research organisations can spin off new firms that attempt to commercialise technology they have developed internally. Second, they can patent their inventions and attempt to licence them to new or extant companies. Third, they can engage the private sector in co-operative research projects with industry. All three of these avenues appear to have gained in importance in high-growth countries. Although limited data exist on spin-off formation across the OECD, the United States appears to generate a much larger number of spin-offs per dollar of public R&D funding – followed by Canada – than do other OECD countries and the rate of spin-off formation appears to be growing (Figure 4.7). The number of patent applications filed by US universities has grown steadily since the 1970s, while patent applications from US government labs peaked in the mid-1990s (Figure 4.8). And, although the fraction of scientific papers resulting from co-operation remains small, their number grew by 50% in absolute terms between 1987 and 1996 (Figure 4.9).

The allocation of intellectual property rights resulting from public research is key to creating appropriate incentives for vibrant industry-science relationships (OECD, 2000*k*; 2001*t*). In nearly all OECD countries there has been a trend towards transferring ownership of publicly funded research results from the state (government) to the (public or private) agent performing the research (Box 4.4). Where countries differ is in the allocation of ownership among performing agents (research institution *vs.* individual researcher). A good practice is to grant IPR ownership to the performing research organisation but to ensure that individual researchers or research teams enjoy a fair share of the resulting royalties (Table A4.5 in Annex). Globalisation of research networks makes such differences more noticeable and suggests a need for further efforts to harmonise IPR regimes and practices.

In general, governments should support development of the all the main channels through which public research contributes to innovation and should leave to individual research organisations the freedom to emphasise those approaches that best fit their research portfolio and industrial environment. A friendly regulatory environment will often suffice to promote public/private linkages through labour mobility, licensing activities and research partnerships. Effective technology transfer often arises spontaneously as researchers in the public and private sectors seek out the expertise they need to carry out a particular research project. In some cases, however, additional efforts are needed. Spin-offs from public research organisations, for example, can face significant challenges in attracting seed capital to help finance early-stage investment, because uncertainty is too high or the size of projects too small for private venture capital. Additional policy measures, such as financial support for spin-offs or the granting of exclusive licences for public research results, can be used to overcome such obstacles (Box 4.5).

Governments can take a more active role in encouraging improved industry-science relations through collaborative research, but the success of such efforts is mixed. Some R&D programmes in the United States, Japan and the European Union have attempted to forge collaborative R&D alliances between public research institutions and industry either by requiring collaboration as a basis for receiving government R&D funding or by favouring joint proposals in awarding competitive funds. Examples include the Advanced Technology Program in the United States and the European Commission's Framework and BRITE EURAM programmes. While bringing together researchers from different countries, companies and institutions, such programmes suffer from a number of drawbacks,

Box 4.4. **Managing intellectual property rights (IPRs)**

Intellectual property is increasingly recognised as a global asset that needs to be strategically managed. Many OECD countries have recently broadened and strengthened the laws and regulations covering intellectual property protection in order to increase incentives for innovation and improve returns on these investments. The changes in intellectual property regimes have influenced the behaviour of firms and research organisations. Throughout the 1990s, the number of patent applications and patents issued in Europe, the United States and Japan grew substantially. These increases may reflect a real rise in innovative activity, but they are also linked to the explosive growth of patent-intensive fields, such as biotechnology and ICT, and increased recognition of the strategic role of IPRs as a currency that allows firms to compete and co-operate.

Industries vary tremendously in the type of intellectual property protection that is relevant to their activities. Patent protection is considered essential for pharmaceuticals, medical technologies and biotechnology. Software developers use a mix of patents and copyrights to protect code, but open source software is gaining in popularity. Such new technologies continuously challenge governments to search for the correct balance between the commercial need for incentives to innovation and the public need for disclosure and access to innovations. Governments should attempt to maintain stability in intellectual property regulations, but must determine whether a new balance needs to be struck between public and private imperatives for research and innovation as new technologies emerge and eventually mature.

To improve the diffusion and commercial impact of publicly funded research results, many OECD countries have experimented with novel approaches to the regulation and institutional management of intellectual property resulting from publicly funded research. Policy measures aim to:

- *Increase predictability and reduce transaction costs*. Regulations governing the ownership of intellectual property often vary within a country according to researcher status, the type of performing institution, or the source of the funding. Governments have tried to make patent and licensing procedures more uniform in order to simplify the transfer of research results to the private sector by standardising ownership rules for publicly funded and publicly performed research.
- *Increase incentives to commercialise*. Exploiting intellectual property is a time-consuming and costly business. Public research organisations (PROs) cannot afford investments in the needed infrastructure and skills if they cannot be assured of sufficient remuneration (*e.g.* through licensing or other fees). Some countries provide subsidies for local or institution-based technology transfer and licensing offices. Other countries let PROs elect title to their innovations in exchange for the promise to seek protection and eventually exploit the invention, thus letting the PRO profit from its research results.
- *Decrease costs of protection and exploitation*. For universities, public laboratories and SMEs, the cost of applying for, maintaining and defending patents represents a burden that governments are seeking to reduce. Application and maintenance costs can be reduced or waived for these institutions, and mediation rather than litigation encouraged.
- *Limit restrictions on publication and scientific enquiry.* Licensing agreements and research contracts can contain clauses that hamper the ability of scientists to continue their exploration in a field or slow the diffusion or access to fundamental research results by other researchers. To minimise clashes between the research and teaching mission of PROs and their commercial activities, governments can play a role in limiting the contractual demands placed on PROs.

including the different objectives and time horizons of private and public sector researchers. They can also accentuate and strengthen existing networks of researchers instead of stimulating the formation of new networks with new participants.

As an alternative, by taking a more systemic approach to funding R&D, governments may foster stronger networks and linkages between industry and universities. Rather than requiring collaboration in specific research proposals, for example, they can fund a portfolio of related research projects that involve researchers from industry, universities and government laboratories as appropriate. The Nordic countries pioneered a systemic approach to technology and innovation policy that emphasises clustering and networks to enhance knowledge exchanges (Pentikaïnen, 2000; OECD, 1999*a*) through such mechanisms.

Box 4.5. **Public research spin-offs**

Public research based spin-offs are small technology-based firms whose intellectual capital originates in a university or a public research organisation (PRO). Public spin-offs encompass: *i*) firms whose founding members include a student, faculty or staff person; *ii*) firms which licence key technologies from the parent institution; and *iii*) firms housed in a PRO incubator facility or which are directly established by the parent public research institution.

Since the 1980s, the number of spin-offs from the public sector has risen steadily. The phenomenon is most evident in North America and Europe. According to the Association of University Technology Managers, the top US and Canadian research institutions see on average about two new start-ups per year. European countries are also reporting more public sector spin-off activity. German data indicate the most impressive growth but relative to the United States, European institutions are generally still lagging behind. In smaller countries like Belgium and Finland, prominent research institutions generate about one spin-off every two years on average. The generation of spin-offs is highly skewed toward "top institutions" in these fields information technologies, biotechnology and biomedical technology, and electronics.

Spin-offs serve as a direct channel for bringing publicly funded know-how and technology to the market. When successful, spin-offs create revenues for the parent institution through licences or sales of equity positions, and generate tax revenues through service or product sales. Spin-off companies also create employment, especially for high-skilled personnel in science and technology, although the greatest gains are probably in ancillary firms such as suppliers and customers. Public spin-offs represent a very small sub-population of new firms, even corporate spin-offs are far more numerous.

Spin-offs have very high survival rates compared to new firms on average. However, they also tend to have low growth rates and remain very small companies in their first decade. Many public sector spin-offs retain close ties to their parent and support themselves through contract research or consulting, thus acting as mediators between public research and its possible commercial application. The entry of such flexible, innovative firms can give rise to novel economic sectors or play a role in the development of high-technology clusters.

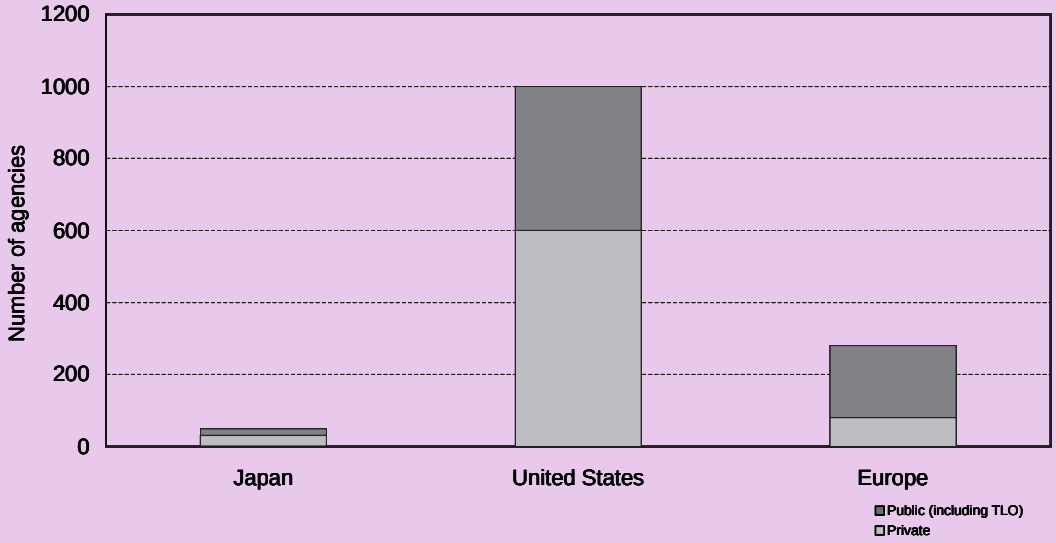
Governments should first and foremost continue to improve the environment for entrepreneurship – through such actions as devising policies for greater researcher mobility, access to risk capital and better IP awareness. An economy with support services for new firms and strong networking among institutions will be better prepared to welcome public spin-offs.

In many countries, additional efforts are needed to create a basic infrastructure supporting spin-offs, such as ensuring that public institutions have easy access to professional intellectual asset management and networking services. Central governments can provide incentives for the formation of technology licensing and transfer offices within PROs, especially by allowing these to retain title to their innovations. They may also need to grant PROs the authority to negotiate exclusive licensing agreements in those cases in which exclusivity is necessary to spur firm creation. The high cost associated with intellectual asset management can be partly alleviated by reducing patent filing or maintenance costs for PROs.

More effective have been attempts by governments to establish policy frameworks and implement organisational changes that stimulate industry-science relations, especially at the local level where policies have the strongest impact and can reach all actors, including SMEs (OECD, 2000*k*; 2001*t*). Growth in patenting in the United States, for example, received significant stimulus from the 1980 Bayh-Dole Act which extended patent protection to publicly funded research and allowed public research organisations to licence patent rights to the private sector, using exclusive licences, where necessary, to bolster technology adoption. Additional impetus came from legislation that allowed government laboratories to enter into co-operative research and development agreements (CRADAs) with industry and mandated the establishment of technology transfer offices in government laboratories.

Many universities have established technology licensing offices to help researchers file patent applications and negotiate licences with private firms. In this respect, the United States continues to have an edge over Europe and Japan (Figure 4.15). Nevertheless, the role of intermediary organisations that help transfer technology between public and private organisations will need to be re-evaluated in the light of changes in the environment for innovation. These changes include the more direct relationships that have emerged between public research organisations and industry, the booming private sector market for technological services, and the increasingly multidisciplinary nature of many innovations.

Figure 4.15. **Intermediary agencies for the transfer of intellectual property rights**



Note: Japanese data are for September 2000; US data are for March 1997 (approximate number); data for Europe are for March 1998 (approximate number).
Source: Japanese Ministry of Trade and Industry (MITI).

Policies to promote greater contribution of public research to economic development must avoid a number of major pitfalls. They should:

- Avoid distorting the market for contract research by allowing (or encouraging) subsidised public research institutes to compete unfairly against private sector research firms. This measure is meant as much to protect fair competition in the marketplace as to ensure that universities do not forsake their mission to generate new knowledge through fundamental research in order to increase the relevance of their work to industry. Policies requiring universities to recoup the full costs of contract research – including overhead costs – may be one way of ensuring a level playing field in the market for private research firms, although continued vigilance will be required to ensure the character and quality of university research.
- Avoid pushing unequipped and inexperienced universities into a patenting race. Evidence from the United States indicates that, as university patenting has increased steadily in recent years, the average quality of university patents (as measured by citation statistics) has declined: universities with a long history of patenting continue to generate the most highly cited patents (Mowery, 1998).[19] While lower quality patents pose no direct risk to industrial innovation, they do represent an ineffective use of public resources.
- Protect the freedom of scientific inquiry and the dissemination of scientific knowledge. When more and more researchers have direct financial ties to the companies sponsoring their work, there is a risk that industry funding restricts dissemination or biases the results of research, *i.e.* reduces the scope for independent scientific expertise (Cho, 2000; Press, 2000).

Enhancing the mobility of scientific and technical workers

The mobility of workers between sectors and firms is particularly important for innovation, not only because of the productivity gains that can result from a more efficient allocation of labour, but also because of the effect on the diffusion of knowledge and technology. Mobility can also foster renewal of

R&D organisations through new recruitment. High levels of mobility have been a hallmark of industry-science relations in the United States for decades. It is estimated that in United States, scientists and engineers change jobs every four years – even more often in sectors such as information technologies. In Japan, only 20% of engineers change jobs, mainly at a later stage in their careers. Evidence from the Nordic countries (Sweden, Denmark, Norway and Finland) shows a relatively high rate of movement of highly educated personnel from public research institutions to other sectors of the economy. The outflow mobility rates are highest in Sweden where knowledge institutions deliver human resources to approximately eight sectors, while the corresponding figures for the others are six for Norway, five for Denmark and four for Finland (OECD, 1999*a*).

In many countries, public research institutes have been privatised or have spun off activities for commercial purposes, affecting employment relations, research prerogatives and training requirements. In Japan, for example, a large number of young S&T personnel in the public research sector are employed in non-tenured posts or part-time positions. This trend towards more flexible employment arrangements in the public research sector is also observed in the United Kingdom and the United States where there has been an increase in graduates entering non-tenured and temporary academic employment.

Regulatory barriers continue to weigh on mobility in several OECD countries. In many OECD countries, researchers in universities and government laboratories are considered as government employees, subject to rules that restrict their ability to consult for private firms, spend sabbaticals in industrial research organisations, or hold equity positions in private firms. Combined with the legacy of massive recruitment in the 1960s and 1970s that has hindered the inflow of new scientists into the university sector, such restrictions limit the ability of the public research sector to collaborate on a personal level with the private sector or to start new technology-based firms. Some countries such as France have undertaken regulatory reforms to permit mobility and collaboration between public researchers and industry while retaining employment rights in public research. Reforms in the science system that allow academics to co-operate with industry in the framework of public-private partnerships can enhance mobility and flows of tacit knowledge. Pension portability is another important factor. Of course, loosening restrictions on mobility requires that governments set basic rules to protect the public interest, such as ethical guidelines to prevent or resolve conflicts of interest.

Conclusions and policy implications

Evidence shows that the ability to harness the potential of science, technology and innovation to improve growth performance has been diverse among OECD countries. Innovation is not always based directly on R&D; it often involves organisational as well as technological change and requires sizeable complementary investments in areas other than R&D (*e.g.* worker training, manufacturing, marketing). Nevertheless, higher levels of R&D intensity are correlated with higher levels of economic performance. R&D appears to be growing in importance as economies become more knowledge-based and fast-growing new industries become more science-based. OECD work in areas such as the management of innovation and science systems, public funding of R&D, industry/science relationships, development of high-tech spin-offs and management of IPRs, shows that the countries that have fared best are those that have successfully adapted their S&T systems to evolving patterns of innovation, enhanced interactions between the private and public sector, and improved framework conditions for innovation. Although much depends on the specific characteristics of national innovation systems, there are important policy lessons be learned and adapted by those countries that have lagged behind. For the most part, these lessons do not require an expanded scope of government action, but rather a more refined use of existing policy tools. Industry has an important role to play, too, in adapting its own practices related to R&D investment and sourcing, knowledge management and industry/science linkages. Changes in government policy may be able to point the way for industry-based initiatives. Below are the main conclusions and policy recommendations for governments to consider as they attempt to promote innovation-led economic growth.

Innovation is an increasingly important contributor to sustained and sustainable economic growth. Innovation generates improvements in labour quality and capital stocks and is the main source of growth in multifactor productivity. Beyond its contribution to economic growth and efficiency, it facilitates the fulfilment of other societal needs, such as improved health and environment protection.

Greater formal and informal knowledge-sharing among* R&D*-conducting firms, as well as support to* SME*s by application-oriented research organisations, are critical for boosting innovative effectiveness. The effectiveness of R&D appears to be higher where the number and variety of R&D performers is greater and where the scope for market transactions of knowledge (*e.g.* through licensing, mergers, and acquisitions) is larger. Although informal networks that ensure the diffusion of tacit knowledge are vital components of innovation systems, important efficiency gains can be derived from increased market-based transactions of codified knowledge and effective regimes of IPR protection. Policies, including international co-operation, that facilitate patenting and lower its cost to firms can therefore improve countries' ability to innovate.

Openness to international flows of knowledge is increasingly important to innovation performance. As the innovation process becomes more global, firms and research institutions draw more on international pools of scientific and technical expertise. This is particularly relevant for smaller countries that rely on external sources of knowledge to supplement their more narrowly focused domestic R&D efforts, but it is of growing importance for larger countries as well. National policies must therefore attempt to both strengthen the domestic R&D base to augment its absorptive capacity and develop international linkages throughout the science and technology system.

A high rate of complementary public and private investments in* R&D *is a prerequisite for sustained innovation performance. Government financing of R&D remains critical in ensuring the generation of the fundamental scientific and technical knowledge that increasingly seeds innovation, and in correcting for other market failures that impede business R&D, especially in SMEs. However, considerable variation exists in the performance of countries with similar levels of R&D investment. At least as important as the level of government R&D funding are the ways in which this funding is channelled (*e.g.* the types of institutions supported, the mechanisms used to finance R&D) and the ways in which public research organisations are structured and managed.

Countries differ in the particular initiatives that can most effectively improve their capabilities in both these areas in order to boost the innovative capacity – and the growth potential – of their economies. Not only do countries have different objectives and different starting points for reform, but no single approach offers the best solution. Countries with low levels of R&D may find it more effective to pursue a broad range of policy initiatives to bolster public and private R&D expenditures using a mix of incentive programmes. Japan and large European economies with high levels of R&D intensity may benefit more from reforms to their public research institutions that would enhance worker mobility and industry-science linkages. The United States might wish to examine its support to small business R&D in light of the rapid expansion in venture capital in that country, and to clarify the regulatory framework of industry-science relationships in order to secure broad access to the results of publicly financed research, prevent conflicts of interest and avoid capture by private interests of vital pools of independent scientific expertise.

All countries could benefit from improved evaluation mechanisms and from greater use of such mechanisms in formulating and implementing reforms of their research and innovation policy. Steps that can be taken to improve the effectiveness of R&D funding include:

- ***Give greater priority to basic and long-term mission-oriented research in government* S&T *programmes***. Basic and long-term research – whether motivated by scientific curiosity or by the challenges facing industry and society – produce new scientific and technical knowledge that is increasingly important in driving innovation. Changes in business R&D strategies are generally accentuating longstanding disincentives for private industry to invest in fundamental research, thus heightening the need for government support.
- ***Ensure a better match between financial mechanisms to support business* R&D *and policy objectives.*** Tax incentives can enhance overall business R&D investment while minimising crowding-out

effects and *de facto* discrimination of specific firms or industrial sectors. Direct government funding is more effective at expanding technological frontiers in areas where a wide gap exists between social and private returns on R&D. Direct funding should be implemented through competitive mechanisms that involve the sharing of costs and risks between public and private actors, and should include regular evaluation procedures.

- ***Improve opportunities for commercial spillovers from mission-related* R&D.** Governments can improve the economic returns from their investments in mission-related R&D (*e.g.* in defence, health, energy, and environment) by emphasising fundamental research and development of enabling technologies with potential commercial applications.
- ***Restructure programmes to support small business***. Small businesses are an increasingly important element of national innovation systems and often face particular challenges in conducting R&D and becoming part of innovative networks of firms. Government programmes to support innovation in small firms must, however, avoid competing with and potentially crowding out the growing amounts of private venture capital that are available in some countries. Countries with limited early-stage venture capital may need to expand public R&D support programmes for a period of time or find other ways of linking small firms into national innovation systems.
- ***Increase the flexibility of public* R&D *funding*.** Greater use of competitively awarded programme funds can improve governments' ability to funnel R&D funding to areas of growing social and industrial importance. A significant core of institutional funding will still be needed to ensure diversity in the research portfolio of public research organisations.
- ***Pursue international co-operation in* R&D *programmes***. Co-operation can lead not only to more effective cost-sharing, but can also enhance international transfers of knowledge. Econometric analysis indicates that such spillovers make a significant contribution to growth, especially in smaller countries. Collaboration among private sector organisations is particularly important, but may need to be seeded by collaboration in government-sponsored (or cost-shared) programmes.

Steps that can be taken to enhance the contribution of public research organisations include:

- ***Restructure public laboratories and universities***. Public laboratories can be made more responsive to emerging needs by establishing new mechanisms for priority-setting and funding that reflect industry input and tie funding to performance, as well as by strengthening their links with the training and education system. Universities would benefit from greater autonomy in decision making coupled with more programmatic R&D funding. Additional efforts to break down disciplinary boundaries would enable both public laboratories and universities to better channel their efforts in emerging scientific and technical areas.
- ***Strengthen mechanisms for transferring knowledge from the public to the private sector***. Regulatory reforms related to IPRs and the licensing of publicly funded research, institutional reforms (such as the establishment of technology licensing offices, public/private partnerships in funding R&D, stimuli for co-operation with business, and support to spin-off formation) can improve the ability of public research organisations to transfer knowledge and technology to the private sector.
- ***Make greater use of competitive funding instruments in supporting public research institutions***. Institutional support remains important, but more competitive funding instruments are needed to improve the quality of research results while ensuring that fields of science of critical economic importance receive attention.
- ***Improve means of evaluating publicly funded* R&D**. More widespread use of evaluation can improve the quality of research in public institutions and provide governments with valuable information in allocating R&D funds. Evaluation criteria need to recognise the quality of the research, its potential social and economic impact, and the value of university research in educating students.
- ***Improve the mobility of* S&T *workers within and among sectors***. Worker mobility is a vital element of industry-science relations and can be enhanced by regulatory reforms that allow public researchers to work more closely with private industry.

Additional analysis would provide improved guidance for countries in strengthening the social and economic returns from their R&D investments. A more detailed examination of the changes under way in business support for R&D, for example, would help policy makers identify emerging market failures in the R&D system and ensure the more effective use of public R&D financing. Work on the management of public research institutions – already ongoing in the OECD – will provide additional insight into the kinds of structural changes that could improve the contributions of universities and public laboratories to the economy while boosting the quality of the work they do in support of their other missions. Underlying all these activities will be international co-operation in the collection of new data and the development of new indicators of R&D and innovation performance. Without internationally comparable information that allows innovation policies and performance to be benchmarked, policy makers will be severely hampered in their ability to fully evaluate their R&D programmes and determine whether and how to make appropriate changes to improve their contribution to economic performance.

NOTES

1. More complete examinations of the innovation process and government innovation policies can be found in several other OECD publications, most notably *Technology, Productivity and Job Creation* (OECD, 1998*a*), *Managing National Innovation Systems* (OECD, 1999*a*) and *Science, Technology, and Industry Outlook* (OECD, 2000*o*).
2. A more detailed discussion of approaches for ensuring sustainable development can be found in OECD (2001*b*).
3. Innovation has been difficult to incorporate directly into economic analysis. Neo-classical models tend to treat innovation as a residual, accounting for growth that cannot be directly attributed to labour or capital inputs. More recent developments in endogenous growth theory and evolutionary economics treat innovation more directly, but are less mature than neo-classical models (Verspagen, 2001; Porter and Stern, 2000).
4. Patents are a better measure of *invention* than of *innovation* as defined in the text. Even so, patents are a somewhat imperfect indicator of inventive activity. Many inventions are never patented, and patent counts alone cannot signify the relative importance of a particular invention.
5. At the same time, the greater availability of research data through the Internet raises important information asymmetry questions related to access to publicly financed research, and highlights the role of governments in the provision of adequate infrastructure (OECD, 2001*s*).
6. A comprehensive treatment of framework conditions for innovation is beyond the scope of this publication. See instead OECD (1998*a*, Chapter 4; and 2000*o*) for further discussion.
7. The term *basic research* is used in this chapter to connote research aimed at understanding fundamental scientific and engineering principles, regardless of whether the work is motivated by scientific curiosity or by its potential applications. This definition is broader than that proposed in the current *Frascati Manual* and encompasses both pure basic research and long-term research in response to government missions and other social and economic needs. DSTI plans to convene a workshop on definitions of research in late 2001.
8. The implications of these changes were perhaps most pronounced in centralised research labs that perform the most fundamental research in the business sector. Several large companies, including AT&T, IBM and Siemens, in the ITC sector, downsized or reoriented their corporate laboratories in the early 1990s to align them more closely with product development divisions and company priorities (Buderi, 1999; CSTB 2000).
9. It should be stressed that the cost of IPR protection incurred by firms should not deter them, and especially SMEs, from engaging in innovative activities that can be patented. In this regard, efforts currently underway at the European level to increase the efficiency and reduce the costs involving in patenting in Europe should be encouraged.
10. The importance of business R&D in raising the overall R&D intensity of a country can be seen in the fact that no OECD country with an R&D intensity above 2% has more than 40% of its R&D funding coming from government, and – with the exception of Iceland – no country with more than half of its R&D funding coming from government has an R&D intensity much above 1%.
11. Between 1996 and 1999, the number of OECD countries offering tax incentives for R&D expenditures increased from 12 to 16.
12. Many OECD countries have implemented government programmes designed to support SMEs. Some of these programmes provide general business support, although a number focus specifically on R&D. Belgium, Canada, Italy, Japan, Korea, the Netherlands and the United Kingdom, for instance, offer R&D tax incentives that are targeted exclusively at small firms. The US Government sponsors a Small Business Innovative Research (SBIR) programme that requires federal agencies with R&D budgets of more than USD 100 million per year to set aside 2.5% of their R&D budgets specifically for competitively selected awards to small firms.
13. These results suggest that the concentration of venture capital in a limited number of industry sectors is driven more by issues of appropriability than by imperfections in capital markets.
14. As a result of this significant increase, ICT grew from 26% to 38% of total business expenditures on R&D in the United States between 1990 and 1998.

15. Based on available statistics, government financial support (through grants or tax incentives) to business-performed R&D that aims at correcting market failures in the financing of innovation cannot be easily monitored and compared internationally.

16. Despite the significant increase in funding, computer science still receives considerably less government R&D funding than, *e.g.*, life sciences, physics, and engineering. This difference may reflect a comparative narrowness of the field compared to the life sciences, a less well-defined government mission associated with ICT (although virtually all government departments can benefit from the technology), and/or the high level of industry funding related to ICT.

17. OECD/DSTI has launched a study of the funding and steering of research institutions that will address these questions in greater detail.

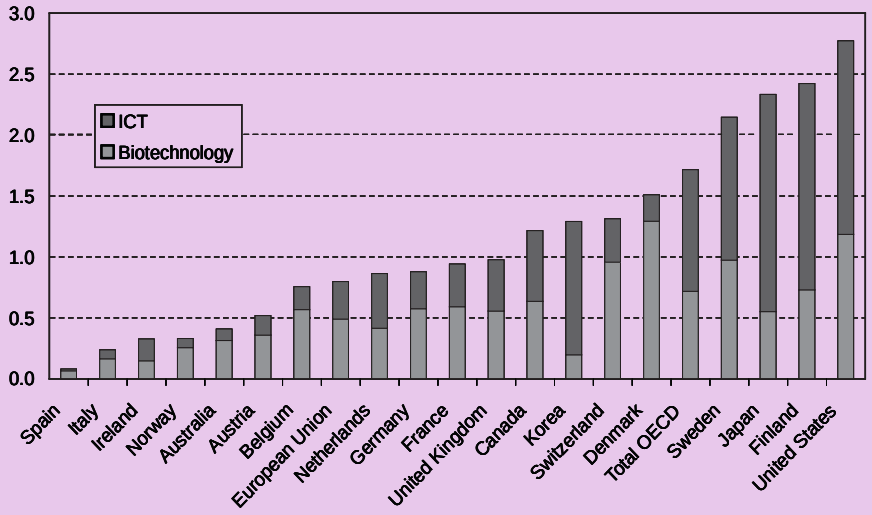
18. More recent examples include the contributions of researchers at CERN (the high-energy physics laboratory in Geneva, Switzerland, that receives funding from several national governments) to the development of hypertext markup language (HTML) and World Wide Web, and the development of the first Web browser, Mosaic, by researchers at the government-funded National Center for Supercomputer Applications at the University of Illinois.

19. Citations can be considered as an indication of patent value. While university patenting has grown rapidly over the period, this growth has been accompanied by a reduction in average patent values.

ANNEX

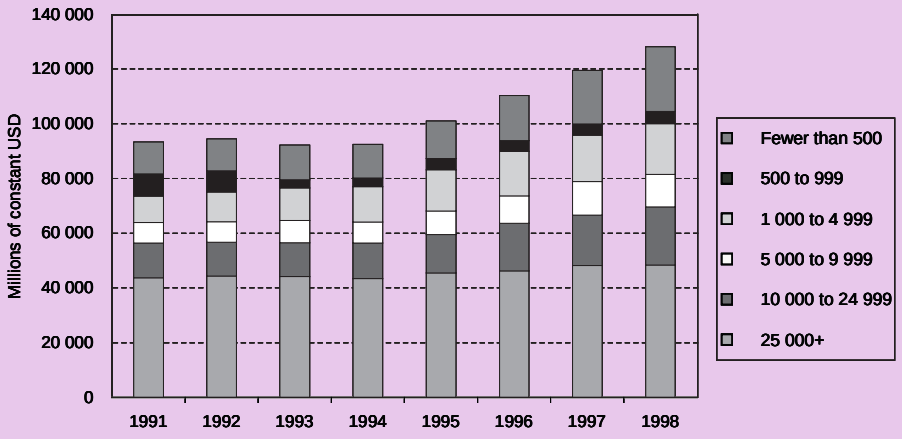
Figure A4.1. **Patents in ICT and biotechnology relative to GDP, 1999**

Patents granted at the US Patent and Trademark Office, by country of inventor



Source: OECD.

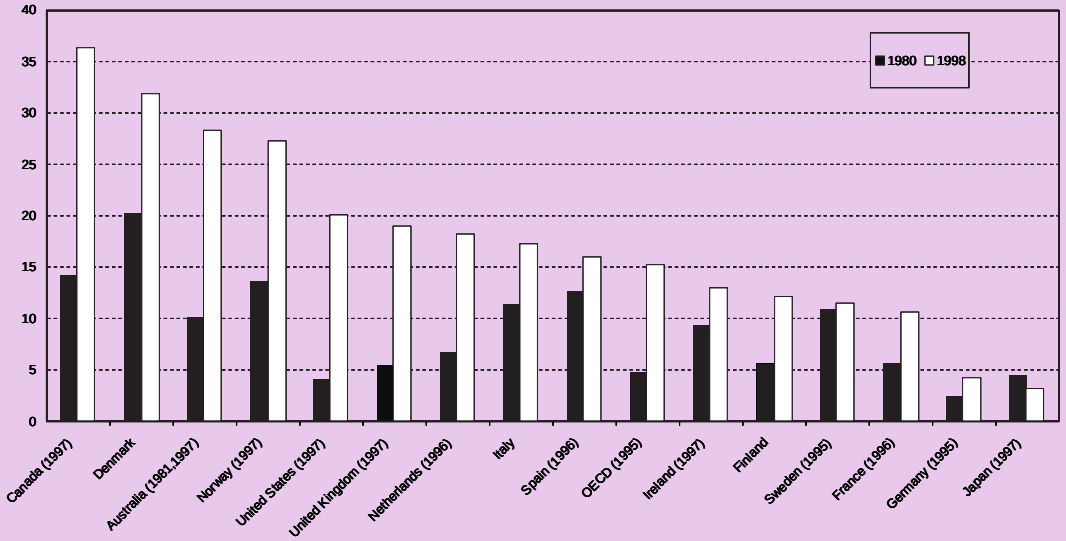
Figure A4.2. **US company funding for R&D by firm size**



Source: NSF (2001).

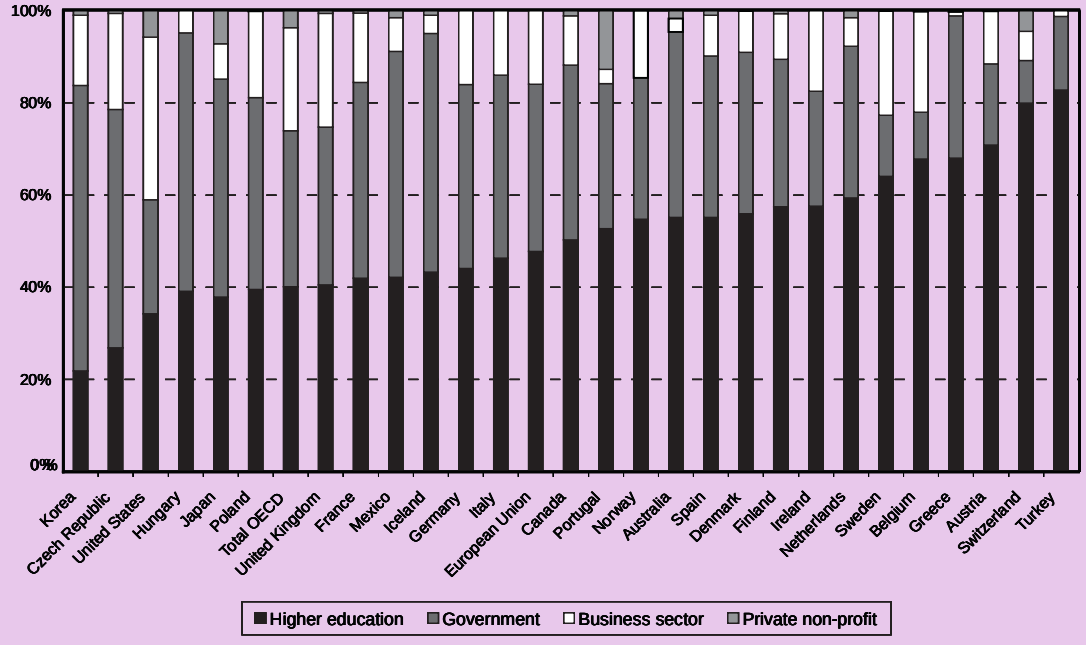
Figure A4.3. **Business expenditures on R&D in services**

Share of services in business R&D, 1980 and 1997



Source: OECD.

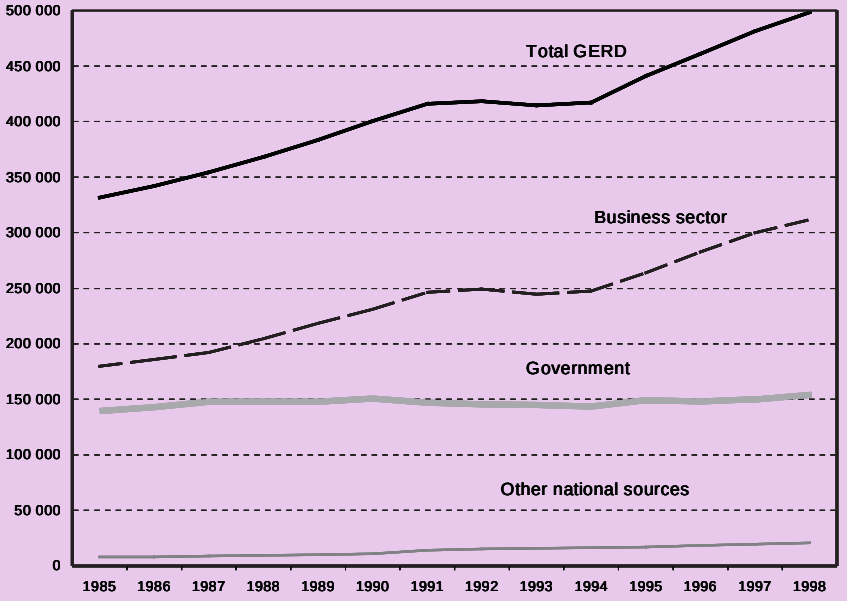
Figure A4.4. **Destination of government R&D funds by sector of performance, 1999**



Source: OECD.

Figure A4.5. **Trends in global R&D expenditures (GERD) funding in the OECD area**

Million USD, 1995 PPPs



Source: OECD.

Table A4.1. **Sectoral technological trajectories**

Category of firm		Representative industries	Determinants of technological trajectories		Means of appropriation
			Sources of technology	Type of user	
Supplier-dominated		Agriculture; housing; private services; traditional manufacture	Suppliers; research; extension services; major users	Price sensitive	Non-technical (*e.g.* trademarks, marketing, advertising, aesthetic design)
Production-intensive	Scale-intensive	Bulk materials (steel, glass); assembly (consumer durables and autos)	Production engineering departments; suppliers; internal R&D	Price sensitive	Process secrecy and know-how; technical lags; patents; dynamic learning economies
	Specialised suppliers	Machinery; instruments	Design and development users	Performance sensitive	Design know-how; knowledge of users; patents
Science-based		Electronics/electrical; chemicals	R&D, Public science; Production engineering departments	Mixed	R&D know-how; patents; process secrecy and know-how; dynamic learning economies

Source: Pavitt (1984).

Table A4.2. **Sources of science and technology cited by enterprises**

Percentage ranking of key sources

Sources of S&T	Manufacturing	Services
Sources within the enterprises	51	52
Other enterprises within the enterprise group	26	39
Competitors	18	19
Clients or customers	46	38
Consultancy enterprises	4	11
Suppliers of equipment; material; components or software	19	18
Universities or other higher education institutes	5	5

Source: Second European Community Innovation Survey.

Table A4.3. **Human resources**

	Distribution of the population aged 25-64 by level of educational attainment, 1998				Flows of graduates in science and engineering in % of total employment	
	Primary and secondary education		Post-secondary tertiary education[2]			
	Below upper secondary education	Upper secondary education[1]	Type B: Study of at least 2 years, focusing on practical skills	Type A: Study of at least 3 years theoretical duration		
Canada	20	41	20	19	1996	0.12
Mexico	79	8	1	12	1994	0.06
United States	14	52	8	27	1995	0.12
Australia	44	31	9	17	1996	0.21
Japan	20	50	13	18	1996	0.04
Korea	35	43	5	17	. .	. .
New Zealand	27	46	14	13	1996	0.18
Austria[3]	27	63	4	6	1996	0.05
Belgium	43	31	13	12	1993	0.05
Czech Republic	15	75	0	10	1996	0.02
Denmark	22	53	20	5	1995	0.04
Finland[3]	32	39	17	13	1995	0.08
France	39	40	10	11	1993	0.16
Germany	16	61	9	14	1995	0.09
Greece[3]	54	30	4	11	1993	0.06
Hungary	37	50	0	13	. .	. .
Ireland	49	30	10	11	1996	0.25
Italy	56	35	0	9	. .	. .
Luxembourg	. .	. .	. .	. .	. .	. .
Netherlands	36	40	0	24	. .	. .
Norway[3]	17	57	2	24	1996	0.04
Poland	22	67	0	11	1994	0.03
Portugal	80	11	3	7	1995	0.03
Spain	67	13	6	14	1995	0.13
Sweden	24	48	15	13	1996	0.07
Switzerland	19	58	9	14	1993	0.05
Turkey	82	12	0	6	1994	0.03
United Kingdom	19	57	8	15	1995	0.19
European Union[4]	46	57	10	12		0.12
Total OECD[4]	38	44	8	14		0.09

1. Also including post-secondary non-tertiary education.
2. See OECD, *Education at a Glance* 2000 for more details.
3. 1997.
4. Average of countries concerned.

Source: OECD, *Education at a Glance* 2000.

Table A4.4. **Commercialisation of publicly funded research**

Selected examples of large public labs

		CNRS (France)	**CNR** (Italy)	**CSIC** (Spain)	**CSIRO** (Australia)	**Centre Juelich (FZJ)** (Germany)	**Lawrence Berkeley** (United States)
Profile	Mission	Multidisciplinary basic research centres					
		The main research centre in the country				One of the largest centres of the HGF Association	One of the DOE (Department of Energy) research laboratories
	Staff	25 400 (11 470 researchers	7 500 (3 700 researchers)	9 000 (2 345 senior researchers)	6 700	4 300	3 800
	Budget (98)	EUR 2.4 billion	EUR 698 million	EUR 340 million	AUD 730 million	EUR 230 million	USD 340 million
Funding	Institutional	90.5% (1998)	76% (1998)	60% (1998)	65.3% (1998/99)	n.a.	n.a.
	Gov. contracts and competitive grants	9.5% (1998)	19% (1998)	n.a.	21.6% (1996/97)		
	Industry		5% (1998)	6.2% (research contracts)(1998)	11% (1996/97)		
Indicators	Contracts and joint labs with industry	3 000 contracts, 26 joint labs	447 contracts	505 contracts, 1 joint lab	Participates in 51 of the 65 Co-operative Research Centres	n.a.	Entered into 140 CRADAs during the 1990s
	Inventions, patents, licences	Stock of 4 000 patents (of which 800 co-patents with industry) and 500 licences	Stock of 550 patents (36 new patent applications) and 95 licences	66 new patent applications (1998), stock of 600 patents and 210 licences	51 new patent applications (1997/98)	Stock of 607 national and 3 944 international patents, and 169 licences	3 new patents issued (1998), 56 new licences (1997), stock of 16 patents
	Licensing revenues	EUR 15 million (1998)	EUR 0.35 million (1999)	n.a.	AUD 5.26 million (1997/98)	EUR 3.6 million (1998)	USD 0.5 million (1997)
	Spin-offs	221 since 1985	n.a.	n.a.	4 in 1999, 56 since 1972	6 in 1998, 26 since 1983	n.a.
	Organisation of knowledge transfer activities	A central unit (DAE) evaluates potential, defines IPR strategy and negociates projects and royalties	A Technology Transfer Office (DAST) deals with all issues related to technology transfer	A Technology Transfer Office (OTT) is in charge of fostering and managing all activities in conjunction with industry	Quite decentralized, with support from the Corporate Business Department (CBD)	A Technology Transfer Office (TTB) deal with all issues related to technology transfers	A Technology Transfer Department (TTD) deals with all issues related to technology transfers
	IPR management	A major part is subcontracted to a specialised affiliate, FIST	Performed by DAST	Performed by OTT	Performed by CBD, under supervision of the Intellectual Property Standing Committee	Performed by TTB	Performed by TTD with support from the Office of Technology Transfer of the University of California
	Start-ubp policy	Low but increasing focus; DAE conselling support to PhD students; initiation of a nation-wide network of local incubators in partnership with other research institutes	Low focus	Low focus	Low but increasing focus; different models of spin-off formation, with equity participation in 16 of the 56 spin-offs formed since 1972	Low but increasing focus; TTB provides some financial and administrative support, takes part in a regional initiative to support entrepreneurs and has a stake in the "Techno-logiepark Jülich"	Low focus

Table A4.4. **Commercialisation of publicly funded research** (*cont.*)

Selected examples of large public labs

		Fraunhofer Gesellschaft (Germany)	**INRIA** (France)	**INSERM** (France)	**Massachussets General Hospital** (United States)	**Independent MRIs** (Australia)	**DERA** (United Kingdom)
Profile	Mission	Multidisciplinary applied research	Thematic research centres				
		The main German applied research institute (federates 48 centres)	Research on IT	Medical research			Defence research
			The main French public institute of research on IT	Federates over 250 labs in hospitals and universities	The largest hospital-based research centre in the US	Institutes that are not departments of a hospital or university	The Agency in charge of most non-nuclear R&D
	Staff	9 000 (3 000 researchers	2 100 (750 permanent staff)	10 000 (2 140 researchers)	10 000 (2 140 researchers)	3 000	11 500 (1 000 PhDs)
	Budget (98)	EUR 665 million	EUR 75 million	EUR 460 million	USD 200 million	AUD 130 million (1996)	EUR 1.5 billion
Funding	Institutional	70% (average over 5 last years)	n.a.	89% (1998)	n.a.	n.a.	92% (1998/99), of which 90% from Ministry of defence (MOD)
	Gov. contracts and competitive grants			5.6% (1998)			
	Industry	30% (average over 5 last years)		5.4% (1998)	18% (1998)	17.5% (sample of 5 MRIs)	8% (1998/99)
Indicators	Contracts and joint labs with industry	n.a.	300 contracts, 4 co-operative ventures	n.a.	n.a.	n.a.	Sub-contracts 32% of all its MOD funded research
	Inventions, patents, licences	417 patent applications, 90 new licences (1998)	n.a.	Stock of 331 national and 1 262 international patents, and 253 licences	145 invention disclosures, 140 patent applications and 57 new patents issued (1998)	n.a.	111 patent applications, 68 new licences (1998), stock of 6 000 patents and 500 licences
	Licensing revenues	EUR 3 million (1998)	n.a.	EUR 8.9 million (1998)	USD 1.8 million (1998)	n.a.	n.a.
	Spin-offs	n.a.	5 in 1998, 40 since origin	15 since origin	3 in 1998	2 in 1999, 11 since origin	n.a.
Organisation of knowledge transfer activities		Decentralised, with support from the Fraunhofer Patent Centre (FPC)	A specialised Department (DirDRI) manages technology transfers and assists research teams in their relations with industrials	A specialised Department (DPES) manages technology transfers and partnerships with private firms	Quite decentralised under the supervision of the Committee on Industrial Relations and Intellectual Property	Arrangements vary from one institute to the other	A DERA Office (DERAtech) manages commercialisation activities, and an outside Agency (DDA) promotes access by SMEs to DERA expertise
IPR management		Performed by the Patent Department of the FPC	Performed by DirDRI	Performed by a specialised unit (PDE) of DPES	Performed by the Office of Corporate Sponsored Research and Licensing	Arrangements vary from one institute to the other	Performed by DERAtech
Start-up policy		Low focus	Important focus; a subsidiary, INRIA-Transfert (created in 1998) supports spin-off creation and holds 34% share in I-Source gestion, a dedicated seed capital fund	Low focus; different models of spin-off formation, with equity participation in 4 of the 40 spin-offs formed since origin	Low focus	Low focus	Low but increasing focus

Source: OECD (2001*f*).

Table A4.5. **National or institutional guidelines for sharing royalties from IPR**

		Share of royalties			
	Applicability	Inventor	Laboratory/ department	Institution	No sharing
Australia	Universities	33%	33%	33%	
Austria	General practice				100% to owner
Belgium	Flemish universities	10 to 30%	50%	20 to 30%	
Canada	Federal research	35% by law	variable	variable	
France	Public labs	25%	25%	50%	
Germany	Max Planck and HGF centres	33%	33%	33%	
Hungary		0%	undetermined	up to 100%	
Israel	Hebrew University	33%	33%	33%	
	Weizmann Institute	40%	0%	60%	
Italy		0%	undetermined	up to 100%	
Japan	Universities				100% to owner
Korea	KIST institute	up to 60%	0%	40%	
Mexico	Public labs				100% to owner
Netherlands	Public labs				100% to owner
Poland		no general rule			
United Kingdom	BBRCs	sharing encouraged in institute guidelines			
United States	Universities	sharing required by law			
	Stanford	33%	33%	33%	

Source: OECD, based on country responses to a questionnaire.

Chapter 5

ENTREPRENEURSHIP AND GROWTH

Introduction

To capture the opportunities presented by new technologies, including ICT, it is crucial to have in place the institutions and incentive mechanisms that allow for effective upgrading of management and workforce skills, as well as industrial restructuring and organisational change. An important but often elusive factor in this context is that of entrepreneurship (OECD, 1998*c*). The concept of entrepreneurship generally refers to enterprising individuals who display the readiness to take risks with new or innovative ideas to generate new products and services. It can characterise the behaviour of firms which are new or old, small or large, low-tech or high-tech. In most cases, however, the focus is on the ability of individuals to start up new ventures, the quantity and quality of start-up firms, and the ease with which enterprises can enter and exit the market.

In a *churning* process, new establishments are constantly being created, some existing ones expand, and others contract or dissolve operations altogether (Baldwin, 1995). It is particularly in times of rapid technological progress, however, that this process becomes of paramount importance for realising product and process innovation, and for driving higher productivity. With rapid technological change and increases in globalisation, there has recently been a shift in industrial structure towards more specialisation and outsourcing, less centralised management and production. In addition, there are indications of new opportunities for small business; in some countries, policies and institutions have facilitated the trend towards a more flexible industrial structure through fostering entrepreneurship.

This chapter initially reviews measures of entrepreneurship and the possible links to economic growth and performance. Available data are used to illustrate differences across OECD countries and to examine the role that entrepreneurship might play in growth. The focus then turns to the factors which influence the levels of entry and exit of small firms, and the associated implications for government policy.

Measuring entrepreneurship

Risk taking and innovation are central characteristics of entrepreneurship. Innovation, which results in new goods and services, and risk taking, which involves identifying new market opportunities, have to coexist and complement one another in order for entrepreneurship to thrive. However, entrepreneurship is a difficult variable to measure within a country and even more problematic when one attempts cross-country comparisons. One palpable manifestation of a vibrant entrepreneurial culture is a high rate of firm formation and of nascent entrepreneurs as well as relatively high rates of enterprise turnover (European Commission, 2000). High turnover is generally indicative of a competitive environment in which innovative entrepreneurs can thrive while less successful firms are forced to restructure or renew their operations.

Entrepreneurship is often related to the number and properties of small businesses, whose performance and survival are important for economic growth. In terms of the overall economy, where there is an appropriate flow of resources, successful firms would be rewarded through their success in making profits, and possibly expanding, while weaker firms would be removed through dynamic competition. In this context, the dynamism of SMEs also reflects some aspects of entrepreneurship. In a few selected OECD countries, a sub-set of small high-growth firms counts among the top 5%-10% of all

growing enterprises (OECD, 2000*n*). A number of characteristics can be observed for these firms, which are record performers with regard to job creation and innovation: they can be found in all sectors and tend to be dynamically managed and technology-based; their performance is strongly attributable to the entrepreneurial characteristics of their owners and founders; they are often young and, increasingly (albeit not in the majority of cases), entrepreneurs are women.

It is also clear that entrepreneurship need not be confined to start-ups and small businesses: a highly entrepreneurial individual can bring about innovative changes in large firms that can result in spin-off enterprises. Product market competition which allows successful existing firms to diversify and divide can be a very important determinant of initiative and firm growth. However, operationalising such a broad concept of entrepreneurship across OECD countries is beyond the scope of the present report. Due to data limitations, the following analysis focuses on a more narrow aspect of entrepreneurship.

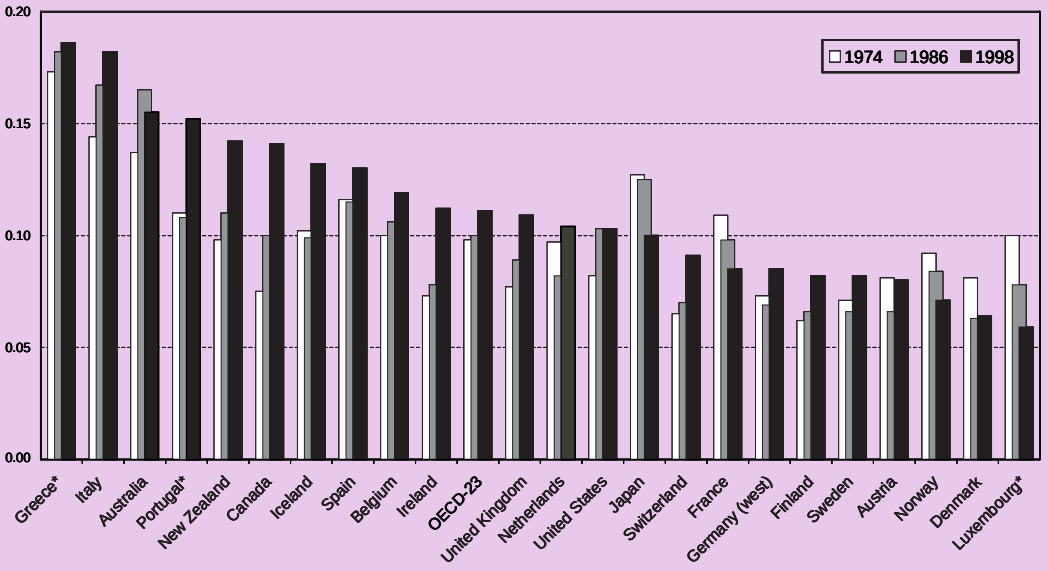
A country's relative standing in terms of entrepreneurship may differ depending on the measure used. Studies focusing on a single country, using either a cross-sectional or time series analysis, have employed a variety of proxy measures of entrepreneurship, including self-employment rates, business ownership rates, and the relative share of output or employment accounted for by small firms (Audretsch and Thurik, 2000). Other studies have attempted to gauge the proportion of adults who intend to or have started their own businesses, or use other surveys to measure entrepreneurial attitudes and perceptions (Reynolds *et al.*, 2000). Efforts have also been made to measure firm entry and exit – or the birth and death of firms – through tax records and business registers (Baldwin, 1995; Baily *et al.*, 1996).

One manifestation of entrepreneurship is *self-employment*, which is growing in the OECD area due to greater outsourcing and downsizing by larger firms. However, data on self-employment and business ownership capture a wide array of activities, ranging from fishermen to barbers to software designers, and may not be the most useful measures of entrepreneurship for comparisons of growth. Self-employed jobs are those where incumbents make operational decisions or are responsible for the welfare of the enterprise, and remuneration is directly dependent upon profits. Most data on self-employment are derived from national labour force surveys, where respondents classify themselves either as employees or as self-employed. Studies of trends in self-employment over time in individual OECD countries indicate that there is a positive correlation with overall employment. For example, in Sweden in 1976-95, entrepreneurship (as measured by self-employment) made a significant contribution to job growth (Folster, 2000). OECD analyses find that the self-employment rate across countries is related to a range of explanatory variables, including GDP per capita, unemployment, the size of the service sector and average taxation levels. In the 1990s, self-employment grew particularly fast relative to civilian employment in Canada, Germany, the United Kingdom and the Netherlands (OECD, 2000*l*).

A related measure of entrepreneurship is the level of *business ownership*, which is growing throughout the OECD area. Measuring the number of business owners is statistically problematic in that some countries define business owners as individuals owning a business that is not legally incorporated, while others use owner/managers of incorporated firms. A study using standardised data on business owners per labour force (excluding agriculture) for 23 OECD countries in the period 1986-98 found large numbers of small businesses in countries such as Greece, Italy, Australia and Portugal (Figure 5.1). In absolute terms, nearly 32% of the total 45 million business owners in 1998 were in the United States. Five countries suffered a decline in business ownership between 1986 and 1998: Australia, France, Norway, Luxembourg and Japan (Audretsch and Thurik, 2000).

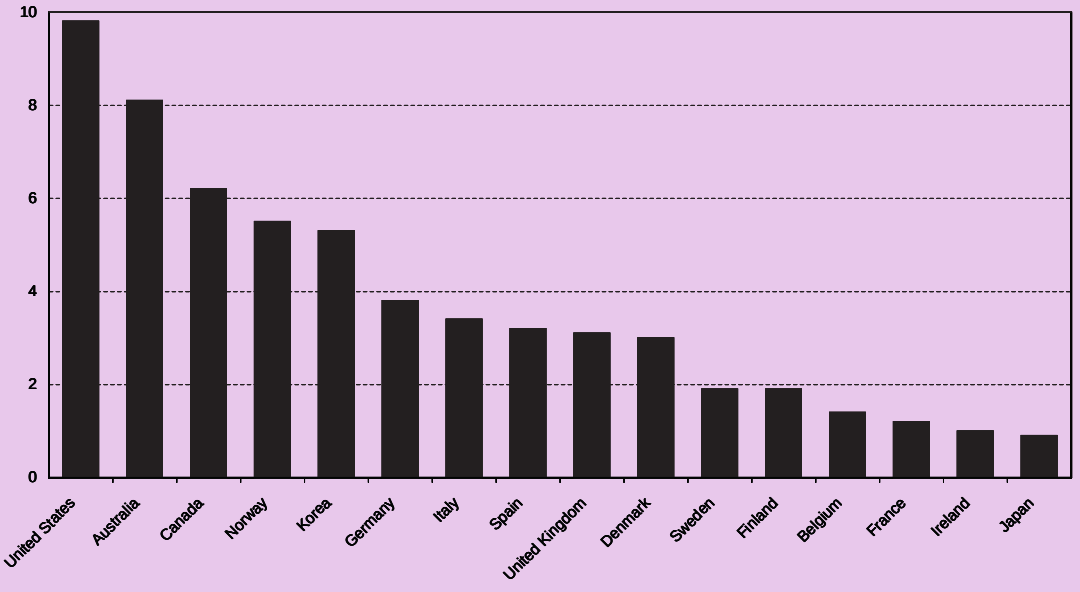
Surveys on *entrepreneurial attitudes* among the adult population, business managers or other groups are another approach to measuring entrepreneurship. Using a population survey, the Global Entrepreneurship Monitor (GEM) estimated active participation in new business creation or the number of "nascent entrepreneurs" in some 20 countries (Reynolds *et al.*, 2000). A representative sample of 2 000 adults in each country was asked a series of questions about their participation in entrepreneurial activities, including whether or not they had been engaged in any activity to start a firm in the past 12 months ("start-up activity") On this basis, entrepreneurial activity seems much higher in North America and Australia than in Europe and Japan (Figure 5.2).

Figure 5.1. **Business owners as a percentage of labour force**



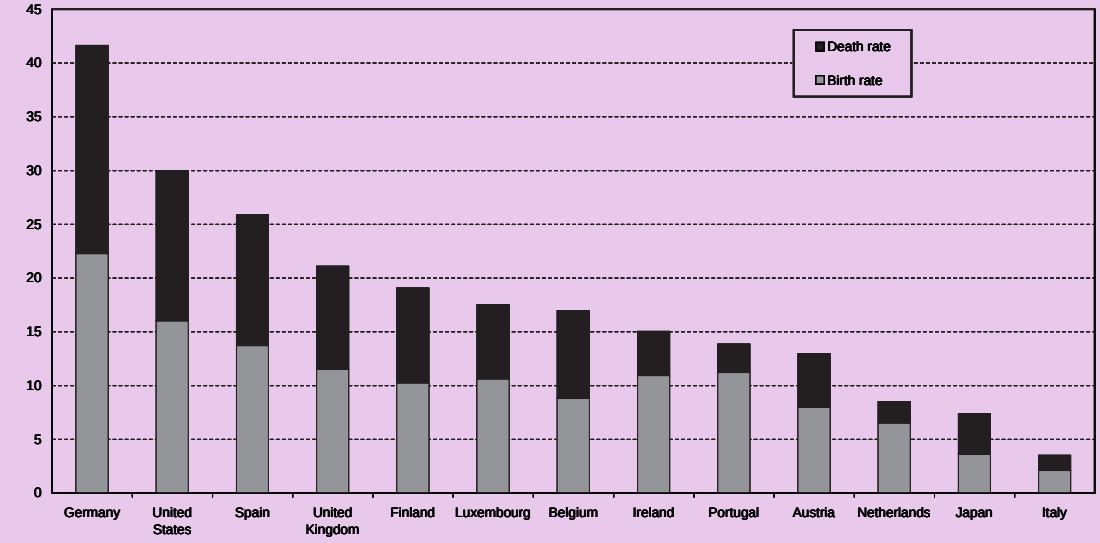
Note: Excluding agriculture.
* = provisional for 1998.
Source: Audretsch and Thurik (2000).

Figure 5.2. **Level of entrepreneurial activity**



Note: Based on percentage of surveyed adults engaged in starting a business in the previous 12 months.
Source: Reynolds *et al.* (2000).

Figure 5.3. **Eurostat comparison of enterprise volatility**



Note: Sum of real births and deaths as a percentage of total enterprise stock.
Source: European Commission (2000).

As governments upgrade their attention to entrepreneurship, national and international statistical bodies are making more systematic attempts to monitor the process of enterprise entry and exit through *business registers*. The study of entry and exit requires longitudinal databases that measure firm performance over time. The sum of births and deaths of firms as a percentage of the existing stock of enterprises gives an indication of the rate of volatility or churning over a given period. In the United States, the Census Bureau is collecting such information in the form of Longitudinal Establishment and Enterprise Microdata (LEEM) which covers service sectors as well as manufacturing. In Europe, Eurostat has developed a special data bank from statistical administrative data on small and medium-sized enterprises.

In comparing countries through business registers, however, small differences in definitions may have large effects on the indicator of total enterprise volatility or *churning*. In a seven-country comparison, Sweden came out with the highest start-up rate but this was due to the completeness of the Swedish data set rather than to high entrepreneurial activity. Later studies using a more harmonised data set found that Sweden's enterprise entry rate was lower than for 15 other European countries (Davidsson and Henrekson, 2000). In a European Commission study of births and deaths in 1998 using non-harmonised national business registers, Germany had the highest volatility rates (sum of real births and deaths as a percentage of total enterprise stock), followed by the United States (Figure 5.3). Nonetheless, these volatility rates provide a rough indication of the levels of entrepreneurial dynamism in the economy.

Role of entrepreneurship

Partly because of measurement difficulties, there is continuing debate regarding the extent and nature of the contribution of entrepreneurial firms to the growth process. In theory, high levels of entrepreneurs facilitate technological change and industrial restructuring. The entry and exit of firms, together with growth and decline, can shift substantial amounts of market share from losers to gainers, a process which should be accompanied by productivity gains. This is deemed essential for ensuring a smooth process of industrial restructuring: as new firms enter new business areas and old ones withdraw from declining industries or reorganise their operations, the economic structure modernises over time.

In addition to turnover, *firm survival* is obviously important. Some analysts maintain that firm survival is key and that professionals, rather than entrepreneurs, are more significant for sustained growth and economic performance. While entrepreneurs may be important in the early phases of growth and can kick-start the process, skilled professionals with high levels of education and training may be needed to implement and extend technological progress (Iyigun and Owen, 1999). On the other hand, high survival rates might point to high entry and/or exit barriers rather than good economic performance. Barriers could lead to low levels of entrepreneurship if entrepreneurs do not perceive sufficient opportunities for innovation, growth and survival. Low churning is likely to be a feature of industries which are not really contestable owing to high entry and exit costs.

There are various indications that entrepreneurship is gaining in economic importance (Audretsch and Thurik, 1997), as might be expected during an era of technological revolution. In recent years, the emergence and expansion of ICT is placing a greater premium on entrepreneurial traits such as individuality, innovative ideas, flexibility and speed. The falling costs of accessing information mean that certain of the advantages accruing to incumbents are diminishing, while new opportunities are arising for individual entrepreneurs, and for small firms, to enter markets. As information barriers and transaction costs fall, there are new opportunities for small firms to grow as well as increasing pressures on existing firms, two factors which favour higher rates of exit. High levels of entry and exit and related *churning* facilitate experimentation and innovation (Eliasson, 1996). ICT is also facilitating firm-level organisational change and transforming traditional production and operational modes into smaller or separated units (United States Department of Commerce, 1999). Jobs in the ICT sector are being created at an impressive rate: 3% per year in the United States between 1990-98; 4% per year in France in 1989-96; and 6% per year in Sweden in 1993-96. The exception is Japan, where employment in the ICT sector declined by 1% per year between 1990-97 (OECD, 2000*m*). This entrepreneurial model may be making unique growth contributions in the current economic paradigm, which were not experienced in the 1980s.

Establishing the *direction of causality* between entrepreneurship and growth raises fundamental problems, however. High levels of entry and exit may contribute to growth in productivity and output but, conversely, sustained economic growth may stimulate higher levels of entrepreneurship. Studies at the national level have attempted to confirm that entry and exit contribute to productivity growth. For example, a number of analyses of Canada in the 1970s and 1980s showed that a dynamic entrepreneurial sector is important to growth in productivity and output; plant openings and closures were responsible for 30% of labour productivity growth (Baldwin, 1995). A similar finding has been reported for Dutch manufacturing, where entry and exit accounted for 30% of labour productivity growth for the 1980-91 period (Bartelsman *et al.*, 1995).

Studies of the US manufacturing sector in the period 1980-90 found that *churning* of businesses within and between industries was correlated with productivity growth (Lansbury and Mayes, 1996). For the 1977-87 period, Haltiwanger (1997) attributes 18% of total factor productivity growth in US manufacturing to net entry. Similarly, a recent analysis of plant-level panel data in Korea (1990-98) found that entry and exit has been an important source of total factor productivity growth in manufacturing – accounting for 45% and 65% for 1990-95 and 1995-98, respectively – due to a process of resource reallocation from plants with relatively low and declining productivity to plants with greater potential to become efficient in the future (Hahn, 2000).

National-level studies have also provided insights on time, regional, sectoral, size and age factors relating to entrepreneurial firms. With regard to *time periods*, entry and exit may be relatively unimportant to growth in the short run particularly when related to levels of employment or shipments. Although the number of entrants may be large relative to the existing stock of firms, they are generally small and capture only a small portion of output; they tend to have a higher cumulative impact in capturing markets over time. A review of studies in Canada shows that greenfield entry and closedown exit have a significant cumulative impact when measured over a decade. Firms may start small and many may die during the maturation process, but the effect of successive cohorts cumulates to meaningful levels (Baldwin, 1995). In the case of the United States, it was found that the contribution of net entry to productivity growth is significant over the long term. Other studies in Europe find that high real births

demonstrate the capacity of the economy to rejuvenate and adjust to new market opportunities, while high exits improve resource allocation (Haltiwanger, 2000).

Entrepreneurship is very much a local phenomenon, and there are important *regional differences* in entry and exit rates within a country which contribute to growth performance. Case studies of regional variations in birth rates in seven countries (United Kingdom, United States, France, Germany, Italy, Ireland, Sweden) found firm entry rates generally to be higher in faster-growing urban areas where average firm size was low (Reynolds *et al.*, 1994). There are also observations of significant divergence between different urban or rural areas. There tends to be a favourable relationship between high levels of entrepreneurship, industrial restructuring and innovative capacity. In other respects, the links to economic performance are less clear, for instance, as regards any relationship between levels of firm creation at regional level and employment growth (Audretsch and Fritsch, 1999).

Sectoral differences in entry and exit rates have been highlighted as important, with services turnover making greater growth contributions than churn in manufacturing. In the United States, a larger number of new service establishments survived and expanded over the 1990-95 period, while manufacturing lost employment because establishment deaths exceeded births; the top entrepreneurial industries (based on both the ratio of births to deaths and to net jobs created) were restaurants, business services, personnel supply services and computer services (Bednarzik, 2000). In Japan in 1988-93, while death rates in manufacturing and services were the same, start-up rates in services were far higher (Morikawa and Tachibanaki, 1999). According to Eurostat data on enterprise creations and closures in ten European countries in 1994-95, technology-based services may be the most important element in firm start-up and survival, especially business and communication services (European Commission, 1999*a*).

Size may also be important. Studies find that smaller establishments tend to have higher entry and exit rates in both manufacturing and services. In general, the entry and start-up of new firms is not greatly deterred in the presence of scale economies and most new firms are very small (less than ten employees). In addition, smaller firms tend to grow faster, at least in relative terms, but are significantly more likely to fail than large firms (Audretsch and Thurik, 2000). Those start-ups which grow the most rapidly, and have the greatest chance of survival, tend to be those established as spin-offs from larger, existing firms (see also Chapter 4, Box 4.5). In Japan, enterprise start-ups and shut-downs were smaller in size, less diversified in products and had lower productivity than surviving establishments (Morikawa and Tachibanaki, 1999). In Europe, the vast majority of enterprises created in 1994-95 were very small (less than four employees) (European Commission, 1999*a*), while in the US service sector, job creation and destruction did not vary significantly by establishment size except for very small establishments (employing between one and four workers) which had much higher rates (Bednarzik, 2000).

With regard to *age*, younger firms are marked by greater volatility of growth patterns than older enterprises. Market entrants take time to learn about their relative efficiency. A selection process takes place and operates with greater intensity during the earlier life cycle of firms. Young firms that are efficient during the initial selection process tend to survive to maturity and illustrate relatively stable employment levels while inefficient firms are weeded out. Even though older firms have a greater probability of survival than younger ones, the proportional growth rate of firms tends to decline with age. A study of high-growth firms in Germany, Italy, the Netherlands, Spain, Sweden, and Canada (Quebec) found that growing firms tend to be younger on average (Schreyer, 2000*b*).

Individuals are the driving force behind entrepreneurship. There is a strong link between the performance of a new enterprise and its owner – the entrepreneur – as the vast majority of new enterprises are founded without any employees. Factors such as the gender, age and educational and professional background of entrepreneurs are thus of interest. Gender differences are of considerable economic importance since women tend to be strongly under-represented in entrepreneurship but have recently demonstrated catch-up, with higher start-up rates than for men in a number of OECD countries. Governments are increasingly seeing women entrepreneurs as an untapped source of business and job creation.

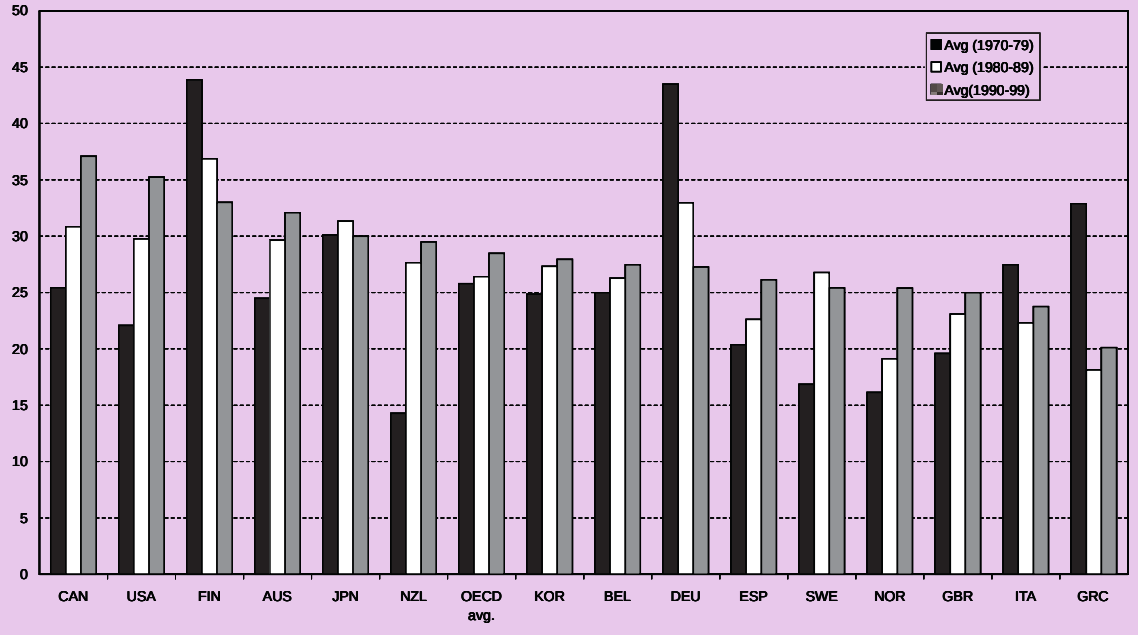
At present, the average share of women entrepreneurs across the OECD is estimated at 28%; in other words, only one in four entrepreneurs in OECD countries is a woman. However, there are notable

differences across countries and over time (Figure 5.4). For example, New Zealand, the United States and Canada registered a significant increase in the share of women entrepreneurs over the period 1970-99, as did Australia, Sweden, Spain, Norway and the United Kingdom. Furthermore, increases in the number of women entrepreneurs have exhibited cyclical patterns, where periods of decline in the early 1970s and 1990s were followed by periods of acceleration in the 1980s and late 1990s. The increase in the share of women entrepreneurs was especially noteworthy in the second half of the 1990s for Canada, the United States and Iceland. However, despite higher female start-up rates in some countries, the broad pattern of under-representation of women in the overall number of entrepreneurs holds true, as confirmed by the recent GEM study covering 21 OECD and non-member countries (Reynolds *et al.*, 2000).

According to the GEM survey, countries that have the highest prevalence of nascent entrepreneurs also have higher female to male start-up ratios. Likewise, it appears that several OECD countries experiencing higher levels of economic growth also show the highest level of female entrepreneurship; these include the United States, Australia, Canada, Korea, Spain and Norway. However, no direct link between these phenomena has been established, and more research is needed to determine whether there is a causal relationship and, if so, its direction.

Women-owned firms appear to follow business creation patterns in terms of sectoral composition; just as new enterprise creation overall after 1995 has been fuelled by ICT and growth in technology-based and service sectors, women entrepreneurs are taking advantage of these "new economy" phenomena to start-up firms in these sectors. Other studies have indicated that women-owned firms are on average relatively small (micro-enterprises), predominate in the service and retail sectors but are increasingly present in other sectors; grow more slowly than businesses owned by men, but tend to stay in business longer; and have better debt repayment rates (OECD, 2001*v*).

Figure 5.4. **Share of women entrepreneurs**



Note: Share of female employers and own-account workers in total employers/own-account workers. Declines in the share of women entrepreneurs in countries such as Germany may be due to a break in the data series.
Source: OECD *Labour Force Statistics* (2000).

There is no doubt that entrepreneurship has a cultural dimension. Cultural attitudes that support risk taking and individual rewards help to provide an environment that is conducive to entrepreneurship. In such an environment, the characteristics and quality of education play an important role as they strongly influence the extent to which creativity flourishes, together with a continuing stream of innovative ideas that can inspire people to launch new business ventures. Education is also important for the build-up of the business and management skills required for successful entrepreneurship. Various surveys in Europe have indicated that there is a positive relationship between the likelihood of starting a business and the level of education (De, 2001; Reynolds *et al.*, 2000). By strengthening its interactions with the business community in a broad sense, education can play a more effective role in fostering entrepreneurship.

Cross-country comparisons

Whatever the measure of entrepreneurship used, cross-country comparisons of the relationship to growth remain problematic. Preliminary correlation analysis (see Figure 5.6 below), along with the empirical studies mentioned above, suggest that rates of entry and exit are positively related to economic growth. However, more sophisticated statistical analysis is needed to further establish the causality relationship between entry and exit and growth performances on a cross-country basis.

Although entrepreneurship has always mattered for economic growth, it may have become a more important driver of economic growth in the 1990s. For the United States and Japan, a comparison of entry and exit of firms relative to GDP growth rates in the 1980s and 1990s indicates such a change (Figure 5.5). First, the United States has exhibited far higher enterprise start-up and closure rates than Japan over the entire period. Second, given a higher level of entrepreneurship in the US economy, economic growth in the United States outperformed that of Japan in the 1990s, but not in the 1980s. Taken together, there appears to be a positive relationship between firm entry and exit rates and economic growth in the 1990s, during which US economic growth was characterised by the rapid development and use of ICT as compared to the 1980s.

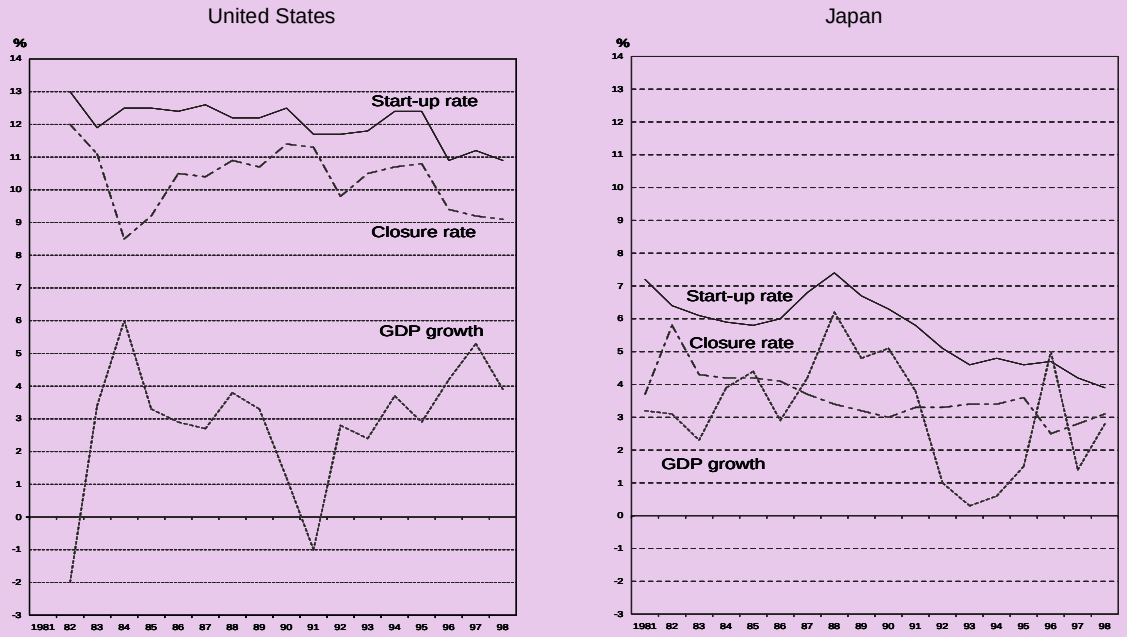
This positive relationship holds across the OECD in the 1990s when GDP growth rates (1989-99) are plotted against enterprise start-up rates (1988-96) (Figure 5.6). High start-up rates as well as strong economic growth are observed in the Netherlands, Ireland and the United States. On the contrary, countries with low start-up rates tend to grow more slowly, with the possible exception of Luxembourg as a special case. Although not shown here, a similar pattern is observed when the proportion of the adult population engaged in start-ups is used as the indicator of entrepreneurship. Higher rates of start-ups and growth are observed in the United States and Australia. According to the GEM survey of "nascent entrepreneurs", the relationship between entrepreneurship and growth is highly significant when countries whose external trade or agricultural activity dominates the economy are excluded (Reynolds *et al.*, 2000). However, exceptions suggest that there is no one catalyst to economic growth.

The effects of entrepreneurship on the economic performance of a country can be further examined by relating the level of PPP-based GDP per capita with the perceived level of managerial entrepreneurship (based on a survey of 3 263 business executives in 47 countries) (Institute of Management Development, 2000) (Figure 5.7). There is a generally positive relationship between the level of per capita GDP and the level of entrepreneurship, *i.e.* a country with a higher level of entrepreneurship tends to have a higher standard of living, which appears very much in line with the observed positive relationship between higher start-up rates and higher growth, as mentioned above. This is true for countries such as the United States, Ireland, Finland and Canada. Japan is an exception to this pattern, suggesting that high levels of GDP per capita in Japan may be explained by factors other than levels of entrepreneurship.

Factors facilitating entry

Given the importance of enterprise entry for economic performance, as well as the subtleties of the factors which determine it, policy makers need to review a number of possible conditions which may impede or facilitate observed performances. Policies fostering entry and those which allow effective

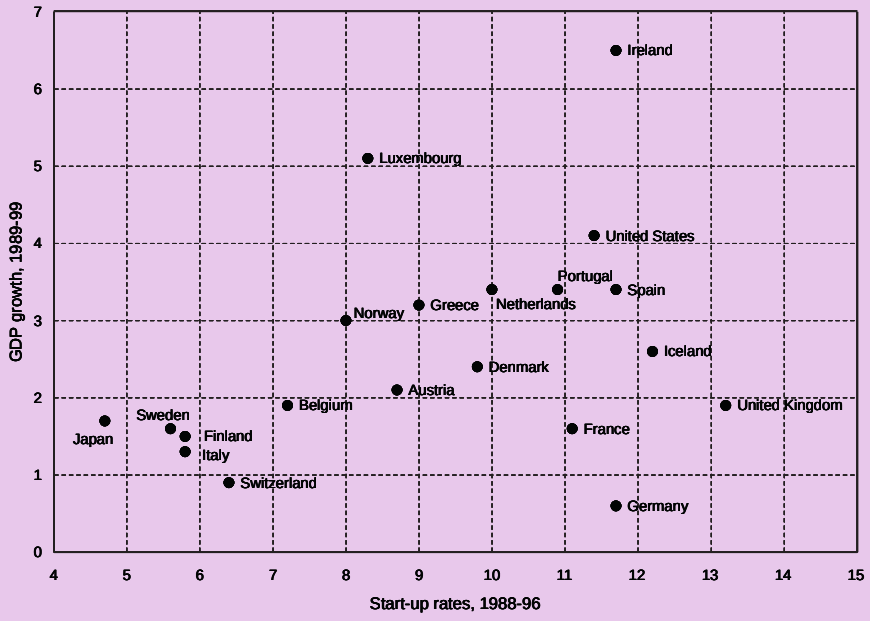
Figure 5.5. **Start-up, closure and GDP growth rates for the United States and Japan**



Note: US figures for start-up and closure rates for 1996-98 are based on estimates of employer firms only. For Japan, start-up (closure) rates are defined as the number of new businesses entering (exiting) in a given fiscal year (FY) divided by the total number of business offices as of the end of the previous FY.

Source: US Small Business Administration, Small Business Economic Indicators (1997, 1998); Japan, 2000 White Paper on SMEs for the 147th DIET; OECD Historical Data HS1999.

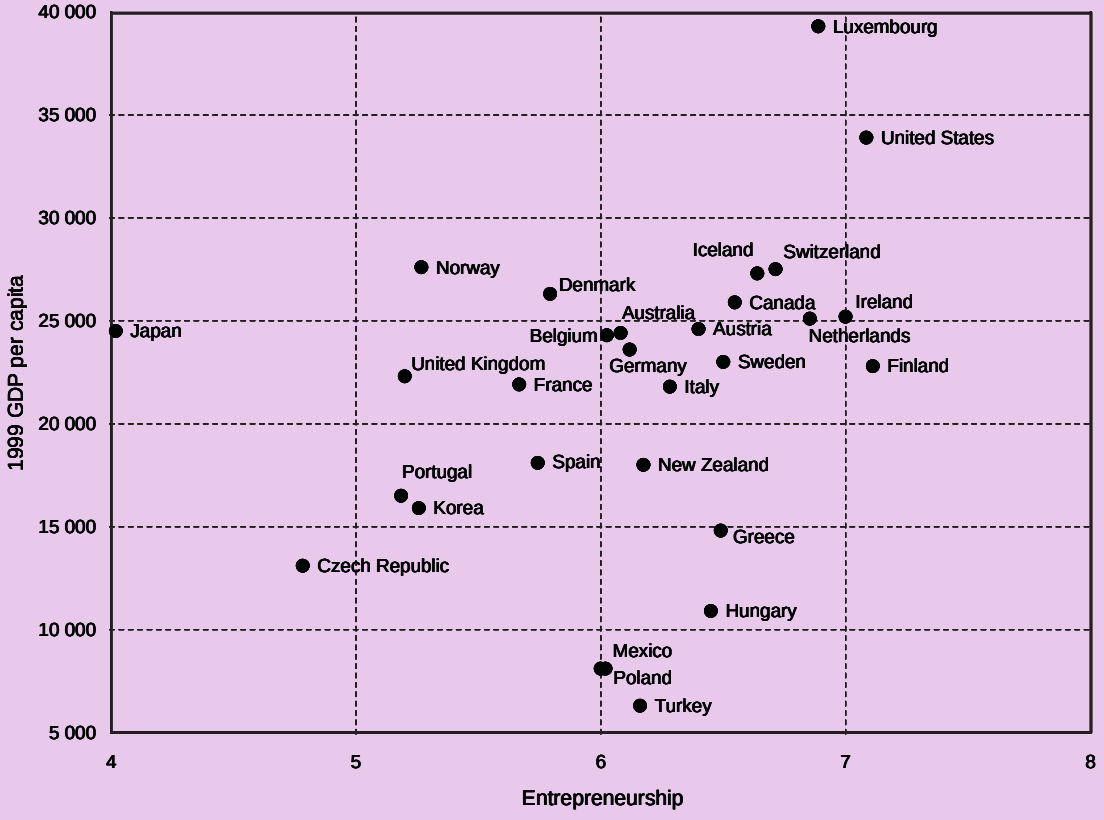
Figure 5.6. **GDP growth and start-ups**



Note: GDP growth rates: 1995-99 for Austria, 1990-99 for Germany.

Source: OECD; European Observatory for SMEs, *Fifth Annual Report*.

Figure 5.7. **GDP per capita and entrepreneurship**



Note: Entrepreneurship based on perceptions of business executives.
Source: IMD (2000); OECD.

exit or restructuring are closely related. However, in this presentation, they are discussed separately. The factors and policies which are most effective in encouraging enterprise start-ups include: *i*) removing regulatory barriers; *ii*) increasing access to venture capital; *iii*) implementing tax regimes that foster entrepreneurship; and *iv*) facilitating use of stock options.

Removing regulatory barriers

Regulations that discourage the creation of new firms and the expansion of existing ones can act as significant impediments to entrepreneurship. The dampening effects on entry of excessive regulation in the registration of new businesses as well as opacity in administrative procedures should not be underestimated. Most important are the administrative procedures and regulations which govern the manner in which companies are created, the information these companies must provide to their governments, and the associated costs. In some countries, business establishment may be an expensive, lengthy and complex process that discourages entrepreneurship. For example, data from 1998 show that formalities for establishing a corporation are relatively low in Denmark, the United States and the United Kingdom, and high in Italy, Spain, Greece and France (Table 5.1). However, reforms have recently been introduced in several countries, including some of the latter, to reduce the length of time required to establish a company and to establish "one-stop shops" for administrative procedures.

Table 5.1. **Formalities for establishing a corporation, 1998**

	Minimum direct and indirect cost (ECU)	Maximum delays (weeks)	Minimum number of services	Minimum number of procedures (pre and post)	Synthetic indicator: Administrative burdens for corporations (0: low – 6: high)
Denmark	300	1	2	2	0.50
United States	200	2	2	2	0.50
United Kingdom	900	1	1	4	0.75
Australia	200	1	1	9	1.00
Sweden	1 130	4	1	6	1.25
Belgium	1 000	6	4	3	1.50
Finland	1 050	6	1	7	1.50
Ireland	650	4	3	6	1.50
Netherlands	1 400	12	1	7	1.75
Japan	4 600	4	1	13	2.25
Germany	750	24	2	8	2.50
Portugal	1 000	24	1	9	2.50
Austria	2 200	8	5	7	2.75
France	2 200	15	1	21	3.25
Greece	750	10	4	25	3.25
Spain	330	28	5	12	3.75
Italy	7 700	22	4	21	5.25

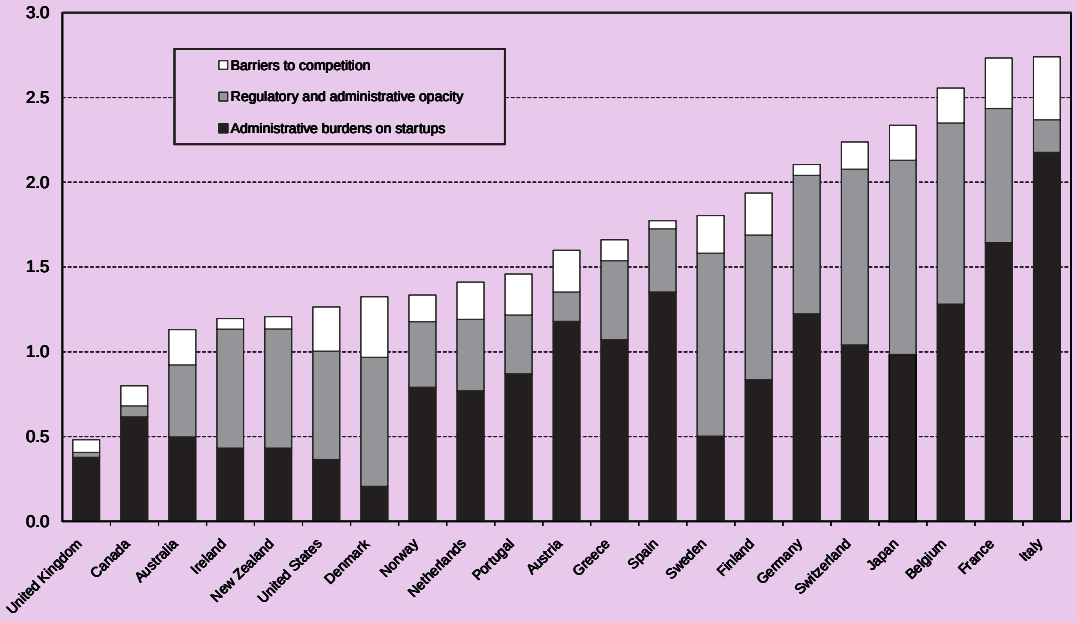
Note: Indicators of product market regulation are based on information on the state of regulation in or around 1998 in each country. Since 1998, many countries have implemented reforms. Details on progress accomplished in some of them, including an update of the indicators, can be found in the OECD *Reviews of Regulatory Reform*.

Cross-country studies show a negative correlation between extensive regulatory barriers and firm entry. A study analysing 75 OECD and non-OECD countries found that for an entrepreneur, legal entry is extremely cumbersome, time-consuming and expensive in most countries of the world (Djankov *et al.*, 2000). In this analysis, the number of procedures ranges from two in Canada to 20 in Bolivia, with a world average of about ten. The minimum official time for a start-up varies from a low of two days to a high of 174 business days, with a world average of 63 business days. The official cost ranges from under 0.25 of per capita GDP to over 2.6 times per capita GDP, with the average of 34% of annual per capita income. The analysis tests the theory that a high level of regulation of entry allows governments to screen new entrants and to ensure their viability and thus reduce market failures and improve firm performance. However, they find that stricter regulation of entry is not associated with higher profitability of firms or higher quality products but rather with a greater relative size of the unofficial economy and corruption.

Regulatory barriers also affect productivity growth through their impact on levels of entrepreneurship. A comparison of OECD countries shows that an indicator of the stringency of regulations affecting entrepreneurship is negatively correlated with growth in multifactor productivity. The indicator is based on: *i*) economy-wide administrative burdens on start-ups of corporate and sole-proprietor firms; *ii*) industry-specific administrative burdens on start-ups in retail distribution; *iii*) features of licensing and permit systems; and *iv*) communication and simplicity of rules and procedures (Nicoletti *et al.*, 1999). Overall, barriers to entrepreneurship appear to be lowest in the United Kingdom and Canada and highest in Italy and France (Figure 5.8). Countries exhibit substantial differences concerning the contribution of the underlying factors to the overall indicator. Thus, for example, Denmark seems to have the lowest administrative burdens on start-ups of all OECD countries, while Italy's unfavourable ranking is almost entirely due to high administrative burdens. In the past few years, however, countries such as Italy have taken significant steps to reduce these regulatory burdens on firms.

Small firms and new entrants are increasingly taking advantage of global markets, although their full potential remains untapped. Compared to large firms, they have a reduced capacity to meet the regulatory requirements imposed by importing countries in addition to those by home countries, as well as to handle international and cultural differences in business practices. Weak discipline in terms of timely payment by private and public customers poses a serious problem in many countries, both in the OECD and elsewhere. Such practices appear to be particularly widely applied against small firms with weak bargaining power, which tend to be more vulnerable owing to liquidity constraints.

Figure 5.8. **Regulatory barriers to entrepreneurship, 1998**



Note: The scale of indicators is 0-6. The components are weighted to show their relative importance in the overall indicator. Indicators of product market regulation are based on information on the state of regulation in or around 1998 in each country. Since 1998, many countries have implemented reforms. Details on progress accomplished in some of them, including an update of the indicators, can be found in the *OECD Reviews of Regulatory Reform*.
Source: Based on OECD Economics Department, International Regulation Database.

Uncertainty in terms of what to expect in foreign and less familiar markets, and the inability to take countervailing measures or to be able to afford to do so, can discourage small firms from initiating international operations and oblige them to maintain an overly domestic focus. Such conditions stifle the preparedness of many SMEs to invest the necessary time and money to learn how to use new tools such as the Internet which, as discussed in Chapter 3, can greatly facilitate SMEs' capacity to access information, make new business contacts and operate internationally. The intensive networking and clustering which is occurring among SMEs is in part a response to such factors, as it enables them to combine the advantages of small size at the firm level with economies of scale and scope at the level of the network, thus allowing firms to share costs and risks and thus overcome such barriers. Indeed in many countries, networks are now seen as a major success factor enabling SMEs to use ICT and internationalise (OECD, 2001*u*). Nevertheless, conditions at home as well as abroad influence the barriers and the opportunities available for firms to overcome them. This accounts for an interdependency among countries in the establishment of appropriate business conditions, not least in order to enable all firms, irrespective of size, to capture the potential benefits of globalisation and the new technologies.

Increasing access to venture capital

One of the greatest impediments to entry of new firms is lack of financing coupled with insufficient management expertise. Venture capital is a special type of finance targeted mostly to new and/or innovative firms who, by the nature of their business, need to obtain capital largely in the form of equity. Venture capitalists also provide management, marketing and legal advice; monitoring of performance; staging of investments; and reputational capital for new firms. Heavy reliance on intangible assets (technology, software) and negative cash flows make it difficult for these firms to

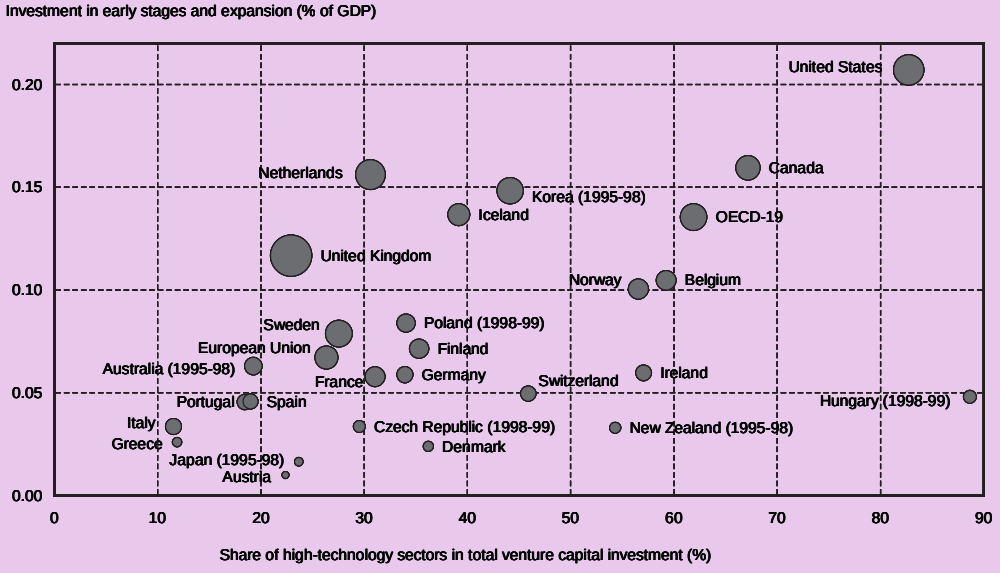
access bank loans or use other debt-financing instruments. There is evidence that venture capitalists, through the provision of finance and management advice, contribute significantly to improved firm performance in terms of survival rates, innovation and growth.

Venture capital activity in OECD countries has grown significantly in the 1990s, although there are considerable variations in the size of venture capital markets across OECD countries. The United States is by far the largest venture capital market in the OECD in absolute terms. While venture capital is fast expanding in Europe, it is still rare in countries such as Japan. It is estimated that the amount of formal venture capital invested in 1999 ranged from 0.85% of GDP in the United Kingdom and 0.64% in the United States to 0.022% in Japan (Baygan and Freudenberg, 2000). In addition, informal investments, such as by *business angels*, are believed to outweigh formal outlays in countries such as the United States.

Perhaps more important than total flows is the share of venture capital investments going to the early stages of enterprise formation and to higher technology sectors. More than three-quarters of total venture capital investment in the United States and Canada finances the early stages and expansion of firms, compared to less than half in Europe. About 80% of US venture capital is invested in high-technology sectors, particularly ICT and biotechnology (Figure 5.9). In North America, venture capital is being directed to where it is most needed: to riskier high-technology start-ups. This is in contrast to Europe and Japan, where investments are in more traditional sectors at later stages of enterprise development. Thus, public co-financing of private venture capital funds may sometimes be necessary to open funding bids for small technology-oriented firms.

Increasingly, one must also look at the role played by international flows of venture capital (Baygan and Freudenberg, 2000). US venture firms are investing in Europe and Asia, while within Europe and Asia, there are substantial cross-border investments. Taking into account international venture flows (*country of destination*), venture investments in countries such as Denmark and Ireland are more than four times as important as investments managed by domestic venture capital firms (*country of management*) (Figure 5.10). These countries appear to have entrepreneurial conditions and domestic demand for

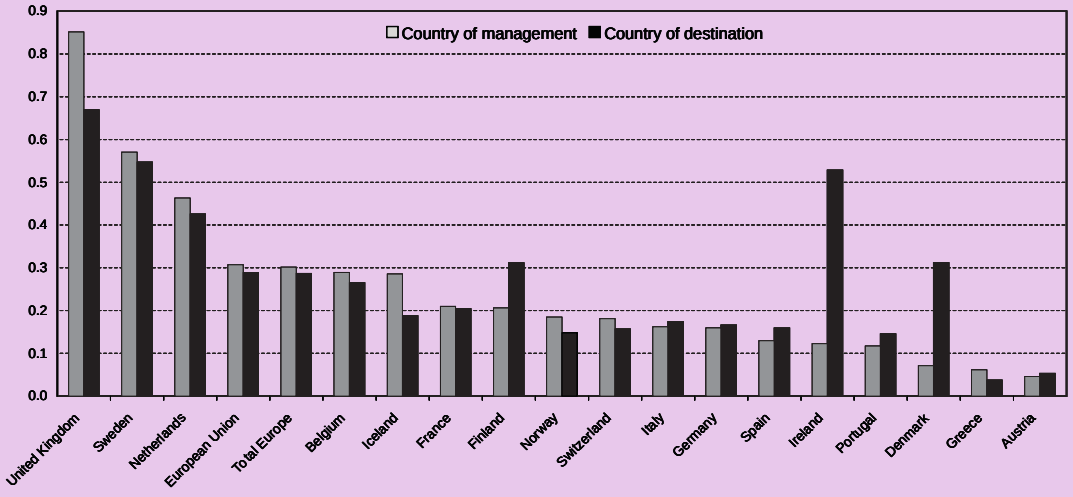
Figure 5.9. **Venture capital investment in early-stage/expansion and high-technology sectors, 1995-99**



Note: The area of the bubble corresponds to the percentage of total private equity/venture capital investment in GDP.
Source: Baygan and Freudenberg (2000).

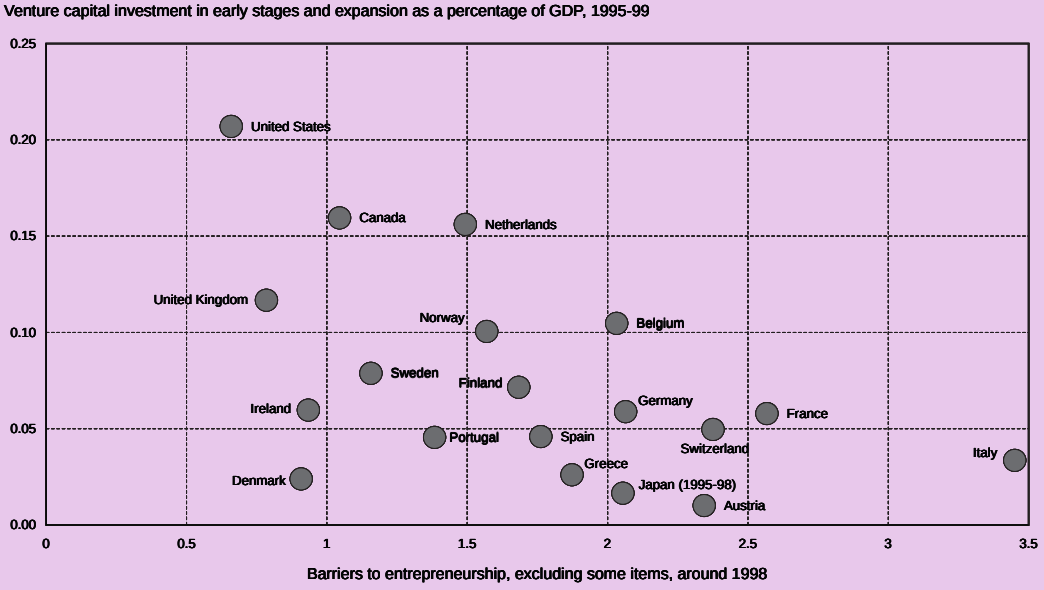
Figure 5.10. **Venture capital investment, 1999**

As a percentage of GDP



Note: Excluding "licence and permit systems", "sector specific administrative burdens" (for road freight and retail distribution), and "antitrust exemptions" (for public enterprises).
Source: Baygan and Freudenberg (2000).

Figure 5.11. **Barriers to entrepreneurship and venture capital activity, 1995-99**



Note: Excluding "licence and permit systems", sector specific administrative burdens" (for road freight and retail distribution), and "antitrust exemptions" (for public enterprises). Indicators of product market regulation are based on information on the state of regulation in or around 1998 in each country. Since 1998, many countries have implemented reforms. Details on progress accomplished in some countries, including an update of the indicators, can be found in the *OECD Reviews of Regulatory Reform.*
Source: Baygan and Freudenberg (2000).

venture funds that attract significant interest from foreign venture capitalists. Moreover, there is a strong negative relationship between regulatory barriers to entrepreneurship and venture capital investment indicating that countries which facilitate enterprise start-up tend to have more active venture capital markets (Figure 5.11).

There are also marked differences across countries concerning the composition of the sources of venture capital funds. In some countries, venture capital is raised from sources with longer investment horizons, *i.e.* institutional investors such as public and private pension funds and insurance companies, rather than banks which may have shorter timeframes and stricter lending conditions. In the United States, pension funds are by far the most important source of venture capital, although corporations have become increasingly active in this area. Similarly, pension funds are important sources of venture capital in Australia and New Zealand, while corporations are significant in Korea. The major sources of venture capital in Europe and Japan are still banks, although investments by pension funds and corporations is increasing.

Removing biases in tax regimes

There are many features of national tax regimes that can encourage or discourage entrepreneurship. These include the relative levels of taxation of corporations *vs.* individuals, incorporated *vs.* unincorporated enterprises, and employees *vs.* self-employed persons, as well as a growing array of special tax incentives geared to small firms. The relative costs and benefits of taxation approaches must be considered within national contexts, where a combination of fiscal measures determines effective tax rates on enterprises. In many cases, the difficulty of defining a fiscally neutral tax system for small businesses leads governments to alter a basket of existing taxes to approximate the desired taxation level. Different combinations of tax rates and exemptions can increase the bias towards self-employment and small-firm incorporation.

Studies find that high personal income tax rates can discourage entrepreneurship and the growth of small business. Since most entrepreneurs are self-employed and/or managing unincorporated businesses, profits are taxed through the application of a progressive rate schedule to personal income. Where personal income taxes are lower, entrepreneurial effort is more highly rewarded. This was confirmed by a US study of returns to sole proprietors before and after tax reform which found that increases in marginal tax rates led to decreases in the entry rate of enterprises (Carroll *et al.*, 2000). OECD countries are now experimenting with ways to reduce personal income taxes in order to spur entrepreneurship; Germany, for example, has lowered income taxes on entrepreneurs through relief from trade taxes under Tax Reform 2000.

The choice of whether to remain unincorporated depends on the relative tax advantages or disadvantages of shifting to a corporate income tax system. Depending on their earnings, unincorporated firms may or may not pay higher taxes than corporations. Several countries have harmonised the tax rate for incorporated and unincorporated firms, including Sweden which has a universal corporate rate of 30%, and Spain which has a lower rate for small firms (30%) *vs.* large firms (35%). Small firms which incorporate also face double taxation: corporate taxes on profits as well as personal taxes on distributed profits (dividends). The United States is fairly neutral with respect to the choice of legal form of business, while other countries often require the self-employed to pay both employers' and employees' contributions (OECD, 1994).

Self-employment tends to be more widespread in countries where employer social security contributions on behalf of employees are relatively high. In other words, high charges discourage entrepreneurs from taking on employees, incorporating and expanding. Studies find that high rates of labour taxation make it profitable to shift service production to the informal economy, particularly in the case of activities such as cooking, laundry, cleaning, gardening, repair and maintenance. Under lower taxation, these activities could lend themselves to a one-person business, a small business, a new enterprise or a family-owned business. Comparisons between Sweden and the United States (California) show that in order for a professional service producer to be competitive in Sweden, due to labour taxes, it must have an extremely high rate of productivity (Davidsson and Henrekson, 2000).

Capital gains taxes also influence entrepreneurial decisions. Taxes on capital gains deter productivity-enhancing investments by reducing the incentive for entrepreneurs to take risks. They can also act as a barrier to business restructuring when high capital gains taxes incite investors to postpone the sale of their assets or restructure their investments. In addition, tax rates on income from venture capital investments or stock options greatly affect the relative availability of such funds for small-firm financing. Capital gains tax provisions concerning the transfer of ownership of a small business affect the ease of entry and exit. Several countries are modifying provisions to facilitate the transfer of small-firm assets and reduce payments associated with succession by inheritance. In 2000, Canada introduced provisions to defer capital gains taxes on the disposition of shares in certain small businesses provided that the proceeds are reinvested in other small firms. In Germany, a new "co-partner tax remission" will facilitate transfer of companies and inter-generational succession of SMEs. Tax rules benefiting debt financing as opposed to equity financing make it difficult for new and small firms to obtain bank loans since such rules favour large, capital-intensive and established firms.

In recent years, special measures to alleviate the tax burden on new enterprises have proliferated in OECD countries. In Austria, for example, newly established firms are exempt from the minimum corporation tax in their first two years of operation. In France, new companies are eligible for a temporary exemption from corporation tax in regional development areas, and micro-enterprises are exempt from value-added taxes (VAT). In Korea, small firms receive a 50% reduction of income and property taxes for up to five years. In Italy, losses suffered by companies in the first three years of business may be carried forward indefinitely. In Sweden, losses incurred by new firms in the first five years of operation can be offset against individuals' earned income. In Spain, the period in which small firms can carry forward losses was raised from five to ten years. However, many of the small-firm tax provisions introduced in recent years have not been evaluated to determine the extent of their impacts on taxation levels, entrepreneurship or performance.

Facilitating the use of stock options

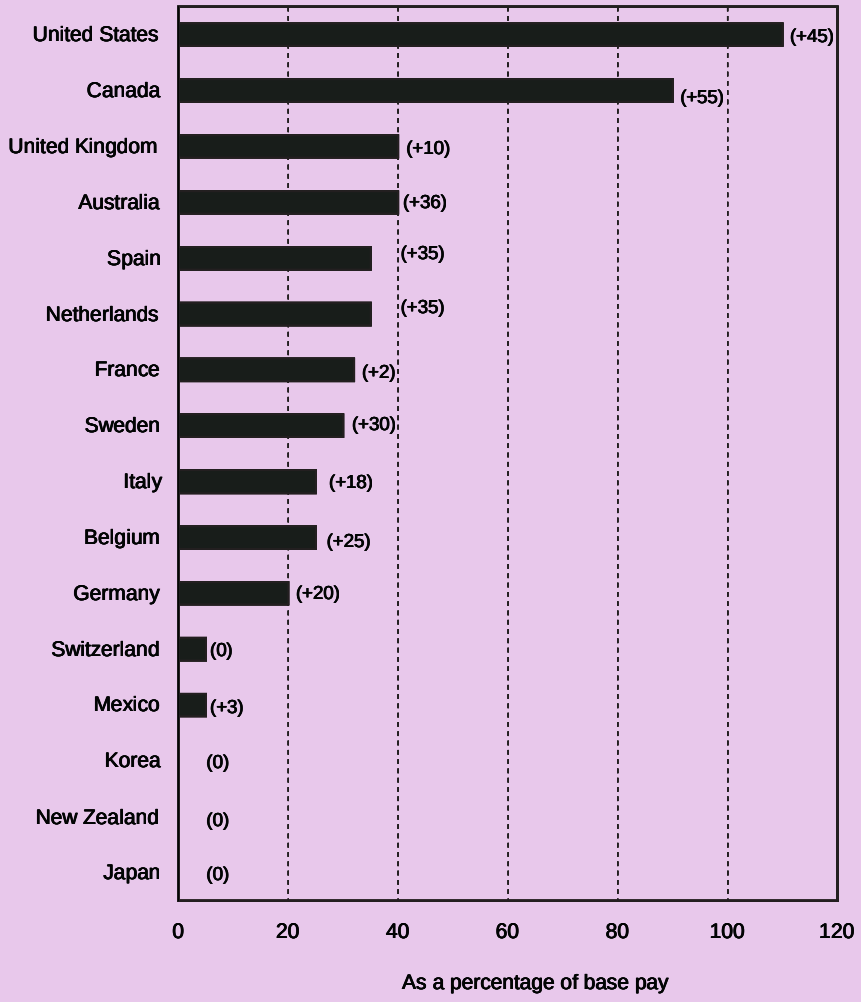
Stock options are a form of compensation that can boost entrepreneurship by encouraging managers to focus more actively on longer-term strategies which can enhance shareholder value. At the same time, stock options can facilitate entry of firms by providing a means through which new enterprises can attract, retain and motivate employees, particularly in the early stages of development when the viability of such companies is uncertain and they lack collateral and tangible assets. The options provide recipients with a right to purchase shares in their company at a pre-determined price – called the "strike" price – at some future date. The strike price is usually established at the time an option is granted and is generally set at a level equal to the fair market value of the stock, at the time of grant. If the market value of the shares appreciates, recipients can profit from the gain; if the value of the shares declines, the options have no value and would not be exercised.

In the 1990s, stock options were a standard feature in most executive pay packages in the United States where they had long been in use; their use has expanded more recently in other OECD countries. In the United States, Canada, the United Kingdom and Australia, for example, stock options amounted to 40%-100% of the level of basic compensation of senior executives in major companies in 2000 (Figure 5.12) (Towers Perrin, 2000). In Japan, on the other hand, they have played a lesser role as they could not effectively be used until 1997 when the Commercial Code was amended with regard to treasury stocks. By 2000, some 17% of all publicly traded firms in Japan (*i.e.* more than 500 companies) had introduced option plans (Tanaka, 2000).

A key development in option use has been their extension to a larger population of workers in a firm. Expansion was particularly notable in Silicon Valley companies in the United States, where keen competition for employees and high turnover rates encouraged firms to find ways to attract and retain workers. Through stock options, those who accept the risks associated with working for dynamic, but unproven, companies are able to share in their potential success. The payoffs have been particularly high in ICT-based firms. The value of shares in Internet companies such as Cisco and Oracle, for example, grew 380-fold and 200-fold, respectively, during the 1990s, before easing in recent months. Similarly, the value

Figure 5.12. **Stock options as a percentage of CEO base pay, 2000**

Change from 1996



Note: Long-term incentives, of which stock options are the largest component.
Source: Towers Perrin (2000).

of stock in Amazon.com – an Internet retailer whose sales and losses have risen in tandem since the company's founding – jumped 57-fold during 1997-99, before sliding precipitously during 2000.

From the perspective of the start-up firm, stock options can be an attractive way to compensate employees as they shift costs from the firm to existing shareholders. In the United States, for example, the sale of stock to employees is considered a "financing activity", with the proceeds recorded as an increase in cash. The only "cost" to the firm is an "opportunity cost" (*i.e.* the stock sold to employees could have commanded a higher price if it had been sold to outside parties at prevailing market prices), with no direct effects on profit and loss performance. Existing shareholders shoulder the burden through the dilution of their ownership stakes. As long as firms do well and the dilution is not excessive, shareholders appear to be tolerant of the practice – especially to the extent that the alternative might be higher fixed compensation costs.

In addition to benefiting start-ups, there are indications that stock option plans may also contribute to improved firm performance. Aligning the interests of employees more closely with management, for example, provides employees with increased incentives to communicate strategic information that could improve firm operations. A recent study supports this thesis. It found that firms with broad-based option plans had higher productivity levels and higher annual growth rates than other firms in 1992-97 (Blasi *et al.*, 2000). Other analysis is more hesitant in linking variable compensation – one of the most important components of which is stock options – to productivity levels (Lebow *et al.*, 1999).

The way in which options are used in countries depends in large part on the tax and regulatory treatment they are accorded. Within the OECD area, these conditions vary considerably. In some countries (*e.g.* Belgium), options are taxed when they are granted, while in most others they are taxed when they are exercised and/or when acquired shares are sold. Many countries, however, have provisions under which options can receive favourable tax treatment, provided they meet certain conditions. These conditions include minimum holding periods, annual limitations on the monetary value of options awarded to individuals, and/or the structure of the option plans. If they do not meet the criteria, the gains realised through the exercise of options and immediate sale of stock are generally treated as employment income, which is subject to social charges as well as income taxes. While these charges may be irrelevant where they are capped (such as in the United States and Canada), they can be significant in countries where they are not capped (*e.g.* France). Recognising that taxation can affect the value of options in spurring entrepreneurship, many OECD countries, including Belgium, Canada, France, Germany, Ireland, Japan, Norway, the Netherlands, Spain, the United Kingdom and the United States, have introduced reforms in recent years, or are contemplating doing so. There appears to be substantial room, however, for further reform. As a general principle, such reform should ensure that tax systems are neutral *vis-à-vis* this form of compensation, and that start-ups are not discouraged from implementing option plans. More attention may also have to be paid to the manner in which options held by internationally mobile workers are taxed, to avoid, for example, double taxation.

Factors facilitating exit

In the context of entrepreneurship, facilitating exit through sale of assets or restructuring is as important as easing entry. One incentive for investing time and resources in start-up activities is the knowledge that failure is possible without undue stigma or financial losses. The ability to sell assets or shares easily and exit the market is central to dynamic *churning* of firms. Factors and policies which can raise turnover include: *i*) amending bankruptcy rules; *ii*) strengthening secondary stock markets, and *iii*) evaluating and streamlining government support.

Amending bankruptcy rules

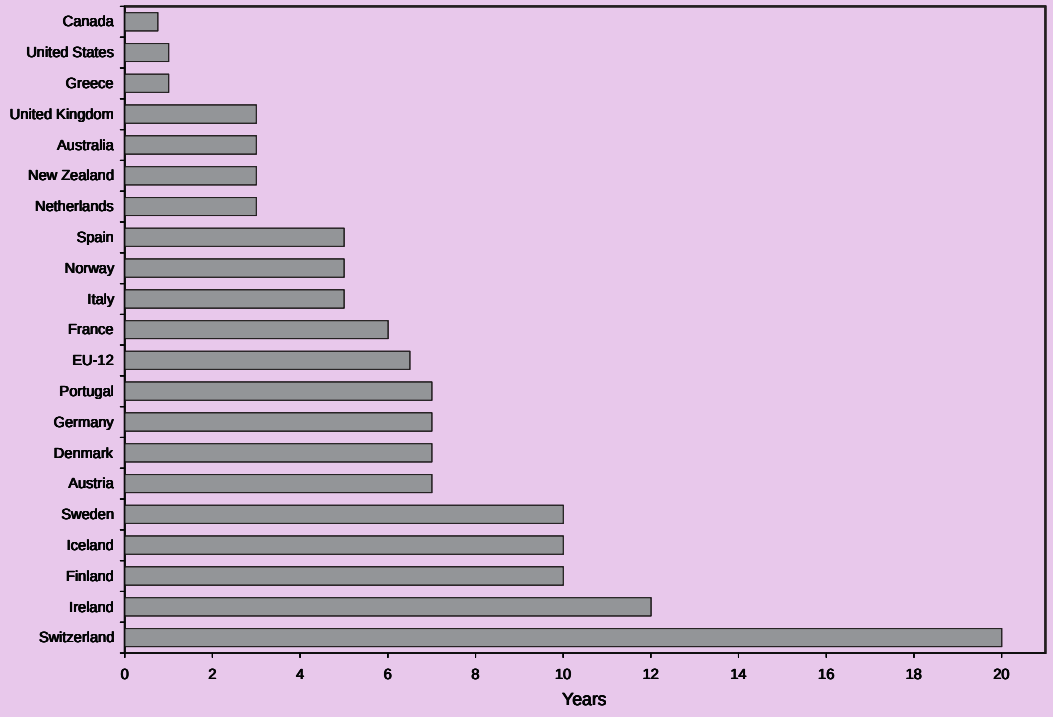
Bankruptcy legislation, which regulates firm exit by imposing financial disciplines on failed firms and the disposition of their assets, has an important influence on entrepreneurship. The exit of unsuccessful enterprises is an important part of the entrepreneurial process and of industrial restructuring. In reality, only a small proportion of firms close through bankruptcy, and most firm closures do not involve losses to creditors. Studies in the United Kingdom found that the most common causes for enterprise failure are loss of market or main customer, failure to deal with tax affairs, and lack of working capital and poor cash flow rather than fraudulent or criminal behaviour. Most firms fail in their first four years and more than half of failed entrepreneurs are under 45 years of age (UK DTI, 2000*b*).

Governments can influence attitudes towards risk-taking through the way they regulate bankruptcy. Innovators, entrepreneurs and investors are discouraged if bankruptcy legislation fails to achieve the appropriate balance between providing adequate creditor protection and encouraging a climate of risk-taking. A failing firm's quick and efficient exit from the market is an economic necessity that improves an economy's ability to reallocate resources among competing activities. In contrast, policies that restrict the scope for enterprises to restructure or close down completely may diminish an economy's ability to adjust quickly and may discourage would-be entrepreneurs.

Countries have widely varying insolvency procedures, including discharge periods, restrictions on firms, assets which may be retained by a firm, and actions that constitute criminal activity. Weak insolvency systems that discourage risk taking are a problem in several countries. In general, reviewing insolvency legislation with a view to preserving value and ensuring a swift reallocation of resources should be considered as a priority. While bankruptcy laws do not lend themselves easily to indicator-based comparisons, one variable is the time period in which creditors can lay claims on assets. In many countries, it is possible to obtain an earlier discharge from bankruptcy provided that certain criteria are met. In this respect, the legal provisions in Canada and the United States are more favourable than those in most European countries and Japan (Figure 5.13). Despite tough bankruptcy rules in the United States, discharge is immediate and individuals are free to start up a new business without restriction. In many European countries, discharge from bankruptcy takes much longer.

Other provisions linked to bankruptcy (*e.g.* restrictions on assuming directorship of a company, readiness of banks to provide capital, ability to obtain a new credit rating or venture capital) also play a role in entrepreneurial decisions to begin again. In the United States, the system is designed to give those who suffer bankruptcy an opportunity for a fresh start and quickly channels resources away from companies that are not competitive. In some cases, managing a company that goes bankrupt is viewed as a useful apprenticeship for starting another company. In contrast, declaring bankruptcy in many European and Asian countries carries a stigma that can destroy an entrepreneur's future. Few European countries have been able to implement comprehensive reforms giving entrepreneurs a real second chance. Austria and Germany, two countries with stringent bankruptcy legislation due to the traditional central role of banks in corporate finance, have introduced some changes but maintain long creditor claim periods. The

Figure 5.13. **Length of time that creditors have claims on a bankrupt's assets, 2000**



Note: The minimum length of time from among a range of different bankruptcy cases or circumstances.
Source: UNICE (2000); data for Australia, Canada and New Zealand from UK DTI, *The Insolvency Service* (2000); Japan data from national sources.

United Kingdom is considering a relaxation of bankruptcy laws to remove the stigma of failure from those whose businesses fail through no fault of their own; they can keep a share of their assets and debts can be discharged after six months rather than three years (European Commission, 1999*b*).

Many Asian countries either have inadequate bankruptcy laws or no laws at all. In Japan and Korea, for example, when a company filed for bankruptcy, management was dismissed, the court appointed trustee oversight, and there was no automatic protection from creditors. It was also difficult and costly to dismiss employees with long-term contracts. Consequently, there was little incentive to declare bankruptcy and many crippled companies continued operations (Nuechterlein, 2000). However, reforms are now being implemented and procedures are being put in place to strengthen the institutional framework for dealing with insolvent firms and managing related debt and creditor claims.

Strengthening secondary stock markets

The financial system in many countries remains geared to the accumulation of physical assets in large stable firms and well-established industries. Greater reliance on capital markets, and particularly on second-tier capital markets, would assist in channelling capital towards riskier and more innovative undertakings. In order to stimulate such markets, securities regulators should strengthen disclosure requirements and investor protection mechanisms. Raising turnover and restructuring, as well as promoting risk-taking by entrepreneurs, is facilitating the sale of shares through the stock market. Those OECD countries that experienced higher growth in the 1990s have been better able to channel risk capital to emerging sectors and firms through the stock market mechanism rather than relying on more traditional lending sources such as banks. Initial public offerings (IPOs) are one of the most profitable means for disposal of investments for entrepreneurs and venture capital investors. The existence of an exit mechanism gives entrepreneurs an additional incentive to start a company, and investors are more willing to supply funds to start-ups if they feel that they can later recoup their investment. However, entry requirements for traditional stock markets may be too stringent and costly for smaller or younger companies lacking collateral or a track record. An alternative is secondary markets especially geared to smaller, technology-based firms. Such secondary markets can foster entrepreneurship and financing of start-ups since they apply less stringent admission requirements and lower initial and continuing costs.

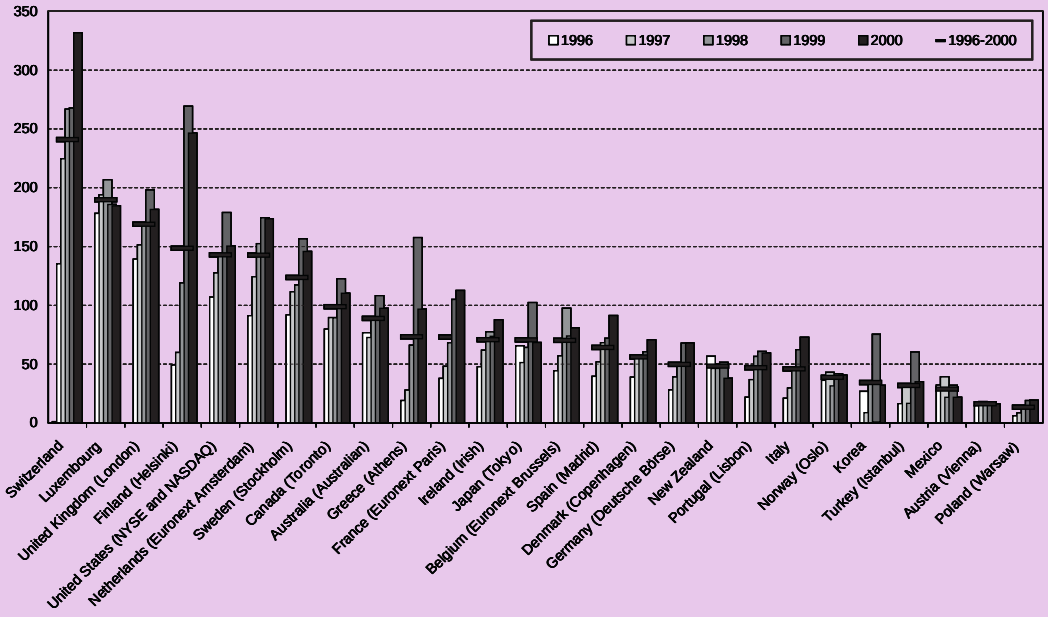
While stock market capitalisation (both main and secondary markets) rose substantially in virtually all OECD countries until the correction in 2000, stock markets vary markedly in size. Stock market capitalisation as a share of GDP between 1995 and 1999 was highest in Switzerland, the United Kingdom, the United States, the Netherlands and Sweden (Figure 5.14). In contrast, stock markets are less developed in countries such as Poland, Austria, Turkey, Mexico, Korea and Italy. However, recent growth has been highest in Finland, Greece, France, Korea and Turkey, perhaps due to changes in securities regulations and/or *stock bubbles*.

Secondary stock markets for younger, smaller firms include so-called second-tier markets, parallel markets, restricted markets, free markets and new markets. The oldest, most important and best-known secondary market is the NASDAQ in the United States, which was created in 1971. Several secondary markets for high-growth companies have been created since the mid-1990s, including EASDAQ (Europe), AIM (United Kingdom), N*ouveau Marché* (France) and N*euer Markt* (Germany). Secondary stock market capitalisation has grown in virtually all countries in recent years, both due to higher stock prices (until the correction in 2000) and to additional listings of new companies. While the much bigger NASDAQ actually experienced a decline in the number of listed companies, secondary markets in other countries showed impressive growth. Capitalisation of these markets relative to GDP is highest in the United States and Germany (Figure 5.15). However, cross-country comparisons are hampered by a lack of common definitions and differences in rules and regulations regarding company listings.

In Europe, until very recently, the possibilities for small firms to raise capital in equity markets were relatively limited. However, the evolution of pan-European equity markets such as EASDAQ will be conducive to the growth of European risk capital. In 2000, nearly 5 000 companies were listed on NASDAQ compared to less than 2 000 in all the European new markets. However, there was a higher number of new introductions in Europe (398) compared to the United States (151). IPOs as a share of

Figure 5.14. **Market capitalisation of shares of domestic companies**

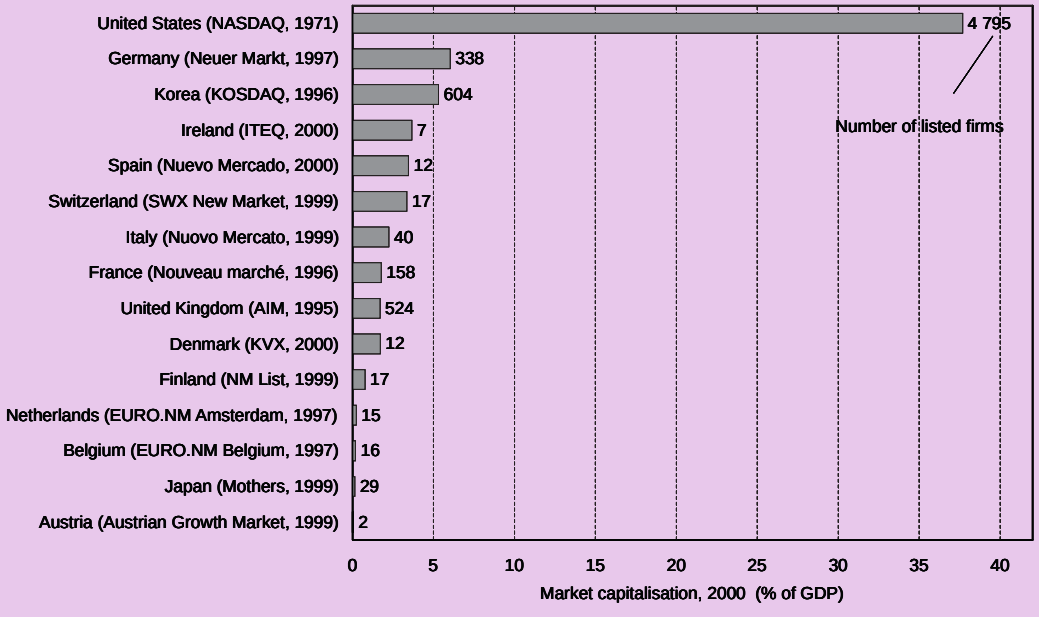
Main and parallel markets, as a percentage of GDP



Source: International Federation of Stock Exchanges (FIBV).

Figure 5.15. **Market capitalisation of "new markets"**

As a percentage of GDP



Source: Compilation from national sources.

venture capital divestments in 1999 occurred in France (37%), Germany (34%) and the United Kingdom (24%). The size of UK deals was about three times the EU average, with Italy and Sweden trailing far behind. While the Korean secondary stock market was recently reported to have more than 600 listings, the Japanese market remains small, with less than 30 companies. As well as fostering the development of secondary stock markets, countries can improve small-firm access through enhancing information and networking, reducing registration complexities and costs, contributing to the costs of IPOs, and encouraging private investors to participate more fully in new equity issues.

E*valuating government support*

It is also possible that overly generous government support or misdirected programmes may be a factor slowing the exit of otherwise unviable small firms. Many government programmes have been defensive in nature and have sometimes resulted in an exaggerated dependence of small firms on government support as well as lower levels of innovativeness and competitiveness. There has been a proliferation of schemes to assist small firms in recent years, in areas such as financing, training, exporting, technology diffusion, etc. While these programmes may act to overcome market and systemic failures relating to firm size, there is a need to streamline SME schemes whose rationale or efficiency may have waned over time. To this end, the OECD is promoting more widespread and continuous use of programme evaluation to examine the continuing relevance and effectiveness of small firm interventions (OECD, 2000*n*).

Low entry and exit rates in Japan have been partly ascribed to overly protective government programmes. Japan has far lower exit rates for small firms than the United States or the United Kingdom. One study found significantly greater enterprise turnover in non-regulated industries than in regulated sectors, particularly in the case of services, indicating that government regulation (in fields such as telecommunications) may be a factor impeding exit in Japan (Morikawa and Tachibanaki, 1999). Another study pointed out that by providing preferential loans to small retail enterprises, the Japanese Government is slowing the exit of unproductive retailers (McKinsey Global Institute, 2000).

In Europe, too, certain policy approaches could be impeding the exit of unviable enterprises. Although the United Kingdom has higher entry and exit rates than many other European countries, a survey of small UK manufacturing firms found that 21% received grant funding for innovation-related activities and that this negatively affected their motivation to seek further funding as well as their general level of innovativeness (Freel, 1999). Bankruptcy provisions can serve to prolong the existence or delay the exit of failing enterprises. For example, insolvency legislation in France and Spain has placed strong emphasis on maintaining employment in loss-making firms, and firms that eventually close generally incur more losses than if they had been allowed to close at an earlier stage. Recent legislation is aimed at correcting this effect (OECD, 1998*c*).

Conclusions and policy implications

In its broadest sense, entrepreneurship may be viewed as being about people with an economically creative spirit, whether they operate within large, established enterprises or in new and small entities. The most common interpretation association is with the ability, or willingness, of enterprising individuals to take on risk and start up new businesses. This chapter has focused on enterprise entry and exit rather than on more general features of entrepreneurship and firm survival. The proxy variables considered here include self-employment rates, business ownership rates, levels of nascent entrepreneurs, the share of small firms in output and employment, and enterprise entry and exit rates. Firm entry/exit shifts market share from losers to gainers, self-selects those firms that are more likely to survive, and leads to knowledge and technology spillovers and productivity increases.

A number of national studies and cross-country comparisons demonstrate correlation between enterprise turnover levels and growth in productivity and output. The presence of such a relationship tends to have strengthened in the last decade. Rapid technological change appears to have placed a premium on the ability of countries to accommodate high rates of business formation and dissolution. It appears that entry and exit rates are significant over the longer term (at least ten years), that *churning* in

service sectors is more important than in manufacturing, and that smaller and younger firms show greater volatility. The ability of small firms to perform well and survive is also critical to growth, but high survival rates may point to barriers to entry and exit and less contestable markets. And, while high rates of enterprise turnover may contribute to productivity growth, sustained economic growth may also raise the turnover rate.

A number of factors clearly impact on entrepreneurship. In countries with a relatively concentrated supply structures for services, for instance, *e.g.* large retail trade chains or public training and health-care services, there are more limited options for profitable entry of new small enterprises. But more fundamentally,variations in entrepreneurship levels to a large extent reflect differences in culture and education. In many cases, observed patterns and trends have more to do with prevailing attitudes towards risk-taking and individualism than with government interventions affecting small-firm start-up and closure. Studies to measure the level of respect in communities for those starting new firms indicate fundamental differences in social and cultural values which affect the level of entrepreneurial activity. Inadequate human capital may act as an impediment to entrepreneurial activity. For instance, education plays a vital role in entrepreneurship. The level of participation in post-secondary education can predict a large share of the differences in entrepreneurial activity across countries (Reynolds *et al.*, 2000). In addition, business schools in countries such as the United States and the United Kingdom – which are lacking in many European and Asian countries – play an important role in fostering innovative and entrepreneurial managers.

OECD countries differ widely in their policy approaches to entrepreneurship. Governments should evaluate their own situations in order to identify critical bottlenecks to entrepreneurship in the national context. In order to increase the number of entrepreneurs and start-ups, priorities for reform must be established and policy packages developed to address obstacles to firm entry and exit. Some countries, *e.g.* Japan, should initiate action on a broad front, ranging from removing regulatory barriers to amending bankruptcy provisions. Other countries, *e.g.* the United Kingdom, are advised to focus on financial aspects such as stimulating early-stage venture capital and expanding secondary stock markets. France and Italy are among those countries that would benefit from lower administrative and regulatory burdens on start-ups. In the United States, significant administrative burdens on small firms remain. Japan and many European countries could usefully examine the costs and benefits of increasing the use of stock options. All countries would potentially benefit from reviewing the effects of tax regimes on entrepreneurs and small firms as well as from improving evaluation of government support programmes.

While recognising the importance of entrepreneurship policy, which covers the early stages of the entrepreneurial process, decision makers should also take account of "SME policy" in formulating entrepreneurship policies as the two are complementary. Broad-based policy approaches towards entrepreneurship are discussed below. However, the effectiveness of each policy will vary according to the economic and social characteristics of the country concerned:

- ***Facilitate entry and exit.*** Governments need to provide an environment conducive to the efficient functioning of markets. High entry and exit rates often indicate high levels of entrepreneurship, whereby old and unsuccessful firms offering outdated products and services are replaced by new firms with new products and services. Steps to facilitate entry and exit include:
  - *Reform regulations and institutional impediments*: Overly complicated and costly business establishment procedures discourage risk-taking and new ventures. In addition, the ongoing costs associated with compliance with government administration and regulatory requirements may act to discourage entrepreneurship. Eliminating and lowering obstacles to business development and enterprise creation should remain a priority goal.
  - *Amend bankruptcy rules*: Effective closure of unsuccessful firms is a necessary component of a dynamic economy in which productive resources can be deployed quickly elsewhere. Governments need to ensure that insolvency and bankruptcy provisions comprise rules on the discharge of debt which remove the stigma of failure and give entrepreneurs a real second chance.

- **Expand access to financing.** The availability of financing is recognised by entrepreneurs as being one of the key impediments to starting up a business. The existing financial systems in most OECD countries favour bank financing over equity, often to the disadvantage of new firms with insufficient collateral. Equity is a more accessible source of financing for new businesses. Ways to improve accessibility to finance for entrepreneurs include:
  - *Increase access to venture capital*: Venture capital plays an extremely important role in bridging the financing gap for innovative projects by new firms and providing managerial advice to start-ups. Governments need to modify legal and fiscal provisions which impede the supply of private capital for risky undertakings and address funding gaps where access to financing is a major business constraint.
  - *Strengthen secondary stock markets*: The financial system in many countries is geared towards the accumulation of physical assets in large and established firms. The existence of second-tier stock markets, which help to channel capital towards riskier and more innovative projects, is an important element of entrepreneurship. Strengthening secondary stock markets for smaller and technology-based firms and taking steps to facilitate access to such markets by unlisted small companies continue to present an important policy challenge in many countries.
- **Reward entrepreneurship.** Entrepreneurship thrives in economies in which risk taking is rewarded. Steps to improve incentives for risk taking include:
  - *Simplify the legal and fiscal treatment of stock options*: Stock options can help to raise the level of entrepreneurship in firms by encouraging managers to focus on long-term strategies. They can also facilitate the entry of new firms by providing a means to attract, retain and motivate employees. In order to increase their use, more attention needs to be paid to simplifying the legal and fiscal treatment of stock options, encouraging broad-based plans for employees, and reviewing the level, types and timing of taxation of options.
  - *Remove undue bias in taxation against entrepreneurship*: High taxes tend to distort economic decision making and lead to a misallocation of resources. Moreover, certain features of the tax system typically discourage entrepreneurial activity. Governments need to review and remove undue biases in personal, corporate and capital gains taxes which penalise the self-employed, the incorporation and financing of small firms, and the transfer of SME assets.
- **Mobilise human resources.** Ineffective use of human resources represents an economic and social loss. Women, for instance, make up half of society but are an under-utilised resource in many countries, both in the OECD and elsewhere. Steps to improve the effective use of human resources include:
  - *Increasing entrepreneurship opportunities for women*: Fostering awareness and enhancing entrepreneurial skills among women through childhood and adult education and management training; alleviating barriers to financing and start-up of firms by women entrepreneurs; and promoting equitable access to and use of new technologies by women-owned businesses would improve prospects for growth.
  - *Develop an entrepreneurial culture*: Increase the number of entrepreneurs by teaching entrepreneurship skills to young people and encouraging risk taking in educational systems. Governments should invest more in training and lifelong learning for entrepreneurs and dissemination of information concerning the start-up of firms.
- **Provide relevant, effective and efficient government programmes.** Well-designed government programmes can complement efficient markets and foster entrepreneurship. Steps to ensure the effectiveness of government programmes include:
  - *Conduct regular programme evaluations*: Ineffective government programmes that sustain unsuccessful small firms create disincentives for successful entrepreneurial firms. Governments should conduct regular evaluations of government policy orientations and programmes in order to avoid measures which can slow the exit of unviable small firms.

Countries should formulate domestic policies which enhance entrepreneurship, while, at the international level, governments should work together to provide a global environment that fosters entrepreneurship. While recognising that the design of policies relating to entrepreneurship will vary across countries due to country-specific factors, it is nonetheless useful to share policy experiences and exchange policy views, with governments subjecting themselves to peer review and reflecting together on their current practices and room for improvement. The effectiveness of entrepreneurial policies could be substantially improved by drawing more effectively on the knowledge and policy experiences accumulated in other countries. As a further step, in some areas, regulatory reform and trade/investment liberalisation require a more active form of international co-operation. For example, globalisation brings new competitive pressures and creates new opportunities for the business community at large, including SMEs. However, the limited capacity for SMEs, particularly in foreign markets, to deal with opaque and ineffective regulatory conditions, or to enforce sanctions for late payment, impede their options for international expansion. Domestic reform alone will not suffice to improve this situation. There is thus a rationale for internationally co-ordinated efforts, both on a regional basis within the EU, in the OECD and also globally, to build a business-friendly environment which is both transparent and reliable, in order to create as level a playing field as possible for new entrants and small firms in foreign markets.

There is considerable scope for further quantitative and policy analysis on the subject of entrepreneurship. Delineating the factors which contribute to entrepreneurship and the relationship of entrepreneurial activity to growth is difficult due to the limited availability of data. Cross-country comparisons are especially problematic due to the different approaches and definitions used at the national level. Better and more comparable measures are needed in relation to entrepreneurship in general and to enterprise demography in particular. Analysis of the relationship of entrepreneurship, however measured, to productivity, employment and output, in periods of economic expansion and contraction, also needs to be improved in the *new economy* context of the 1990s and beyond. Benchmarking entrepreneurship policies, regulatory environment and performance can serve to identify the key issues which need to be addressed and can help policy makers to put in place effective solutions.

Chapter 6

CONCLUSIONS

What is new?

Building on the OECD Growth Project, which analysed the recent variation in growth patterns across countries, this report has examined in some depth the contributions of ICT, science, technology and innovation, and entrepreneurship, to economic growth. The reported findings strengthen the message that significant changes are under way in the fundamentals of economic growth. These changes showed up in higher trend growth in some countries in the 1990s and, especially towards the end of the decade, in higher MFP growth in several countries with already high productivity levels. There was also a prolonged boom in the United States which displayed little sign of building inflationary pressures even at exceptionally low levels of unemployment and high levels of capacity utilisation. Indications of such changes were visible elsewhere as well. Taken together with a number of observations at firm and industry level, these developments suggest that new technologies – including ICT – innovation, and associated skills upgrading and organisational change, are attaining greater influence in shaping economic growth.

Differences in countries' ability to adapt to these changes appear to be influencing growth performance. While there was no overall increase in productivity growth in the OECD, previous tendencies towards convergence in productivity levels across OECD countries were overturned, primarily as countries with strong productivity performances strengthened their positions even further. There were also signs of increasing income differences within many countries. The rapidity with which fortunes were overturned in 2000 as the US economy cooled rapidly and stock prices tumbled – phenomena that were not confined to the technology sector or to the United States – has been interpreted by some analysts as providing evidence of further risks and challenges in this new environment. Regardless, the basic conclusions regarding structural change remain valid. Important long-term changes are under way, in particular "new factors" are becoming more important for growth, with far-reaching implications for policy.

The key challenge is to formulate comprehensive policy frameworks that are better able to capture the benefits of the new growth factors. This special edition of the Science, Technology and Industry Outlook identifies a number of concrete policy levers that governments can use to improve their countries' growth prospects. However, this is not only an issue for individual ministries and public authorities; rather, it spans a range of policy domains. Addressing it will call for broad-based communication and governance, embracing the key social actors and stakeholders.

Formulating the responses

Improving the prospects for economic growth will require complementary actions by many stakeholders in both the private and the public sectors (*e.g.* industry, academia, unions, governments). This report focuses on those actions that governments can and should be taking. Governments will need to consider their actions in an increasingly global context. Trade and investment flows are expanding, and industrial restructuring as well as social and environmental challenges transcend national borders. As this report has emphasised, the benefits to be had from international technology and knowledge flows are also growing in importance, not only in small countries where they often dwarf the contribution of the domestic S&T base, but also in large nations with much greater S&T resources.

Regulatory and institutional conditions continue to vary across countries, impeding cross-border trade and restructuring. Many of these issues can be dealt with by domestic policy, but there are limits to what national governments can achieve in isolation. Continued globalisation serves to increase interdependencies among countries, and many of the issues raised above require international solutions that will only come about through increased international co-operation. Similarly, many of the obstacles to communication, scientific development, innovation and entrepreneurship, simply cannot be removed with national means alone.

In the area of ICT, countries need to work together on: *i*) improving data and measurement in order to better understand market developments and policy challenges; *ii*) liberalising and freeing up competition in network infrastructure; *iii*) establishing confidence and trust, *e.g.* in the Internet and online transactions through appropriate privacy, security and consumer protection; and *iv*) establishing appropriate policies for taxation of electronic commerce. In the area of science and technology, there is a growing need for international co-operation on a range of issues, from large-scale science projects to improved conditions for international flows of knowledge. International co-ordination is further needed to ensure that business and regulatory environments are transparent and allow for a more level playing field for new entrants and small firms in foreign markets.

At the same time, it is essential for countries to implement more comprehensive domestic strategies. This is clearly the case for ICT, an enabling technology with wide-ranging applications that are most productive when diffused and used in conjunction with organisational change, training and education. Although ICT production has contributed to growth in a number of OECD countries, the most significant economic benefits are likely to accrue to those countries that most effectively deploy ICT throughout their economies. In order to improve the basis for broad ICT development and use, governments are advised to: undertake pro-competitive market liberalisation policies; enhance the development of high-speed communication networks and services and their diffusion throughout society, paying special attention to local communication infrastructures; foster innovation and entrepreneurship within national and global networks; embrace e-government, in order to improve internal efficiency and government reach to citizens while enabling public demonstration and diffusion effects; and ICT training and education, both to address short-term skills gaps and to ensure the long-term development of a flexible and competent workforce.

Policy frameworks should promote the benefits of ICT, innovation and entrepreneurship for all citizens, without undermining incentives for restructuring and re-skilling. In order to overcome differences in access within OECD countries, attention needs to be given to: *i*) improving diffusion to individuals and households via access through schools and other public institutions; *ii*) improving diffusion to businesses via ICT training and information diffusion for small businesses; *iii*) IT education and training in schools, vocational training, teacher training; and *iv*) judicious use of government services on line, and government procurement to provide demonstration effects. The presence of information and resource gaps calls for enhanced information flows and training programmes, while underscoring the need for improved transparency and efficiency in regulatory frameworks.

While ICT has emerged as significant for economic performance, an even more fundamental source of growth is innovation. The development and deployment of new products, processes and services, drives improvements in labour, capital and multifactor productivity. It also facilitates the fulfilment of numerous societal needs, such as improved health and environment protection. Innovation often involves organisational as well as technological change and requires sizeable complementary investments in worker training, manufacturing and marketing, in addition to formal R&D. Innovation appears to be playing an increasingly important role in driving economic growth; those countries that have fared best in recent years tend to be those that have successfully adapted their S&T systems to evolving patterns of innovation. Key ways forward include improved means for: formal and informal knowledge-sharing among R&D-conducting firms; increased openness to international flows of knowledge in policies and programmes; and greater complementarity between public and private investments in R&D to ensure that government-financed R&D generates fundamental scientific and

technical knowledge that can seed innovation, and corrects for market failures that limit business investments in R&D.

At least as important as overall levels of government R&D funding are the ways in which this funding is channelled (*e.g.* the types of institutions supported, the mechanisms used to finance R&D). Steps that can be taken to improve the effectiveness of R&D funding include: *i*) giving greater priority to basic and long-term mission-oriented research in government S&T programmes; *ii*) ensuring a better match between financial mechanisms to support business R&D (*e.g.* tax credits *vs.* direct funding) and policy objectives; *iii*) improving opportunities for commercial spillovers from mission-related R&D; *iv*) restructuring programmes to support small business without crowding out private venture capital; *v*) using more flexible financing instruments (*e.g.* contracts *vs.* institutional funds) to make R&D funding more responsive to areas of growing social and industrial importance; and *vi*) pursuing international co-operation in R&D to enable more effective cost-sharing and international knowledge transfers. Collaboration among private-sector organisations is particularly important, and can be seeded by collaboration in government-sponsored (or cost-shared) programmes.

Governments can also improve innovation by taking steps to enhance the contribution of public research organisations to national innovation systems. A key element of such efforts comprises the restructuring of universities and public laboratories to make them more responsive to the needs of business and society while maintaining their strengths in training and education. This involves a number of steps, including: *i*) establishing and strengthening mechanisms for transferring knowledge from the public to the private sector; *ii*) implementing regulatory reforms related to IPRs and the licensing of publicly funded research; *iii*) making greater use of competitive funding instruments in supporting public research institutions; *iv*) removing or reducing regulatory barriers that impede the mobility of S&T workers within and among sectors; and *v*) instituting formal evaluations of publicly funded R&D to improve the quality of research and provide governments with valuable information on how best to allocate R&D funds.

The role of ICT and innovation in economic growth is enhanced in a dynamic entrepreneurial economy. Entrepreneurship reflects the ability of an economy to mobilise resources in order to capitalise on new market opportunities based on innovative ideas. To the extent that entrepreneurship harnesses new technologies and innovation, it is increasingly recognised as being central to economic growth and its role is not likely to diminish in the knowledge-based economy where flexibility and speed are key attributes. A country with many entrepreneurial activities would likely create many new firms with innovative products and services replacing old firms with outdated products and services, thereby improving its growth prospects. It is important to recognise that the economic environment is often a determining factor in entrepreneurs' decisions to start new businesses.

The essential role of government is to provide an entrepreneurial policy environment in which there are ample economic opportunities and rewards for risk taking. Although the private sector is undoubtedly the key driver of entrepreneurship, government actions can either facilitate or hinder business start-ups. It is thus extremely important to implement a set of policies that fosters entrepreneurship.

The following policy principles can help to create a business-friendly environment: *i*) facilitate entry and exit by reforming regulations and institutional impediments and amending bankruptcy rules; *ii*) reward entrepreneurship by simplifying the legal and fiscal treatment of stock options and removing undue bias in taxation against entrepreneurship; *iii*) mobilise human resources by fostering awareness and entrepreneurial skills among women entrepreneurs; and *iv*) provide relevant effective and efficient government programmes by conducting regular programme evaluations. In essence, wherever possible, governments should refrain from interfering with market mechanisms so that decisions made by entrepreneurs reflect a proper balance between rewards and risks.

In all of these areas, there is a considerable variation across OECD countries, *e.g.* in terms of their level of development and recent growth trajectories, as well as in the specific strengths or weaknesses that affect future options and risks. The policy recommendations listed above are generally applicable, but there are important variations among countries as regards objectives and starting points for reform.

Not only will there be significant differences as regards appropriate timing, sequencing and phasing of the "right" policy mix, no single approach will offer a universally optimal solution. Systemic factors need to be taken into account, as relevant policies in individual areas will interact with a broad spectrum of partly context-specific conditions. Furthermore, national and international policy frameworks cannot be separated but will have to be developed in tandem. The OECD provides a forum in which countries can address issues which require common solutions on an ongoing basis, while sharing experiences and pushing for progress in those areas which fall under the responsibility of national administrations.

Growing together

The uneven growth performances recorded by the OECD countries, the weakening of economic convergence, and the simultaneous appearance of growing income disparities within countries, have given rise to serious concerns. This anxiety is often associated with enhanced competition, rapid restructuring and fast-evolving needs for skills upgrading and re-skilling, which bring about not only benefits but also losers and transition costs. As noted at the outset of this report, globalisation has mostly pushed towards convergence in factor prices and growth rates, as international capital, labour and technology flows have served to spread the economic opportunities. International co-operation will become even more important in the present environment marked by fierce competition and increasingly mobile resources. Many of the activities that are important for knowledge creation and use, such as R&D, are subject to increasing returns to scale. This has benefited the United States – the single largest economy in the world and the productivity leader in most areas – but smaller economies, such as Ireland, Australia, and the Nordic countries have demonstrated that similar benefits can accrue through closer international integration and co-operation.

The recent economic performance of many smaller OECD countries compared with larger countries, such as Germany, Japan, and to some extent Italy, reinforces the notion that size plays a diminished role in economic growth. Rather, it appears that the variation in growth performance across OECD countries primarily reflects another sort of diversity. Given that considerable convergence has taken place in macroeconomic policies, as ensuring that monetary and fiscal policies are conducive to stability has been given the very highest level of priority in the policy agenda of most countries, the evidence points to a major influence of continued differences in institutional conditions and structural, microeconomic, government policies. This underscores the importance of strengthening policy frameworks for the "new growth factors", in such a way that can bring together a broad spectrum of structural policy domains, *i.e.* of formulating a comprehensive policy response at the microeconomic as well as macroeconomic level. Again, in some instances, where fragmentation and inconsistency are costly without producing compelling benefits, the task involves the creation of common playing rules. In other instances, no single best solutions exist and the processes of multiple policy experimentation should continue; here the task is one of engaging in effective mutual learning in order to gain a better idea of what works and what does not work.

At a general level, greater efforts are needed to remove existing impediments to change. Economic growth should be made compatible with other objectives such as social stability and a healthy environment, and hence prove themselves sustainable for the long term. For both these reasons, a comprehensive policy agenda needs to engage the private sector, as well as other stakeholders such as labour and civil society, in such a way that they can articulate the need for, and contribute to, change – rather than oppose it. Measures to counteract socially unacceptable income differences have to be an integral part of the package. However, actions of this sort must be designed so as not to weaken incentives for work, innovation and entrepreneurship, in order not to undermine flexibility and growth prospects.

Future directions

Following the "OECD Growth Study", initiated by the 1999 Ministerial, it is clear that the analysis and policy evaluation undertaken, some of which is described in this and the preceding chapters, as well as current economic developments, call for continued work in many directions.

On the issue of measurement, the Growth Project has inspired a consolidated effort across the OECD area. One result no doubt will be the adoption of more comparable methodologies in different countries, partly aided by the parallel work undertaken to compile a Manual on Productivity Measurement (OECD, 2001*w*). Additional work is needed to develop improved indicators of R&D and innovation performance, which is important for enabling countries to strengthen the social and economic returns from their R&D investments. Another example is the renewed efforts, in close co-operation with statistical agencies throughout the OECD, to ameliorate the measurement of firm demography, *i.e.* the birth and death and growth of firms. As a result, ten years or so from now, it should be easier to assess, for instance, the impacts on growth deriving from ICT, other new technologies and changes in firm organisation. Progress in this respect cannot be taken for granted, however, but will require continued effort and co-operation among countries.

Some of the issues addressed will have to be examined more carefully in the context of globalisation. The framework for international trade – a topic not addressed in detail in this report – is of course of fundamental importance. Progress in many of the areas discussed, such as intellectual property rights and the need for freeing up new avenues in services, is strongly influenced by the resumption of an effective WTO agenda. Meanwhile, further work is needed to better understand the impact of globalisation on S&T policy, which continues to be framed by domestic initiatives aimed at strengthening national innovation systems. As science, technology, and innovation become more international, it will be essential to find ways to open national systems to greater international collaboration. Human resource issues also require further examination in an international context. For instance, while international mobility of skilled labour is of great importance today for knowledge transfers and rapid adjustment to changing needs, important work remains to be undertaken to improve our understanding of the driving forces of globalisation and to devise policy measures that can help to bring about mutually beneficial outcomes for different countries.

To enable effective implementation of the recommendations made in this and other reports which have been part of the OECD Growth Project, further work is needed to tailor the conclusions to the specific conditions prevailing in individual countries. This calls for further benchmarking of country performances and identification of "best practices" in response to critical issues. Such work goes beyond the wide-ranging effort of the past two years. It would benefit from a strengthening of forums for the frank and free exchange of experiences among countries on the establishment of comprehensive and consistent policy frameworks favouring not only established interests, but also entry by newcomers and the evolution of "new growth factors".

REFERENCES

Andersson, T. (2000),
"Seizing the Opportunities of a New Economy: Challenges for the European Union", OECD *Growth Project Background Paper* No. 8, OECD, Paris.

Anton, J.J. and D.A. Yao (1994),
"Expropriation and Inventions: Appropriable Rents in the Absence of Property Rights", *American Economic Review*, Vol. 84, No. 1, pp. 190-209.

Association of University Technology Managers (AUTM) (1999),
AUTM *Fiscal Year* 1998 *Survey*.

Audretsch, D. and M. Fritsch (1999),
"The Industry Component of the Regional New Firm Formation Process", *Review of Industrial Organization* 4, p. 2.

Audretsch, D. and R. Thurik (1997),
"Sources of Growth: The Entrepreneurial *vs.* the Managed Economy", *Centre for Economic Policy Research Paper* No. 1710, London.

Audretsch, D. and R. Thurik (2000),
"Linking Entrepreneurship to Growth", paper prepared for the OECD Directorate for Science, Technology and Industry.

Australian Bureau of Statistics (ABS) (2000),
Business Use of Information Technology.

Baily, M.E., E.J. Bartelsman and J. Haltiwanger (1996),
"Downsizing and Productivity Growth", in David Mayes (ed.), *Sources of Productivity Growth*, Cambridge University Press.

Baldwin, J.R. (1995),
The Dynamics of Industrial Competition: A *North American Perspective*, Cambridge University Press.

Bartelsman, E., G. Van Leeuwen and H.R. Nieuwenhuijsen (1995),
"De Industrie Benenschepper of Banenvernietiger?", *Economische Statistische Berichten*, pp. 504-508.

Baygan, G. and M. Freudenberg (2000),
"The Internationalisation of Venture Capital Activity in OECD Countries: Implications for Measurement and Policy", STI *Working Paper* 2000/7, OECD, Paris.

Bednarzik, R. (2000),
"The Role of Entrepreneurship in US and European Job Growth", *Monthly Labor Review*, July.

Blasi, J., D. Kruse, J. Sesil and M. Kroumova (2000), *Public Companies with Broad-Based Stock Options: Corporate Performance from* 1992-1997, at *www.nceo.org*

Buderi, Robert (1999),
Engines of Tomorrow: *How the World's Best Companies Are Using Their Research Labs to Win the Future*, Simon & Schuster, New York.

Bundesministerium für Bildung und Forschung (BMBF) (2000),
Basic and Structural Data 1999/2000, Federal Ministry of Education and Research, Bonn.

Cameron, G. (1998),
"Innovation and Growth: A Survey of the Empirical Evidence", mimeo, July.

Caroll, R., D. Holtz-Eakin, M. Rider and H.S.Rosen (2000),
"Personal Income Taxes and the Growth of Small Firms", NBER *Working Paper* No. 7980, National Bureau of Economic Research, Cambridge, Mass.

Cezard, M. and L. Vinck (1998),
"En 1998, plus d'un salarié sur deux utilise l'informatique dans son travail", Premières synthèses n° 53.2, December 1998, DARES – ministère de l'Emploi et de la Solidarité, *Enquête Conditions de travail de* 1998, *premières synthèses*, Paris. Available at: *www.travail.gouv.fr/publications/p_detailPublication.asp?idTitre*=316

Cho, M. (2000),
"Safeguarding the Freedom of Research and the Broad Diffusion of Knowledge", paper presented at the German/OECD Conference on "Benchmarking Industry-Science Relationships", Berlin, October.

Cohen, W.M. and D.A. Levinthal (1990),
"Absorptive Capacity: A New Perspective on Learning and Innovation", *Administrative Science Quarterly* 35, pp. 128-152.

Colecchia, A. (2001),
"The Impact of ICT on Output Growth", STI *Working Paper*, OECD, Paris, forthcoming.

Computer Science and Telecommunications Board (CSTB) (1999),
Funding A Revolution: Government Support for Computing Research, National Research Council,National Academy Press, Washington DC.

Computer Science and Telecommunications Board (CSTB) (2000),
"Making IT Better: Expanding Information Technology Research to Meet Society's Needs", Computer Science and Telecommunications Board, National Research Council, National Academy Press, Washington DC.

Davidsson, P. and M. Henrekson (2000),
"Institutional Determinants of the Prevalence of Start-ups and High-Growth Firms: Evidence from Sweden", *Small Business Economics*.

De, D. (2001),
"Fostering Entrepreneurship in Europe", in A. Lundström and L. Stevens (eds.), (2001), *Entrepreneurship Policy for the Future*, Swedish Foundation for Small Business Research, Stockholm.

Djankov, S. *et al.* (2000),
"The Regulation of Entry", NBER *Working Paper* No. 7892, National Bureau of Economic Research, Cambridge, Mass.

Eliasson, G. (1996),
Firm Objectives, Controls and Organisation: The Use of Information and the Transfer of Knowledge within the Firm, Kluwer Academic Publishers, Dordrecht/Boston/London.

Eliasson, G. and E. Taymaz (2000),
"Institutions, Entrepreneurship, Economic Flexibility and Growth – Experiments on an Evolutionary Micro-to-macro Model", in U. Canter, H. Hanusch and S. Klepper (eds.), *Economic Evolution, Learning and Complexity*, Physica-Verlag.

European Commission (1999*a*),
Enterprises in Europe, Enterprise Policy, Luxembourg.

European Commission (1999*b*),
European Economy, Supplement A, No. 12.

European Commission (2000),
"Benchmarking Enterprise Policy", SEC(2000)1842, Commission Staff Working Document.

European Technology Assessment Network (1999),
Report on Promotion of Employment in Research and Innovation Through Indirect Measures, European Commission, Brussels.

Fixler, D. and K. Zieschang (1999),
"The Productivity of the Banking Sector: Integrating Approaches to Measuring Financial Service Output", *Canadian Journal of Economics* 32.

Folster, S. (2000),
"Do Entrepreneurs Create Jobs?", *Small Business Economics* 14.

Freel, M.S. (1999),
"The Financing of Small Firm Product Innovation Within the United Kingdom", *Technovation* 19.

Gans, Joshua and Scott Stern (2000),
"When Does Funding Research By Smaller Firms Bear Fruit? Evidence from the SBIR Program", NBER *Working Paper* No. 7877, National Bureau of Economic Research Cambridge, Mass. Available on line at *www.nber.org/papers/w7877*

Gera, Surendera, Wulong Gu and Frank C. Lee (1999),
"Information Technology and Productivity Growth: An Empirical Analysis for Canada and the United States", *Canadian Journal of Economics*, Vol. 32, No. 2, April, pp. 384-407.

Guellec, D. and B. Van Pottelsberghe (1999),
"Does Government Support Stimulate Private R&D?", OECD *Economic Studies*, No. 29, OECD, Paris.

Guellec, D. and B. Van Pottelsberghe (2001),
"R&D and Productivity Growth: A Panel Data Analysis of 16 OECD Countries", STI *Working Paper*, OECD, Paris, forthcoming.

Hahn, Chin-Hee (2000),
"Entry, Exit, and Aggregate Productivity Growth: Micro Evidence on Korean Manufacturing", *Economics Department Working Paper* No. 272, OECD, Paris.

Hall, Bronwyn and John Van Renen (2000),
"How Effective Are Fiscal Incentives for R&D? A Review of the Evidence", *Research Policy* 29, pp. 449-469.

Haltiwanger, J. (1997),
"Measuring and Analyzing Aggregate Fluctuations: The Importance of Building from Microeconomic Evidence", *Federal Reserve Bank of St. Louis Review*, May/June, pp. 55-85.

Haltiwanger, J. (2000),
"Aggregate Growth: What Have We Learned From Microeconomic Evidence?", *Economics Department Working Paper* No. 267, OECD, Paris.

Hicks, D. (2000),
"Using Indicators to Assess Evolving Industry-Science Relationships", paper presented at the German/OECD Conference on Benchmarking Industry-Science Relationships, Berlin, October.

HM Treasury (2001),
"Increasing Innovation: A Consultation Paper", Inland Revenue, London, March.

Institute of Management Development (IMD) (2000),
The World Competitiveness Yearbook.

Iyigun, M. and A. Owen (1999),
"Entrepreneurs, Professionals, and Growth", *Journal of Economic Growth* 4.

Jaffe, A. and J. Lerner (1999),
"Privatizing R&D: Patent Policy and the Commercialisation of National Laboratory Technologies", NBER *Working Paper* No. 7064, National Bureau of Economic Research Cambridge, Mass.

Jorgenson, D.W. and Z. Griliches (1967),
"The Explanation of Productivity Change", *Review of Economic Studies*, Vol. 34, pp. 249-283, July.

Lansbury, M. and D. Mayes (1996),
"Entry, Exit, Ownership and the Growth of Productivity", in David Mayes (ed.), *Sources of Productivity Growth*, Cambridge University Press.

Lebow, D., L. Sheiner, L. Slifman and M. Starr-McCluer (1999),
Recent Trends in Compensation Practices, Board of Governors of the US Federal Reserve System, 15 July, at *www.fereralreserve.gov*

Litan, R.E. and A.M. Rivlin (2000),
"The Economy and the Internet: What Lies Ahead?", Conference Report No. 4, Brookings Institution, Washington DC, December.

Maddison, A. (1995),
Monitoring the World Economy 1820-1992, Development Centre Studies, OECD, Paris.

McKinsey Global Institute (2000),
Why the Japanese Economy is Not Growing: Micro Barriers to Productivity Growth, Washington DC.

Ministry of Economic Affairs (2001),
Entrepreneurship in the Netherlands, The Hague, The Netherlands.

Morikawa, M. and T. Tachibanaki (1999),
"Entry, Exit, Job Creation and Job Destruction: An Analysis Based on the Micro-Data of Japanese Manufacturing Industry", MITI/RI *Discussion Paper* No. 99-DF-32.

Mowery, D. (1998),
"The Effects of Bayh-Dole on US University Research and Technology Transfer", paper presented at the OECD/TIP Workshop on Commercialisation of Government-Funded Research, Canberra, 25 November.

Narin, F. (1999),
"Tech-Line Background Paper", *www.chiresearch.com/techline/tlbp.htm*

Narin, F., M. Albert, P. Kroll and D. Hicks (2000),
Inventing Our Future: The Link Between Australian Patenting and Basic Science, Commonwealth of Australia.

National Science Foundation (2000),
Science and Engineering Indicators 2000, Arlington, VA.

Nicoletti, G., S. Scarpetta and O. Boyland (1999),
"Summary Indicators of Product Market Regulation with an Extension to Employment Protection Legislation", *Economics Department Working Paper*, No. 226, OECD, Paris.

Nuechterlein, J.D. (2000),
"International Venture Capital: The Role of Start-up Financing in the United States, Europe, and Asia", Council on Foreign Relations & Westview Press.

Observatoire des Sciences et Techniques (OST) (2000),
Indicateurs 2000, Economica, Paris.

OECD (1994),
Taxation and Small Businesses, OECD, Paris.

OECD (1995),
Purchasing Power Parities and Real Expenditures, Vol. 1993, OECD, Paris.

OECD (1998*a*),
Technology, Productivity and Job Creation, OECD, Paris.

OECD (1998*b*),
University Research in Transition, OECD, Paris.

OECD (1998*c*),
Fostering Entrepreneurship, OECD, Paris.

OECD (1999*a*),
Managing National Innovation Systems, OECD, Paris.

OECD (1999*b*),
"The Research Global Village", STI *Review*, Special Issue No. 24, OECD, Paris.

OECD (2000*a*),
"Is There a New Economy – First Report from the OECD Growth Project", OECD, Paris.

OECD (2000*b*),
"Recent Growth Trends in OECD Countries", OECD *Economic Outlook*, No. 67, OECD, Paris.

OECD (2000*c*),
"Links between Policy and Growth: Cross-country Evidence", OECD *Economic Outlook*, No. 68, OECD, Paris.

OECD (2000*d*),
Purchasing Power Parities and Real Expenditures, 1996 *Results*, Paris.

OECD (2000*e*),
Measuring the ICT *Sector*, OECD, Paris.

OECD (2000*f*),
STI *Review*, Special Issue on Sustainable Development, No. 25, OECD, Paris.

OECD (2000*g*),
Main Science and Technology Indicators, No. 2, OECD, Paris.

OECD (2000*h*),
"Role of Competition and Co-operation in Innovation and Growth", internal working document, OECD, Paris.

OECD (2000*i*),
"Public Support to R&D and Innovation in the Context of the New Economy", internal working document, OECD, Paris.

OECD (2000*j*),
"A New Economy? The Changing Role of Innovation and Information Technology in Growth", OECD, Paris.

OECD (2000*k*),
"Industry-Science Relationships: Interim Report", internal working document, OECD, Paris.

OECD (2000*l*),
OECD *Employment Outlook*, "Recent Developments in Self-employment", OECD, Paris.

OECD (2000*m*),
OECD *Information Technology Outlook* 2000, OECD, Paris.

OECD (2000*n*),
OECD *Small and Medium Enterprise Outlook*, OECD, Paris.

OECD (2000*o*),
OECD *Science, Technology and Industry Outlook* 2000, OECD, Paris.

OECD (2001*a*),
The New Economy: Beyond the Hype. The OECD *Growth Project*, OECD, Paris.

OECD (2001*b*),
Sustainable Development: Critical Issues, OECD, Paris.

OECD (2001*c*),
OECD *Science, Technology and Industry Scoreboard* 2001: *Towards Knowledge-based Economies*, OECD, Paris.

OECD (2001*d*),
Knowledge, Work Organisation and Economic Growth, OECD, Paris, forthcoming.

OECD (2001*e*),
New Patterns of Industrial Globalisation: Cross-border M&As and Alliances, OECD, Paris.

OECD (2001*f*),
"The Software Sector", OECD, Paris, forthcoming.

OECD (2001*g*),
"Impacts of Electronic Commerce on Business", OECD, Paris, forthcoming.

OECD (2001*h*),
OECD *Communications Outlook* 2001, OECD, Paris.

OECD (2001*i*),
"Understanding the Digital Divide", OECD, Paris.

OECD (2001*j*),
"The Digital Divide: Diffusion and Use of ICTs", internal working document, OECD, Paris.

OECD (2001*k*),
ICT *Skills and Employment*, OECD, Paris.

OECD (2001*l*),
Education Policy Analysis, OECD, Paris.

OECD (2001*m*),
Intermodal Freight Transport: Institutional Issues, Road Transport and Intermodal Linkages Research Programme, OECD, Paris.

OECD (2001*n*),
"Competition Issues in Electronic Commerce", internal working document, OECD, Paris.

OECD (2001*o*),
"Knowledge Management, E-government and Information Communication Technologies", internal working document, OECD, Paris.

OECD (2001*p*),
"The Impact of Information and Communications Technologies on Output Growth: Issues and Preliminary Findings", internal working document, OECD, Paris.

OECD (2001*q*),
"Third Conference on the Global Research Village", Amsterdam,internal working document, OECD, Paris.

OECD (2001*r*),
Entrepreneurship, Growth and Policy, OECD, Paris, forthcoming.

OECD (2001*s*),
"Public Funding of R&D: Emerging Policy Issues", internal working document, OECD, Paris.

OECD (2001*t*),
Benchmarking Industry-Science Relationships in OECD *Countries*, OECD, Paris, forthcoming.

OECD (2001*u*),
Enhancing SME *Competitiveness: The* OECD *Bologna Ministerial Conference*, OECD, Paris.

OECD (2001*v*),
Women Entrepreneurs in SMEs: *Realising the Benefits of Globalisation and the Knowledge-based Economy*, OECD, Paris.

OECD (2001*w*),
Measuring Productivity: OECD *Manual on the Measurement of Aggregate and Industry-level Productivity Growth*, OECD, Paris.

Office of Technology Assessment (OTA) (1995),
The Effectiveness of Research and Experimentation Tax Credits, OTA-BP-ITC-174, US Congress, Washington DC, September.

Oliner, S.D. and D.E. Sichel (2000),
"The Resurgence of Growth in the Late 1990s: Is Information Technology the Story?", *Finance and Economics Discussion Series* 2000-20, Federal Reserve Board, Washington DC.

Pavitt, K. (1984),
"Sectoral Patterns of Technological Change: Towards a Taxonomy and a Theory", *Research Policy* 13, pp. 343-373, reprinted in K. Pavitt (ed.) (1999), *Technology, Management and Systems of Innovation*, Edward Elgar.

Pavitt, K. (2000),
"Public Policies to Support Basic Research: What Can the Rest of the World Learn from US Theory and Practice?", SPRU *Electronic Papers Series*, No. 53. *www.sussex.ac.uk/spru/publications/imprint/sewps/sewp53/sewp53.html*

Pentikaïnen, T. (2000),
"Economic Evaluation of the Finnish Cluster Programme", Espoo, VTT, Working Papers No. 50/00.

Pilat, Dirk and Frank C. Lee (2001),
"Productivity Growth in ICT-Producing and ICT-Using Industries: A Source of Growth Differentials in the OECD?", STI *Working Paper* 20001/4, OECD, Paris.

Porter, M. and S. Stern (2000),
"Measuring the "Ideas" Production Function: Evidence from International Patent Output", NBER *Working Paper* No. 7891. National Bureau of Economic Research, Cambridge, MA, *www.nber.org/papers/w7891*

Press, E. (2000),
"Managing and commercialising know-how and core competencies of universities and public research institutions", Rapporteur's report presented at the German/OECD Conference on "Benchmarking Industry-Science Relationships", Berlin, October.

Reynolds, P., M. Hay, W.D. Bygrave, S.M. Camp and E. Autio (2000),
Global Entrepreneurship Monitor: 2000 *Executive Report*, Babson College/London Business School.

Reynolds, P.D., D.J. Storey and P. Westhead (1994),
"Cross-National Comparisons of the Variations in Firm Formation Rates", *Regional Studies*, Vol. 28, No. 3.

Romer, P.M. (1990),
"Endogenous Technological Change", *Journal of Political Economy* 98, Supplement, pp. 71-102.

Sara, V. (2000),
"The National Investment in Research", paper presented at the German/OECD Conference on "Benchmarking Industry-Science Relationships", Berlin, October.

Scarpetta, S., A. Bassanini, D. Pilat and P. Schreyer (2000),
"Economic Growth in the OECD Area: Recent Trends at the Aggregate and Sectoral Levels", OECD *Economics Department Working Paper* No. 248, OECD, Paris.

Schreyer, P. (2000*a*),
"The Contribution of Information and Communication Technologies to Output Growth", STI *Working Paper* 2000/2, OECD, Paris.

Schreyer, P. (2000*b*),
"High-Growth Firms and Employment", STI *Working Paper* 2000/3, OECD, Paris.

Solow, R.M. (1957),
"Technical Change and the Aggregate Production Function", *Review of Economics and Statistics*, Vol. 39, pp. 312-320, August.

Solow, R.M. (1987),
"We'd Better Watch Out", *New York Times*, July 12, Book Review, No. 36.

Statistics Finland (J. Nurmela) (1998),
"Does Modern Information Technology Select its Users?", *Reviews* 1998/5, Helsinki.

Statistics Finland (J. Nurmela, R. Heinonen, P. Ollila and V. Virtanen) (2000),
"Mobile Phones and Computers as Parts of Everyday Life in Finland", *Reviews* 2000/5, Helsinki.

Stiroh, K.J. (2001),
"Information Technology and the US Productivity Revival: What do the Industry Data Say?", *Staff Report*, Federal Reserve Bank of New York, No. 115, New York, January.

Stokes, D. (1997),
Pasteur's Quadrant: Basic Science and Technological Innovation, Brookings Institution, Washington DC.

Tanaka, N. (2000),
"A New Economy' for Japan", presentation to the OECD Secretariat, 18 October.

Teece, D.J. (1987),
"Profiting From Technological Innovation: Implications for Integration, Collaboration, Licensing, and Public Policy", in D.J. Teece (ed.), *The Competitive Challenge: Strategies for Industrial Innovation and Renewal*, Ballinger, Cambridge, Mass., pp. 185-220.

Towers Perrin (2000),
"2000 Worldwide Total Remuneration", New York.

Triplett, J.E. (1999),
"The Solow Productivity Paradox: What do Computers do to Productivity", *Canadian Journal of Economics*, Vol. 32, No. 2, pp. 309-334.

UNICE (2000),
"Stimulating Creativity and Innovation in Europe: The UNICE Benchmarking Report 2000", Brussels, Belgium.

United Kingdom Department of Trade and Industry (UK DTI) (2000*a*),
Business in the Information Age. International Benchmarking Study 2000, September, London.

United Kingdom Department of Trade and Industry (UK DTI) (2000*b*),
Bankruptcy: A *Fresh Start*, The Insolvency Service, London.

United Kingdom National Statistics (2000),
Internet Access, 1st Quarter 2000, 10 July; *Internet Access*, 26 September, London, at *www.statistics.gov.uk/pdfdir/inter*0700.*pdf* and *www.statistics.gov.uk/pdfdir/inter*0900.*pdf*

United States Bureau of Labor Statistics (2001),
"Producer Price Indexes – Current Series", *www.bls.gov*

United States Council of Economic Advisors (2001),
Economic Report of the President, Washington DC.

United States Department of Commerce (1999),
The Emerging Digital Economy II, Economics and Statistics Administration, Washington DC.

United States Department of Commerce (2000),
Falling through the Net: *Towards Digital Inclusion*, Washington DC. (report IV) and *Falling through the Net*, I, II, III, available at *www.esa.doc.gov/fttn*00.*htm*

Verspagen, B. (2001),
"Economic Growth and Technological Change: An Evolutionary Interpretation", STI *Working Paper* 2001/1, OECD, Paris.

Whelan, K. (2000),
"Computers, Obsolescence and Productivity", *Finance and Economics Discussion Series* 2000-20,Federal Reserve Board, Washington DC.

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