POLICY BRIEF

OECD

January 2004

Science and Innovation Policy: Key Challenges and Opportunities

Introduction

Science and technology exert a growing influence on society and the economy. Scientific achievements continue to expand the frontiers of knowledge and increasingly contribute to the technological progress that affects how people live and work. New science-based technologies help protect the environment, build safer homes, schools and factories, and develop energy-saving transport systems. Advances in genetics save lives and improve health standards throughout the world. Industries based on new technologies employ millions of highly skilled workers in the OECD and beyond. Information and communications technologies (ICT) have enhanced their productivity and made it possible for a greater number of individuals, firms and countries to take part in the knowledge-based economy.

Continuing progress in biotechnology, nanotechnology and ICT promises further improvements in living standards and economic performance. Such benefits, will not, however, occur without strong commitment to research. The same advances that can save lives and create jobs can prove harmful to populations and disrupt economies. Such concerns foment debates within society on issues ranging from genetically modified foods and nuclear energy to biometric identification using characteristics such as retinal scanning. Furthermore, considerable effort will be needed to ensure that research results are translated into new products, processes and services by the business sector.

What can OECD governments do to harness scientific and technological advances to the benefit of society at large? How can public research best contribute to innovation and economic growth? In an era where knowledge is key to competitiveness and where intellectual property plays a greater role in giving innovators market power over competitors, to what extent should scientific research data resulting from publicly funded research remain available and who should have access? Against a background of growing public concerns about scientific advances and waning interest in science among youth, how can society supply the scientists and engineers needed to keep the knowledge economy moving? Globalisation is also shaping – and is shaped – by scientific progress. Increasingly, international co-operation is necessary to advance scientific knowledge and technological capacity, whether in large scientific ventures such as the Large Hadron Collider at CERN or in emerging fields such as neuroinformatics. How should OECD governments organise such co-operation so that all can share the burden and rewards?

This Policy Brief looks at what OECD governments are doing, and can do in the future, to ensure that science and technology continue to provide solutions to economic and social challenges while minimising potential risks and taking into account the needs and interests of a growing number of stakeholders in government, academia, industry and civil society at large. ■

oecd Observer

© OECD 2004

How to harness science for society?

Scientific discoveries can have enormous implications for society and everyday life. The connection between an area of research or even a particular scientific discovery and a new product, process or service may be far from obvious. However, in a fast-changing knowledge economy, it is all the more important to ensure that systems are in place to link the work of scientists with the innovators in business who can see a potential commercial use for the product.

In OECD countries, businesses conduct the largest share of total research and development (R&D), but this work tends to focus mainly on activities with a commercial end in sight. This does not allow for the fact that many technological advances that are taken for granted today came about as a result of publicly funded research that was not undertaken in pursuit of an immediate commercial use.

That is what happened with the Internet. Many of the fundamental technologies underlying today's Internet – World Wide Web, the Web browser, and e-mail – derive from publicly funded research (Box).

In addition, many of the most dramatic scientific advances in the life sciences, including the mapping of the human genome which has opened the way for a whole new range of health research and discoveries, have benefited from the participation of public research institutions. Research to develop new products, processes and services based on these discoveries is carried out by the private sector, but private sector efforts would hardly have been possible without public research.

This vital link between a scientific discovery and practical applications is becoming all the more important as science is increasingly driving innovation. The interaction between science and innovation has always been something of a two-way street, with innovation often preceding the science to explain it (*e.g.* the steam engine was invented well before the development of the principles of thermodynamics that made it work). While this remains true today, scientific advances increasingly lay the basis for innovation. In dynamic, growing fields such as electronics, computing and, more recently, biotechnology, science and technology are tightly interwoven. The question is how best to manage such relationships and ensure that science is fully harnessed for innovation in society.

The relationship between public and private research is a key element in ensuring that science and innovation work together in the most productive way for society. Key challenges in the public sphere – delivery of healthcare, social services for ageing populations, sustainable transport, online security and privacy – offer promising opportunities to harness the creative capabilities of the private sector via public/private partnerships to achieve productivity gains and service improvements that can benefit society.

In addition, publicly funded research is likely to remain critical in initiating new waves of revolutionary technologies in areas such as ICT, biotechnology and nanotechnology. For one thing, work in these and

Box: The importance of public research in driving industrial innovation

Business may drive the development of new products, but many of the key innovations that society takes for granted have their origin in publicly funded research. The Internet and all that grew out of it, from e-mail to e-commerce, is a case in point.

The Internet was not the result of competitive market processes, but emerged largely from government-funded defence research conducted in universities, industry and government laboratories. What is more, important ICT innovations such as computer timesharing, workstations, and even e-mail all involved significant government-funded R&D on novel types of computing systems. Much of this R&D was conducted as part of government programmes, in some cases after the market had abandoned the research.

The subsequent development of the World Wide Web is also a salutary reminder that the purpose behind a particular research path often has little direct relationship to the ultimate outcome. The Web was developed for a specific scientific purpose: to help hundreds of scientists working in different countries to share and access data from the European Laboratory for Particle Physics (CERN). It was the private sector that took this publicly available research and made it into the universal communications tool it is today.

other socially important areas increasingly tends to be multidisciplinary, and innovation often requires mobilising the complementary competencies of both the public and private research sectors.

Indeed, in some fields the work of public and private research functions are converging as the delay from academic research to industrial practice is shortening. Much work in large industrial research laboratories and in high-technology start-ups in the private sector is at the cutting edge of the search for new knowledge, while university-based scientists may find themselves exploring the commercial applications of their discoveries almost as soon as they are made.

Public research organisations are encouraged to work more closely with the private sector to both enhance the relevance of their research and facilitate its use by industry. This has led to the emergence of broad alliances as well as formal market-based relationships between universities and firms. Universities are entering the growing market for technology themselves, by patenting their discoveries and licensing their use, conducting research under contract for the private sector, or participating in collaborative public/private research partnerships.

There is significant evidence, including from the OECD, of the positive effects of public-sector R&D on growth and productivity as well as on business spending on research. The government share of total R&D expenditure is declining in OECD countries (Figure 1), but public research is expected to enhance its role in fostering innovation in knowledge-based economies. Indeed, as innovation becomes more science-intensive and firms increasingly acquire scientific and technical knowledge from external sources, businesses make more intensive use of public research. They increasingly fund it directly and collaborate more with public research institutions. New patterns of industry-science relationships are further encouraged by the expansion of public/private partnership programmes in many OECD countries.

Public research itself, however, cannot generate market demand for science and technology. A business environment that is conducive to innovation depends on a wide range of policies from macroeconomic fundamentals, such as stable prices, to competition policies flexible enough to allow collaboration but firm enough to prevent collusion. Many governments are rethinking ways to maximise national benefits from industry-science relationships involving industrial participants with a more global perspective.

Public research also has a key role to play in providing balanced, objective advice on the potential risks and advantages of a particular area of research or its results. This is all the more true in an age where rapid scientific advances raise questions about issues from genetically modified food and gene therapy to online privacy. There is also pressure for governments to invest in tackling public concern for safety and security, not just physical security against weapons, but also bio-security against infectious diseases in the

Figure 1. **Public and private shares in total R&D funding, 1990-2001**

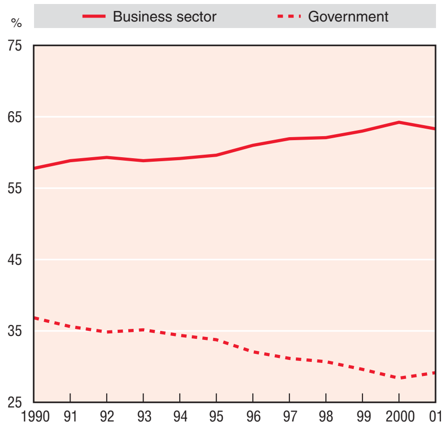
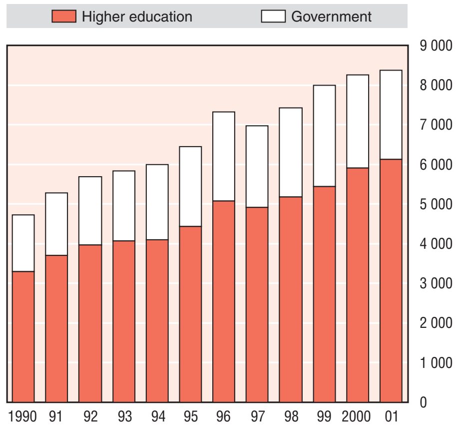


Figure 2. **Business funding of public R&D, 1990-2000, millions of 1995 USD PPPs**



Source: OECD, *Main Science and Technology Indicators*, September 2003.

wake of outbreaks such as the recent SARS epidemic, and cyber security in light of the rapid spread of computer viruses across the Internet. ■

Why are intellectual property rights so important?

Intellectual property rights, particularly patents, are increasingly important for science and innovation as they influence the distribution of financial returns to innovation, as well as the ease with which others can obtain access to and use new technological discoveries. The number of patents granted worldwide has risen sharply in the past 10 years, largely due to developments in new technologies, particularly ICT which accounts for nearly half of the increase and now covers about a third of all patent applications. More than 850 000 patent applications were filed in the US, Europe and Japan in 2002, up from 600 000 in 1992.

Patent rights have been strengthened and extended over the past two decades. Although differences remain between countries and geographic regions, patents now cover software, genetic and business method inventions, and procedures for registering patents have been made more flexible and less costly, particularly at international level. The introduction of new governing bodies, usually with more power to enforce rights, such as the World Trade Organization and the World Intellectual Property Organization, has been coupled with stronger enforcement of patent holders' rights in the courts.

OECD countries have encouraged the use and enforcement of patents to stimulate investment in innovation and enhance the dissemination of knowledge. But the expansion of patenting has also raised concerns that it may in fact hamper innovation and performance, for instance if companies use patents to unduly block competitors from entering certain markets. Other questions relate to the quality of patents granted, the availability of patented inventions for research use; and the development of markets for technology. As patents play an increasingly central role in innovation processes in both the private and public sectors, patent policy must be subject to closer scrutiny. ■

Going international

Many of the key areas where science is helpful to society, such as health, sustainable development, and safety and security are international by nature and there are compelling reasons for harnessing the diverse capabilities of many nations to achieve solutions. International scientific co-operation stimulates ideas and improves efficiency by sharing financial resources, information and facilities. Co-operation with developing countries can help build research capacity by providing access to world-class training and knowledge and thus help to stem the "brain drain".

The links between science and innovation have tended to be forged at the national level, initially structured around national research organisations and domestic firms. International links were mainly created through the scientific community. This situation evolved through the 1970s and 1980s as government-sponsored international co-operation in technological development intensified, especially within Europe. The more recent globalisation of firms' R&D strategies and access to public research, together with the increased mobility of scarce highly qualified labour, are leading to much more fundamental changes.

International collaboration among scientists has always led to the sharing of research data. However, this was traditionally restricted to well-connected networks of scientists, to well-identified research subjects and to certain scientific communities. If one did not belong to such networks or communities it was difficult to know about existing data or to access them. Modern communications technology has changed this, making it possible to collect and process more data, make them readily accessible and distribute them via the Internet.

The question then arises whether publicly funded research data should be made more openly available. Many stakeholders believe that this will advance science, enable researchers to improve the quality of research results as well as the quality of researcher training, and lead to economic and social benefits. But national legislation with regard to privacy, trade secrets, intellectual property rights and national security often limits open access to research data.

International guidelines and principles for successful arrangements for data access and data sharing, covering areas such as standardised processing, quality control, privacy and protection of intellectual property rights, could be useful. The OECD has some experience in establishing similar guidelines and could provide an appropriate forum to examine options for guidelines and principles on access to digital research data obtained with public funding.

Governments have tended to be cautious in granting foreign access to publicly funded R&D programmes, for reasons of national security but also for reasons of technological and economic competitiveness. Yet in a number of countries foreign firms make more intensive use of public research than domestic ones, and national measures are more efficient when recipients of government support are part of dynamic international networks. In addition, international policy commitments and pooling of public and private resources are often necessary to address common or world-scale issues, such as the environment or infectious diseases.

One area which has traditionally benefited from international collaboration is high-energy physics (HEP) or particle physics, where research has made advances possible in a variety of industries from semiconductors to cancer therapy and food sterilisation. But most of the major particle accelerators needed to carry out research in this area have been conceived, funded and built on a national basis or, in the notable case of the European Particle Physics Laboratory (CERN), as a regional collaboration.

Now HEP is entering a new phase where the financial and intellectual resources needed for the most advanced accelerators will exceed those available on even a regional scale. Among the highest priorities identified by scientists and policy-makers working under the aegis of the OECD Global Science Forum is the development of a new generation linear electron-positron collider (LC). Scientific communities in Europe, Asia and North America have called upon their governments to collaborate on a global scale to develop this ambitious project which aims to deliver major advances in exploring the realm of physics.

Another crucial international scientific challenge for the 21st century is understanding the human brain. Advances in this field will lead to breakthroughs in the prevention and cure of nervous system disorders and to improvements in the quality of life for millions of people. Neuroscientists have already developed elaborate methods for investigating the brain in fine detail. But they now face the challenge of managing the enormous amounts of raw information available about this 1.5-litre package containing 100 billion nerve cells, 3.2 million miles of nerve fibres and a million billion neural interconnections.

The huge amount of information available and the complexity of the subject have led to the creation of a new field, neuroinformatics, which will deal with handling, storing, and using the data.. Working through the OECD Global Science Forum, an international group of neuroscientists and science policy-makers has identified the benefits of strengthening the co-ordination of research on a global scale, with specific actions that might be undertaken by interested countries, notably as regards the standardisation, sharing and updating of neuroinformatics databases.

More generally, effective international collaboration in other aspects of the life sciences also remains a priority for many countries. Better use of existing resources and the sharing of information and materials developed through biological research should enable more rapid advances in the fight against disease, in conservation of biological resources, and in benefiting from the latent value in the biological systems that surround us. In 2000, OECD countries agreed a range of actions that would be necessary to deliver a co-ordinated international network of centres that collect and conserve biological resource data. These countries are now working to develop the necessary detailed standards to make such a network a reality. A viable international scientific infrastructure is essential if life science research and biotechnology are to fully contribute to economic growth and global sustainable developmentt.

International co-operation is also needed to realise science and technology's full potential to enhance global sustainability. For example, new generations of enzymes are becoming available that could facilitate the use of renewable biomass to fuel industrial processes. However the rate of uptake of these and other technologies – and their subsequent impact on sustainability – will be affected by the choices made by governments, industries and society. International efforts will be necessary to develop a clear vision for moving towards a bio-based economy and the sustainability gains it promises. ■

Attracting more scientists and engineers?

Qualified scientists and engineers are essential to scientific advances, innovation and productivity growth, but there is worrying evidence that young people are losing interest in science in many OECD countries. The number of science and engineering graduates is falling, just as demand for scientific advances and technological innovation is increasing. If the EU, for example, is to meet its goal of raising R&D spending to 3% of GDP by 2010 it will require an estimated 700 000 new researchers. But where will they come from?

There are many possible causes for the dwindling attractiveness of science, including unattractive or poorly adapted curricula in schools and universities, lack of talented teachers, the status of scientists and engineers in society and social concerns about the effects of scientific and technological progress.

Many OECD countries have launched initiatives to improve general interest in science such as staging science exhibitions and renovating scientific museums. They are also working with research institutions, firms, NGOs and scientists to respond to social concerns about the risks inherent in technological progress by fostering public debate on scientific issues such as nuclear power, genetically modified foods or medical ethics.

Such activities alone will not help to meet the rapidly rising demand for trained scientists and researchers in business and universities. In recent years, employment for people educated in science and technology has grown more than for all other categories in manufacturing and services. People using these skills account for 20% to 35% of the labour force in a number of OECD countries and between 1991 and 2000, the number of researchers in OECD countries rose from 2.4 million to 3.4 million.

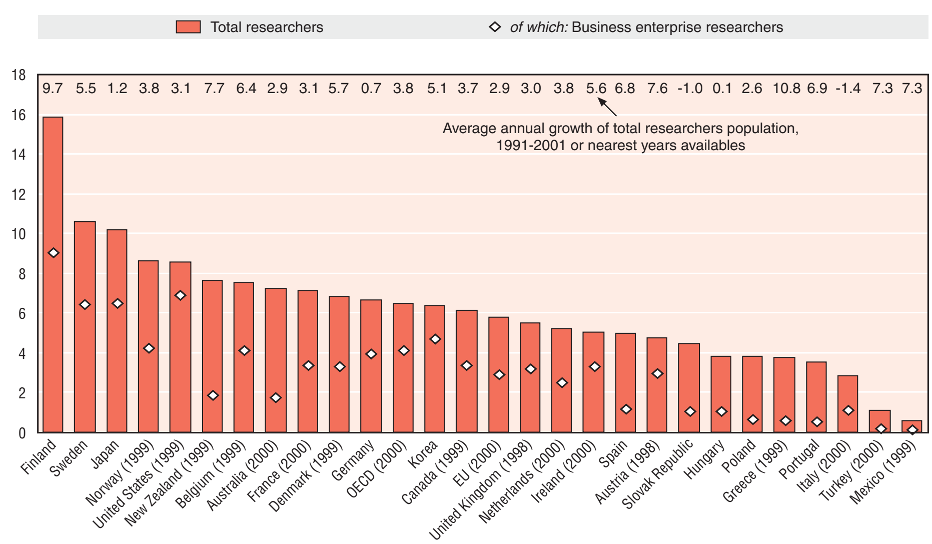
The supply of new science and technology staff depends to a great extent on new entrants into higher education. Across the OECD, more people than ever are obtaining a tertiary-level education and more than a fifth of graduates are in science and engineering, but the proportion varies widely between countries. In the EU and Japan in 2000, around a quarter of all university degrees were granted in science and engineering, but the figure for the US was only about one sixth of the total.

Women could offer one way of increasing the supply of science and engineering graduates. More women than men graduate from university, but they remain under-represented in science and engineering, especially at PhD level. Recent research suggests that efforts to encourage more students, particularly women, to take up science, must begin at the earliest levels of schooling.

The quality of science and mathematics teaching clearly plays an important role in students' performance and interest in these subjects. Initiatives implemented in OECD countries include special teaching programmes, often in partnership with industry, as well as measures to recruit PhDs for secondary teaching. At university level, many OECD countries have reviewed undergraduate curricula and reformed PhD training, for example by responding to growing demand for researchers who can work across scientific fields. But breaking down traditional disciplinary barriers is no easy task and higher education institutions often have to rely on raising new money, including from industry, to develop multidisciplinary programmes such as neuroinformatics.

There is also the question of matching the supply of science and technology graduates to demand for

Figure 3. **Researchers per thousand total employment, 2001**



Source: OECD, MSTI database, May 2003.

their particular skills in the labour market. Shortages of staff in certain fields co-exist with reports of surpluses or mismatches in skills. Many types of graduate are in excess supply, and many have not gained the necessary non-technical skills (*e.g.* communication, interpersonal and business skills) or had the prior work experience that would make it easier to find a job in business, which is where most new graduates are employed. Some 80% of US graduates in science and engineering seek employment in industry, while in many European OECD countries the figure is closer to 50%.

It is difficult to predict future demand for researchers in the short term, particularly for specific categories such as chemical engineers or IT workers. But long-term demand for tertiary-level graduates and science and technology workers is expected to continue to grow in many OECD countries, especially as a high proportion of current researchers and teachers are due to retire in the next few years. The US National Science Foundation estimates that employment in science and engineering will increase three times faster than the overall rate of employment between 2000 and 2010. ■

Brain drain or brain gain?

One way of meeting demand for science and technology personnel is to widen the net beyond national borders. OECD countries concerned about losing their competitive edge are encouraging foreign students into their higher education and research systems and making it easier for qualified science and technology professionals to immigrate. International mobility of students and highly skilled workers has increased over the past decade, with the main flows from Asia, especially China and India, to OECD countries and within the EU. A quarter of the people holding PhDs in science and engineering in the US are foreign-born.

The current economic downturn in OECD countries, however, coupled with greater security concerns since 11 September 2001, suggest that while foreign talent can bridge supply gaps in OECD countries, it cannot be a permanent replacement for national investment in the science and technology workforce. For one thing, sending countries, especially in Asia, are themselves creating opportunities for education and employment in science and technology.

While there is a risk of "brain drain" for sending countries, they can also benefit from returning emigrants who bring back new competencies, create new business ventures and build links to global research and innovation networks.

For governments, fostering mobility both within and across national borders is a question of removing regulatory barriers and of creating incentives. One problem is lack of movement between the public and private sectors. Many OECD countries are encouraging more scientists to move between public research and business. Competition for research funds can also indirectly stimulate the mobility of researchers, as they will follow allocations. Human resource management policies in businesses and public research institutions that reward mobility as part of career advancement are also important.

It is no use encouraging researchers to be mobile if their qualifications are not recognised in another country where there is a shortage of their skills. The EU is tackling this issue by encouraging member states to harmonise higher education diplomas under the Bologna Process. While mobility schemes targeted to young researchers help expose them to different environments, mobility for mid-career scientists and faculty remains a greater challenge.

Together with broader labour market and education policies, science and technology policies can help address challenges such as shortages of science teachers or researchers and barriers to mobility. But the right conditions have to be put in place to stimulate business investment in innovation and provide incentives for students to pursue education and careers in science and technology. These conditions include effective venture capital markets, regulations that facilitate firm entry and exit, and, more broadly, a business climate that rewards risk. At the firm level, they include management policies that provide competitive salaries and opportunities for researchers to pursue careers in senior management and that reward mobility.

One problem for planning education and research training policies is lack of data for determining likely future demand for science and technology personnel. More could be done to exploit existing data, such as censuses, labour force surveys, population registers and industrial occupation data. Better coverage of recent science and technology graduates is needed to measure trends and inform policymaking about their career paths.

For further information

For further information about the OECD's work on science and innovation, contact Daniel Malkin,
e-mail: *daniel.malkin@oecd.org*,
Tel. 0033 01 45 24 93 43. ■

For further reading

www.oecd.org/sti/stpolicy

- **OECD Science, Technology and Industry Scoreboard**, 2003
  ISBN: 92-64-10364-3, 200p, €49.
- **Governance of Public Research: Towards Better Practices**, 2003
  ISBN: 92-64-10374-0, 164p, €40.
- **OECD Science, Technology and Industry Outlook**, 2002
  ISBN: 92-64-19844-X, 328p. €73.
- **Drivers of Growth, Information Technology, Innovation and Entrepreneurship, Special Edition of the OECD Science, Technology and Industry Outlook**, 2001
  ISBN: 92-64-19538-6, 107p, €30.
- **Turning Science into Business: Patenting and Licensing at Public Research Organisations**, 2003
  ISBN: 92-64-10022-9, 312p, €60.
- **Benchmarking Industry-Science Relationships**, 2002
  ISBN: 92-64-19741-9, 200p, €35.
- **Report of the Neuroinformatics Working Group**, 2002
  Free document, available at *www.oecd.org/sti/gsf*
- **Introductory Paper on High-Energy Physics**, 2002
  Free document, available at *www.oecd.org/sti/gsf*
- **Biotechnology and Sustainability: The Fight Against Infectious Disease**, 2003
  Free document, available at *www.oecd.org/sti/biotechnology*

OECD publications can be securely purchased from the OECD Online Bookshop
www.oecd.org/bookshop

The OECD Policy Briefs are prepared by the Public Affairs Division,
Public Affairs and Communications Directorate.
They are published under the responsibility of the Secretary-General.

Where to contact us?

FRANCE
OECD Headquarters
2, rue André-Pascal
75775 PARIS Cedex 16
Tel.: (33) 01 45 24 81 81
Fax: (33) 01 45 24 19 50
E-mail: sales@oecd.org
Internet: *www.oecd.org*

GERMANY
OECD BERLIN Centre
Albrechtstrasse 9/10
D-10117 BERLIN
Tel.: (49-30) 2888353
Fax: (49-30) 28883545
E-mail:
berlin.contact@oecd.org
Internet:
www.oecd.org/deutschland

JAPAN
OECD TOKYO Centre
Nippon Press Center Bldg
2-2-1 Uchisaiwaicho,
Chiyoda-ku
TOKYO 100-0011
Tel.: (81-3) 5532 0021
Fax: (81-3) 5532 0036/0035
E-mail: center@oecdtokyo.org
Internet: *www.oecdtokyo.org*

MEXICO
OECD MEXICO Centre
Av. Presidente Mazaryk 526
Colonia: Polanco
C.P. 11560
MEXICO, D.F
Tel.: (00.52.55) 5281 3810
Fax: (00.52.55) 5280 0480
E-mail:
mexico.contact@oecd.org
Internet: *www.rtn.net.mx/ocde*

UNITED STATES
OECD WASHINGTON Center
2001 L Street N.W.,
Suite 650
WASHINGTON D.C. 20036-4922
Tel.: (1-202) 785 6323
Fax: (1-202) 785 0350
E-mail:
washington.contact@oecd.org
Internet: *www.oecdwash.org*
Toll free: (1-800) 456 6323

00 2004 02 1 P 4

The OECD Policy Briefs are available on the OECD's Internet site

www.oecd.org/publications/Pol_brief