Internationalisation of Australian Science

Position paper

February 2010

Australian Academy of Science

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GPO Box 783, Canberra, ACT 2601

This publication is also available online at: www.science.org.au/reports/index

ISBN 085847 279 1

Cover: Stockxpert

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1 Introduction

The benefits of integrating Australia's scientific endeavour with the efforts of the international scientific community are clear to Australian scientists. International collaboration invariably improves the quality and breadth of research. Increasingly, quality science is undertaken and underpinned by formal and informal international collaboration and networks. Without working access to the vast majority of the world's scientists and infrastructure, particularly at the idea development and early research stage, Australia is unlikely to maintain its significant contribution to world science and to the productivity of the Australian economy.

The last major Australian invention that did not involve some international input was probably the stump-jump plough in 1876. The subsequent globalisation of scientific development and our dependence upon technological systems have ensured that without a competitive strategy to engage with the international scientific community, ongoing innovation will be increasingly challenging.

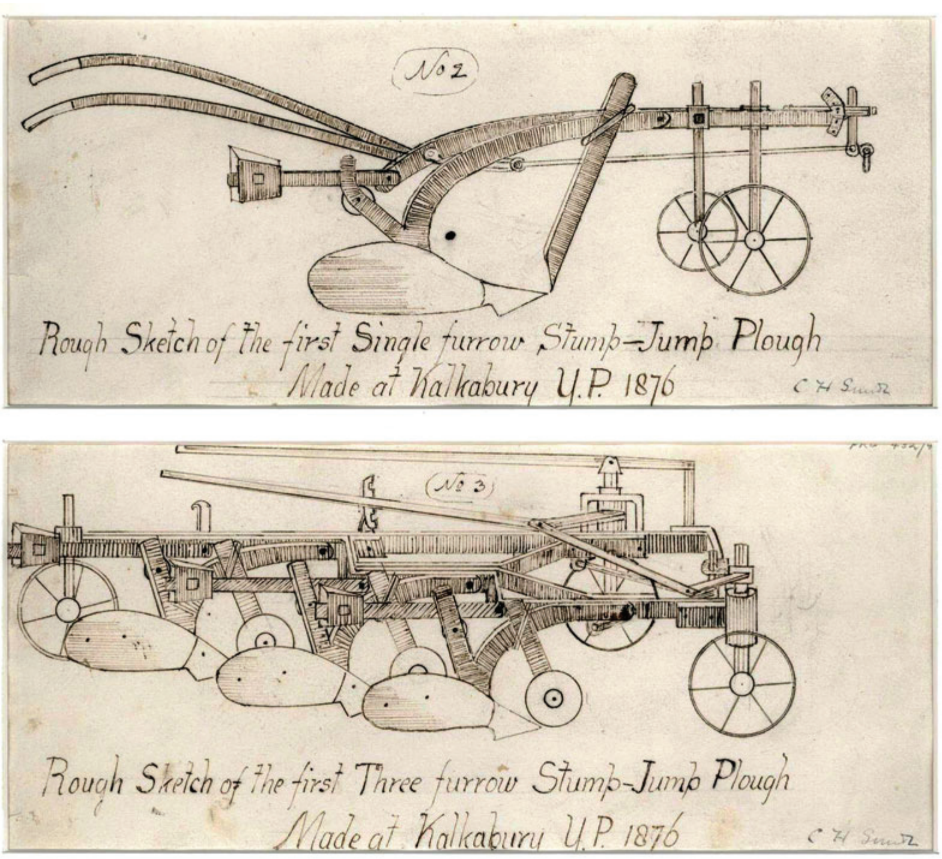


Figure 1 Stump-jump plough. Image by the State Library of South Australia

This paper makes the case for a strategic approach to internationalise Australian science, and elaborates upon the 9 September 2009 address on this topic to the National Press Club by Australian Academy of Science President Professor Kurt Lambeck.[1] The paper argues that to make effective use of the less than 3 per cent of knowledge developed by Australia, we need timely and ready access to much of the other 97 per cent created and developed overseas.

Australian scientists have a productive history of working overseas in order to access the brightest minds and the best technology. These scientists gain knowledge, perspectives and skills that they apply to their own research and disseminate to other colleagues and students in their field. This approach is essentially a seed from which grow larger, enduring networks, bilateral/multilateral agreements, joint publications, patents and commercial and industrial outcomes.

Australia is not alone in the need to develop collaboration. Key developed and developing nations are investing heavily in science (see Appendix 1), with appropriate strategic consideration given to maximising the return on their investment with current and potential international collaborators. These countries have also recognised that ongoing access and researcher-to-researcher engagement has to be planned and supported if their scientists are to remain competitive and productive in terms of research, innovation and developing solutions for problems with major impacts both nationally and globally, such as energy, water and food security.

The Australian Academy of Science believes that it is important the various policies and programs currently deployed to support Australian scientists to engage internationally should be enhanced and refocused into an integrated strategy to maximise our contribution to global science to the long-term benefit of the nation.

The Academy believes that there will be serious negative implications for the quality of Australian science and knock-on consequences for economic productivity unless a more coordinated approach to the internationalisation of Australian science is adopted. The status quo or bandaid fixes do not suffice.

With respect to broader national interests and global challenges, Prime Minister Rudd said in his 2008 address to the United Nations General Assembly:

> Through our membership of the United Nations, we are committed to using creative middle power diplomacy to help overcome the great challenges of our age. Challenges which lie beyond the power of individual nation states to resolve. Challenges which can only be solved by unprecedented cooperation between states.[2]

The Academy believes that science and technology are critical components in overcoming these great challenges, and that science and technology are essential to the achievement of these foreign policy objectives. For Australian scientists to meet national needs and assist with national ambitions, Australia's current arrangements in international scientific engagement require increased strategic focus and commensurate support.

This paper seeks to inform that process and makes recommendations about objectives and elements of programs required to enact the effective internationalisation of Australian science strategy.

2 Research and development: an economic necessity

Investment in Australian science and technology research should be a high priority for any government, particularly during periods of global economic downturn. This is because for a modern economy such research is essential infrastructure that underpins future economic productivity and innovation. While it may seem that innovation can be achieved by the purchase of technology as and when required, this simplistic approach is neither supported by evidence, nor accepted as a viable strategy by our global competitors. President Obama in his 2009 address to the United States (US) National Academy of Science said:

> At such a difficult moment [referring to the Global Financial Crisis in April 2009], there are those who say we cannot afford to invest in science, that support for research is somehow a luxury. I fundamentally disagree. Science is more essential for our prosperity, our security, our health, our environment, and our quality of life than it has ever been before.[3]

President Obama is not alone in this view and countries as diverse as the United Kingdom (UK),[4] China,[5] India[6] and Denmark[7] have all recognised the link between innovative research and prosperity, and are developing policy accordingly. The Academy is strongly of the view that science and technology investment is essential for Australia's future prosperity. The Australian economy is expected to become more reliant on value added to its natural resources and services through the development of new knowledge suited to our particular circumstances, and the application of innovative ideas.

In the 21st century, Australia cannot afford to wait for new technologies and ideas to flow in. In the past, the introduction of new products, processes or services into a market did not necessarily require pushing the frontiers of knowledge. But the days when growth of a national economy could be achieved by transforming existing knowledge into cheaper products are undoubtedly limited. Japan has seen the consequences of this, and China recognises it as well.

To innovate and to make effective use of science and technology increasingly requires an ability to generate, absorb and adapt new information and transform it into new knowledge. Innovation requires an ability to make creative use of knowledge, to experiment and build on it in order to address issues that are important for Australian conditions, and to exploit niche areas where we can be globally competitive. This ability is not something that can be codified in instructions or blueprints to be purchased along with a particular technology.

Statistical information that accurately links research and development expenditure to national prosperity remains a matter of debate. The statistics of the expenditure itself are disputed, as is the complex relationship between this expenditure and economic benefits. But all indices show a high positive correlation between the technological activity and the level of human capital of a country on the one hand, and per capita gross domestic product (GDP) on the other. They support the often implicit assumption that current research and development expenditure lays the foundations for tomorrow's prosperity.

3 Rapidly developing science and technology

During the last 50 years there have been tremendous changes in science and technology:

- there has been growth of scale; global and Australian scientific communities have increased substantially, as has scientific infrastructure
- interdisciplinary science has grown and new disciplines have emerged
- technological advances have increased the speed with which research is undertaken
- explosions in our computational capacities have enabled far greater quantities of data to be collected and processed; although in some areas collection capacities currently exceed processing capacities
- the communication revolution has resulted in greater and faster data and ideas exchange and has led to an increased pace of collaboration between researchers.

In addition, there is increasing participation in global science by both developed and developing countries that have recognised that failure to collaborate hampers progress and want to improve in economic and social development. Countries now at the forefront have become increasingly interlinked with global networks of technological activity in order to access information at the earliest stage, commercialise innovations ahead of competitors, and address local problems in the most cost-effective manner.

These developments mean that science has become exceedingly complex and that science and technology has come a long way from the days when Australia's innovation was driven by its isolation. It is a long way from the stump-jump plough! Now, no single scientist can understand all, no single institution can afford all the facilities required to do leading edge science, and no single country can alone address some of the truly big science challenges.

4 Participation in international networks and linkages

Via a variety of mechanisms, many of them significantly funded by government, Australia has successfully participated in international science and technology research efforts. Whether through individual visits to laboratories and facilities overseas, or co-investment in large-scale scientific instruments, Australian science has significantly gained from its access to the scientific and technological knowledge being generated globally.

It is particularly important to highlight that much of Australia's participation in the international frontiers of science and technology has its origins in interactions between individual scientists. These personal engagements typically involve minimal initial investment but often have long-term scientific, economic and social benefits that can only be assessed in retrospect.

The Academy of Science has, since its foundation in 1954, been actively engaged in stimulating such interactions via its longstanding connections with other national science academies. This is also achieved through the activities of its national committees for science (covering 22 natural science disciplines equating to key international scientific unions), and through the administration of funding for exchange programs and workshops provided to the learned academies under Department of Industry, Innovation, Science and Research (DIISR) International Science Linkages program and bilateral science cooperation agreements.

Following are just a few of many possible examples that illustrate the different types of benefits that have flowed from Australia's participation in international science and the circumstances in which they have occurred.

4.1 The Australian Synchrotron

The Australian Synchrotron has its origins in early experiments by Australian scientists invited to work in England and France during the late 1970–80s. By the mid 1980s, this had developed into a pattern of short working trips (which became known as 'suitcase science'), in which a growing body of Australian researchers were supported to become familiar with the power of synchrotron science. With the gained experience, researchers were able to argue cogently that Australia should develop specialised beamline facilities in Japan and this was ultimately supported by a consortium of publicly funded research organisations. The facility performed well but was soon oversubscribed, leading to other beamlines being supported at US synchrotrons.

While Japanese and US facilities were successful and significantly advanced Australian synchrotron science across a range of disciplines, the limitations of being reliant on other nation's facilities soon became apparent. Issues with carrying sensitive and fragile samples with a short lifespan to foreign countries, and the need for timely access to facilities eventually resulted in the proposal for an Australian synchrotron. In 2001 the Victorian Government took up this challenge and since then the synchrotron has been constructed and developed, with the support of a diverse range of stakeholders including the Australian and other governments and industry, into a national facility of international calibre.

The important lesson is that the now hugely successful project could not have been achieved without international collaboration at all stages: in setting up the early contacts; in facilitating access to the overseas facilities; in the overseas training of graduate students in synchrotron science; in accessing leading-edge technology; in recruiting leading scientists and engineers to Australia; and in attracting overseas partners to the facility (eg New Zealand).

Australia's research and development capability across diverse fields, from medical research through engineering, would be poorer if not for the programs that facilitated the international linkages at every step and have resulted in Australia's own world-class synchrotron facility. Box 1 depicts an example of the use of the Australian Synchrotron for water purification research by the Commonwealth Scientific and Industrial Research Organisation's (CSIRO).[8]

Box 1 CSIRO use of the Australian Synchrotron for water purification research

Hybrid organic-inorganic membranes for water purification

CSIRO scientists are currently using the infra-red beamline at the Australian Synchrotron to study the cross linking of hybrid organic-inorganic membranes based on polyvinyl alcohol and silica for use in water purification. The improved spatial resolution achieved by using a synchrotron light source is expected to provide clearer insights into cross linking in the membranes. Such information is critical for understanding the structure–performance relationship of the hybrid membranes. The work is part of a research project under CSIRO's Water for a Healthy Country Flagship program.[9]

4.2 Real-time ocean forecasting

Another instructive example comes from the real-time ocean forecasting system, BLUElink. BLUElink's beginnings came from government support of young Australian researchers' early exposure to the US space program where they developed experience in the use of radar altimeters to improve understanding of the dynamics of the ocean surface. From this and a later series of short-term visits to France came the appointment of two Australian co-principal investigators to the joint US–France altimetry mission known as Topex-Poseidon that was launched in 1992. This in turn led to the University of Tasmania's important work in calibrating satellite altimeters of this and its successor mission, thereby providing quality control over the instruments.

Parallel early exchange visits occurred independently with the US National Oceanic and Atmospheric Administration, the European Space Agency and European meteorology centres. These led to a home-base competence in a number of important and increasingly complementary areas, and to the experience and confidence to integrate the various observations and numerical modelling into an ocean forecasting capability.

The BLUElink forecasting system of CSIRO, the Australian Bureau of Meteorology and the Royal Australian Navy grew out of this seed money. The system now provides real-time and routine information used for maritime and commercial operations, defence applications, safety at sea, ecological sustainability and regional and global climate studies.

For example, in late 2009, BLUElink data were used to model and track the West Atlas oil spill off the north-west coast of Western Australia. In March 2009 it was employed to locate 31 shipping containers of ammonium nitrate lost overboard from the container ship *Pacific Adventurer* off the south coast of Queensland.

Due to its practical success, BLUElink is a leading contributor to the Global Ocean Data Assimilation Experiment[10] – a global system of observations, communications, modelling and assimilation that seeks to deliver comprehensive information on the state of the world's oceans.

4.3 The decoding of genomes

Short-term visits to genome centres around the world by Australian biologists have been critical to keeping Australia in the race to adapt to the genomics paradigm that has revolutionised biology in the last ten years. Unfortunate strategic decisions that limited genomic research in Australia led to the genome of the Brazilian opossum, rather than the kangaroo, being sequenced at the US National Institutes of Health in 2006. However, ongoing government support for access to leading international research efforts enabled some Australian researchers to continue to contribute to this rapidly evolving field. As the importance of genomics became clearer, these scientists were able to provide the academic foundation upon which a growing number of Australian genomic researchers now make a significant contribution to global genomic knowledge.

Australian researchers recently partnered with the US National Institutes of Health to sequence a marsupial (tammar wallaby) and the platypus, and through the quality of the science that they brought to the table, built consortia that ensured major representation of more than 25 young Australian scientists in high-profile publications. Several of these young scientists established collaborations with scientists at major sequencing centres while participating in a joint workshop organised by the US and Australian academies.

4.4 Modelling the Great Barrier Reef

The financial cost of early stages of international engagement is typically limited to relatively modest facilitation expenses while research returns are demonstrable in terms of the creation of knowledge, ideas, tools, relationships and capabilities. A 2009 travel bursary of A$6,000 from the Australian Government for an Australian scientist to undertake work in Canada for three months illustrates how personal international collaboration can productively build upon and leverage multiple research fields and the work of other scientists.

As a 'multi-use' World Heritage area, the Australian Great Barrier Reef Marine Park (GBRMP) requires managers to balance the needs of traditional owners, historic commercial and recreational fishing practices, and the conservation requirements.[11]

During the mid 1990s the researcher developed an ecosystem model of the GBRMP based upon a survey of 1000 taxa over 10,000 square nautical miles across the marine shelf using Ecopath EwE software developed at the University of British Columbia, Canada. At the end of 2007, a comprehensive biodiversity survey of the entire GBRMP (133,000 square nautical miles) was completed, providing an unprecedented data set with which to validate the initial ecosystem model. The researcher spent 12 weeks with the group who created the Ecopath EwE software. Ready and ongoing personal access to the software developers, their facilities and the latest versions of their software enabled the Australian researcher to efficiently assess and validate the original model with reference to the biodiversity survey of the entire GBRMP.

In addition to the traditional outcomes of such collaboration – such as publications, scientific debate, ongoing collaborations and student/staff exchanges – this project also resulted in a robust knowledge system for subsequent use by the Australian and Queensland governments and managers of the GBRMP. The validated and functional ecosystems model provides for the first time a tool to model, assess and ultimately assist the management of the resources of the GBRMP. Such work would not have been developed as quickly, cheaply or effectively without the close interaction between the Australian researcher and the owners/developers of the modelling software.

4.5 Gardasil – the cervical cancer vaccine

In 1989 Professor Ian Frazer undertook a sabbatical at The University of Cambridge, UK, to gain specialised skills in virus expression and molecular biology to help him develop the techniques necessary to express papilloma virus proteins in cell culture. As important, he met future collaborator Dr Jian Zhou, who was visiting Cambridge from China.

Dr Zhou later joined Professor Frazer in his Brisbane laboratory, where his molecular biology skills were crucial to the development of a system of expressing a particle that mimicked the appearance of papilloma viruses (see Figure 2). Within a year they had confirmed that this mimicry could be used to develop a vaccine, which a pharmaceutical company went on to develop – the Gardasil vaccine – that is now being used worldwide as a preventative treatment for cervical cancer.

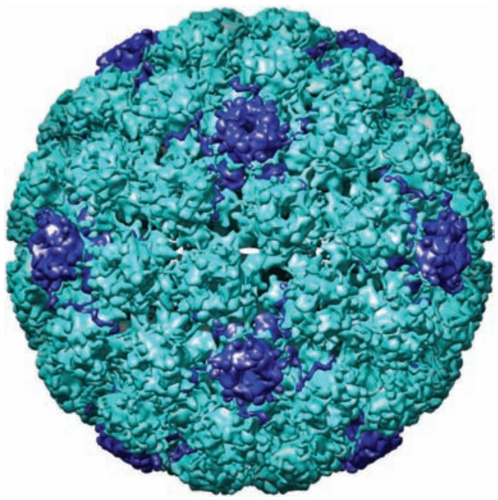


Figure 2 Human papilloma virus. Image by the Royal Society of Chemistry

4.6 Building relationships with the developing world

In the previous examples, the collaborations were born from Australian researchers' knowledge of international researcher capabilities and grew upon a foundation of individual partnerships that developed over many years. As developing countries have increased their participation in science and technology research, Australian researchers are building new personal science partnerships with these countries. In the process both parties gain understanding of the other's research capabilities and complementarities, establishing the basis for future long-term collaborations.

China provides a constructive example of the types of relationships the Australian scientific community has been nurturing with developing countries. Many of the current collaborations between Australian and Chinese scientists have their origins in 'fact finding' missions and scoping workshops by scientists between the respective science and technology academies of the two nations. This involved quite small initial investments by the governments of both countries from which long-term, mutually beneficial outcomes are now beginning to emerge.

One such partnership on clean energy technologies had its beginnings in a meeting between two researchers from Australia and China. Common research interests were identified and later reinforced at the Australia–China Symposium on Energy. The collaboration now encompasses three joint projects, exchanges of staff (five scientists per year) and joint supervision of PhD students.

The outcomes of these collaborations have, to date, included more than 50 scientific papers, and research and development funding of nearly A$5 million, all born from an initial investment in 2001 of one airline ticket by the Chinese Academy of Sciences and a similar Australian Academy of Science investment for in-country costs.

4.7 Essential elements of past participation

The previous examples illustrate important elements of collaboration:

The Australian Synchrotron – expertise gained overseas by Australian researchers during the early days of synchrotron science enabled Australia to develop, build, operate and creatively use a complex and powerful research tool.

Real-time ocean forecasting – international collaboration produced significant economic, social and environmental benefits via downstream applications within Australia over the medium- to long-term.

The science of genomes – diverse international engagement by individual Australian scientists enables the Australian science community to maintain quality and relevance in a far greater range of research fields than can be significantly supported within Australia.

Modelling the Great Barrier Reef – demonstrates the effectiveness of personal international engagement to capitalise upon and properly leverage existing Australian research to make further discoveries and develop useful tools.

Gardasil – early stage international collaboration engaged Australian researchers with world-leading ideas, scientists and solutions.

Exploratory missions – personal contact between scientists at the early research stage is fundamental to the development of innovative ideas and research.

Fruitful international collaborations often start on a small scale and build understanding between researchers and institutions. Researchers recognise compatible competencies and seize opportunities to develop applications of national interest, while continuing to contribute to a scientific knowledge base. Rarely can success be achieved by staying within institutional and national boundaries and rarely can the path of discovery and development be predicted. Even more rarely will the lessons that led to the success be fully recognised once success is achieved.

Importantly, it should be understood that while many engagements are begun, not all are as productive in ways that can be easily or immediately described, and that this is a normal part of the discovery process. In research there is no shame in failure, and insistence on demonstrable success at every stage can lead to conservative investment strategies and incremental outcomes rather than major breakthroughs.

5 Benefits from international engagement

Countries engage in bilateral and multilateral collaborations not only for reasons of altruism, and it is constructive to evaluate what Australia has gained out of past collaborations. Australia's current and past international collaborations outlined above highlight that early and unanticipated interactions and linkages were critical in reaching a final outcome such as a vaccine or an ocean forecasting service. Yet there are significant difficulties attributing particular economic outcomes to a specific past collaboration. For example, accurate ocean forecasting of internal waves across Australia's North West Shelf provides information for operators of natural gas drilling and production platforms. But how are its benefits, in terms of reduced operating down time and production efficiency gains within a multibillion-dollar industry traced back to the original scientific collaborative work? It is a long financial bow to draw but it is as real as it is difficult to accurately measure.

Complete estimations of the benefits of international linkages in science and technology have not been attempted and most of the evidence is either anecdotal or applicable to one component of the linkage. The examples that follow illustrate some of the difficulties in making such an assessment, but taken together with many other examples they point to long-term national benefits.

For example, as a consequence of long-standing collaborations between the Walter and Eliza Hall Institute of Medical Research (WEHI) and French researchers at institutions such as the Institut Pasteur, there are currently 14 French nationals working at WEHI. In evaluating the economic benefits of this there is not only the increased scientific knowledge that may have helped hasten the translation of research into clinical outcomes in Australia, but also education and training costs that Australia has not had to meet.

The Colombo Plan of 1950,[12] of which Australia was a founding member, aimed to support Asia–Pacific economic and social development through economic and technical assistance. One aspect of the plan involved the sponsorship of students from the Asia–Pacific region to study in Australian tertiary institutions. Many of the plan's students returned to their own countries and eventually occupied high-level positions within science and/or government. Is the success of the Colombo Plan to be measured in terms of the number of students from the Asia–Pacific region who have gained a tertiary education, or should it be judged by the unquantifiable benefit of the positive bilateral relationships subsequently built, based upon the positive experiences and contacts these students took with them into their senior science, industry or government positions?

A 2001 review of the Academy's government-funded bilateral exchange programs from 1998 to 2000 indicated that the government's financial contribution to the cost of facilitating exchanges and collaboration was leveraged by a factor of 7.7.[13] Data from the most recent analysis undertaken in 2009 using the same methodology, indicates government investment in funding rounds between 2001 and 2008 has been leveraged by a factor of 6.6 (noting that funding per person has not changed and exchange costs have increased significantly since 2001). When commercial outcomes, and the attraction of international funding to the end of the survey period were taken into account, the leverage factor increases to 21.

Although data establishing economic outcomes of international scientific collaboration is limited (models of the relationships between knowledge and GDP are not robust), the link between innovation and economic productivity has been established in a number of studies, most recently by the government's 2008 Cutler Review.[14] Similar to the trends illustrated in the various case examples described in this paper, there is a solid though under-quantified case that Australia receives significant economic benefits from its public investments in scientific research, and that international scientific collaboration is an increasingly important dimension of Australian research.

Alongside difficult to quantify medium- to long-term economic benefits, there are a number of important qualitative benefits for both the scientific community and Australia as a whole. These include:

- **Access** to the frontiers of science and to technology, facilities and data sets too expensive to replicate in Australia.
- **Training** of researchers in emerging areas of science and technology through the two-way flow of researchers and students. A survey of the Academy's US National Science Foundation program of visits by early-career researchers to Australia indicated that some 35 per cent of the US participants returned to Australia for postgraduate work.
- **Benchmarking** of our scientists and their research. Working scrutiny by peers in the international community provides an assurance that Australia's scientists are indeed performing to the highest standards.
- **Facilitation** of bilateral and multilateral commercialisation that benefits the economy through increased business.
- **Aligning future expertise with future demand,** according to national need and opportunity. International research facilities, such as the Square Kilometre Array, will be staffed and operated by scientists of the highest international standard. Participation will depend upon qualifications and expertise, which will depend upon significant medium- to long-term engagement with international scientists.

There is also increasing recognition of the positive contribution that science can make to foreign policy through the provision of science-based advice (science in diplomacy), facilitating international cooperation (diplomacy for science) and the improvement of international relations (science for diplomacy).[15] Potential science diplomacy benefits have included:

- **Influence and visibility** on international and regional science programs. Our international scientific standing enables Australia to direct efforts at particular local issues and national priorities while contributing to the global knowledge system, and demonstrates that Australia is more than a source of raw materials or a convenient observation platform.
- **Geopolitical influence** through the provision of science and technology aid to developing countries to contribute to their social and economic development.

- **Security enhancement** – where traditional or formal relationships have broken down, or where relationships stand to be deepened, the conduct of science can aid diplomatic relations and deliver long-term development benefits.
- **Disaster management** such as opportunities to study exotic species and pests, natural phenomena to facilitate our ability to deal with disease outbreaks, or natural disasters that could otherwise lead to social disruption with direct consequences for Australia.

The previous accounts were selected from many potential examples of productive international collaboration to illustrate the different types of benefits that Australia has derived from such activities, and to show how collaboration works in practice.

As outlined in Section 3, the international science effort is dynamic in both its function and outputs. The following section outlines how our competitors (who for the most part are, or could be, our collaborators) are already taking steps to improve the way they collaborate and enable appropriate international access for their scientists.

The Academy believes that the collaborative support mechanisms Australia deployed in the 20th century and those that remain today are inadequate for the rest of the 21st century.

6 Australia's collaborators and competitors

It has become increasingly clear to even the most technologically and scientifically advanced nations that no nation can go it alone and no single country can lead in all fields. US President Obama said:

> We also need to work with our friends around the world. Science, technology and innovation proceed more rapidly and more cost-effectively when insights, costs and risks are shared … And that's why my administration is ramping up participation in – and our commitment to – international science and technology cooperation across the many areas where it is clearly in our interest to do so.[16]

Further, in presenting the President's research and development (R&D) budget to Congress, science and technology advisor Dr John Holdren said:

> With the President's encouragement, (my office) is working to reduce unwarranted barriers to international exchanges in science and technology fields and to take advantage of the opportunities many other countries are eager to offer for collaborative efforts that are clearly in the US interest.[17]

Other developed countries with strong practice in science and technology have announced similar aspirations and follow-up actions. During Lord Sainsbury's 2007 review of progress towards implementation of the UK's 10-year investment plan in science and innovation, international collaboration was identified as one of the steps which had not been sufficiently fulfilled. In response, the UK Government established offices of its Research Council (the UK's major science funding body) in China, India and the US to coordinate research activities between these countries and the UK. In addition, a UK funding program that supports collaborations between the UK and the US (Science Bridges Scheme) was extended to include India and China. Denmark has also extended its innovation network with specific focus on China (see below for accounts of US, UK and Danish government support for the internationalisation of their nation's scientific endeavours).

The Japanese Council for Science and Technology Policy identifies the participation of Japanese scientists in international programs as one of its four key objectives. It also aims to use science to project power in the international stage, to provide scientific advice to international policy making, and to help to build science capacity in developing countries.[18]

Developing countries are following suit with their science and innovation programs, including a focus on international collaborations. Most notable is China, where its 2006 Plan for the Development of Science and Technology spells out how it intends to become an 'innovation oriented society by the year 2020 and a world leader in science and technology by 2050'. For China to reach its goals outlined in its Medium- to Long-Term Plan for the Development of Science and Technology (2006–20),[19] there is acknowledgement that it will need to ramp up participation in the global knowledge system.

Note that the global emphasis on collaboration is in pursuit of knowledge and competitive advantage. In all cases there is a strong emphasis on self-interest and an acknowledgement that national innovation systems increasingly draw on knowledge created in other systems.

But others' self interest can also be in our interest. In the China plan there is a clearly enunciated argument that it is faced with the same global issues as the rest of the world, and that how China responds is of great interest and concern to the world. The Chinese acknowledge that if they were to reach a high level of development via the route travelled by the present developed countries, the negative consequences for the rest of the world would be severe.

Alongside traditional bilateral and multilateral programs there are now more and more examples of science and technology initiatives that are truly global on a scale where no single country can develop them alone. Examples include the Large Hadron Collider to explore the inner secrets of subatomic particles, the Square Kilometre Array for exploring the origins of the universe, and the Integrated Ocean Drilling Program for exploring the ocean floor. These are part of the human exploration of the universe, participation in which provides major intellectual challenges and direct participation at the frontiers of science. However, as the space programs of the 1960s clearly demonstrated, pursuit of great goals also generates applications and understandings that can transform, or even replace, existing industries.

6.1 United States

The Science and Technology Adviser to the US Secretary of State identifies as her priorities strengthening partnerships across international scientific communities, building science capacity within her department and scanning the scientific horizon for developments that could impact on US national interests.

There are about 50 US Foreign Service staff located in US embassies and consulates around the world designated as Environment, Science and Technology and Health (ESTH) officers. In addition to these positions, there are numerous officers and locally-engaged staff worldwide in embassy and consulate economic or political sections who deal with ESTH issues as part of their larger portfolio.

In China, the US has six State Department ESTH officers who work on bilateral cooperation in Beijing and four additional Foreign Service officers who cover ESTH issues in Shanghai, Chengdu and Guangzhou. These diplomatic positions are supplemented by more than 20 employees of US technical agencies like National Science Foundation, National Institutes of Health, Centers for Disease Control and Prevention, Food and Drug Administration, and Department of Energy who focus on specific collaborative programs with China.

These personnel are supported by a further 150 staff who comprise the US State Department's Bureau of Oceans and International Environmental and Scientific Affairs.

Objectives of the ESTH officers include:

- promoting cooperation on international environmental issues, including climate change, oceans and fisheries
- working to support strong relations among US and host country scientists by sponsoring programs to connect US researchers with host country researchers
- coordinating closely with the Department of Energy, the National Science Foundation, and the Agency for International Development offices in the embassy on programs covering a range of topics
- facilitating US industrial competitiveness through initiatives that enhance US access to host country technology and by reporting on important host country science and technology developments.

In November 2009, US Secretary of State, Hillary Clinton, announced the appointment of three prominent US scientists as science and technology envoys to bolster collaboration with Muslim communities around the world. The Secretary of State's media statement announced that:

> In the coming months, the first science envoys will travel to countries in North Africa, the Middle East, and South and Southeast Asia. They will engage their counterparts, deepen partnerships in all areas of science and technology, and foster meaningful collaboration to meet the greatest challenges facing the world today in health, energy, the environment, as well as in water and resource management. Additional US scientists and engineers will be invited to join the science envoy program to expand it to other Muslim countries and regions of the globe.
>
> The envoys will be supported by new embassy officers who will also engage with international partners on the full range of environmental, scientific and health issues, from climate change and the protection of oceans and wildlife to cooperation on satellites and global positioning systems. They will work with multilateral institutions, non-governmental organisations and private sector partners to promote responsible environmental governance, foster innovation, and increase public engagement on shared environmental and health challenges.[20]

Further details about the US science specialist presence at embassies and consulates can be found in Appendix 2.

6.2 United Kingdom

The UK Foreign Commonwealth Office (FCO) established the Science and Innovation Network in 2001 in response to government recognition of the growing importance of science, technology and innovation. The network is jointly supported, funded and managed by the UK FCO and the UK Department of Innovation, Universities and Skills.

Approximately 90 staff (a mix of UK expatriates and locally-engaged experts) who focus exclusively on science and innovation are now located at embassies and consulates in 40 cities in 25 countries, including around 13 officers located at the UK embassy and consulates in China.

Objectives of the UK's Science and Innovation Network include:

- promoting access to and sharing of scientific expertise, resources and facilities through international scientific collaboration and exchange
- strengthening the UK's capacity to innovate through international research and development (R&D) investment, R&D partnerships and technology transfer
- informing effective domestic and international policy making and leadership based on the best available science
- using science and innovation to influence in an increasingly globalised world and forging strategic alliances.

A Chief Scientific Adviser to the FCO was appointed as a direct counterpart to the Science and Technology Adviser to the US Secretary of State in 2009. Further details about the UK science specialist presence at embassies and consulates can be found in Appendix 2.

6.3 Denmark

Small economies are also expanding the scale of their international science and technology links. For example, the government of Denmark, a country with a nominal GDP one third that of Australia's, is focussing its international science and technology support towards three countries – China, Germany and the US – employing approximately 30 staff at these three locations. This is in addition to with single science attachés posted to several other embassies.

In response to the Danish Government's Globalization Strategy, Denmark established an Innovation Center Denmark in Shanghai in 2006,[21] which has 12 staff led by a science attaché from the Danish Ministry of Science, Technology and Innovation. The center is dedicated to:

- commercial R&D and innovation – supporting Danish companies to improve their business though scouting/analysis, sourcing for innovation talent, connecting to new partners or helping to establish a platform in China
- science, technology and higher education – connecting Danish and Chinese researchers, institutions and universities
- investing in Denmark – attracting Chinese companies to invest in Denmark.

Further detail about the Danish science specialist presence at embassies and consulates can be found in Appendix 2.

7 Supporting Australia's participation in international science

Australian governments have a long history of support for international science. In the science portfolio this occurred both directly, via the negotiation of bilateral science and technology agreements and programs such as the International Science Linkages (ISL) program, and indirectly through its funding of science agencies with international remits such as CSIRO and ANSTO. Other portfolios, such as Agriculture, Defence and Health, also routinely engage in international collaboration as part of the research programs that they fund.

The current Australian Government has clearly recognised the importance of international scientific collaboration. As well as opening up the ARC grants programs to international competition, changes to the eligibility of foreign owned companies conducting research in Australia for the R&D tax concession were introduced under the *Powering Ideas* agenda. In addition, funding has been committed to international astronomy projects such as the Giant Magellan Telescope and the Square Kilometre Array under the Super Science initiative. These actions demonstrate the government's understanding of the value of long-term investment in Australian shared science infrastructure. In *Powering Ideas*, Senator Kim Carr, Minister for Innovation, Industry, Science and Research, stated:

> the Commonwealth's ambition [is] to increase international collaboration in research by Australian universities and public research agencies over the next decade … The Australian Government will continue to promote Australian participation in international research partnerships and networks.[22]

More recently, Prime Minister Kevin Rudd announced that Australian Government investment would allocate $50 million over five years for the Australia–India Strategic Research Fund to build upon scientific links with India.[23] This significantly boosts the research fund's previous $20 million resourcing and in so doing sets a 'gold standard' for strategic support for Australian scientific international collaboration with a single country.

Currently the future of DIISR's ISL program, aimed at promoting access to and participation in leading edge, international scientific research and technology, requires clarification. The program has been successful in significantly enhancing strategic alliances between Australian and overseas researchers.

The Academy of Science, along with the other learned academies, has been directly involved in administering travelling fellowships that target early- to mid-career researchers and the bilateral grants schemes. As a consequence we have seen first hand the high quality of applications and the value of these programs, particularly in supporting promising younger scientists, not yet sufficiently experienced to win ARC funding, to establish the networks and opportunities that can form the foundation of their future careers.

The recent decision to extend elements of the ISL program for 12 months to the end of financial year 2011, while welcome, precludes administrative and logistical efficiencies that were achieved under previous arrangement that enabled planning over 3-year cycles and creates uncertainty in long term partner countries.

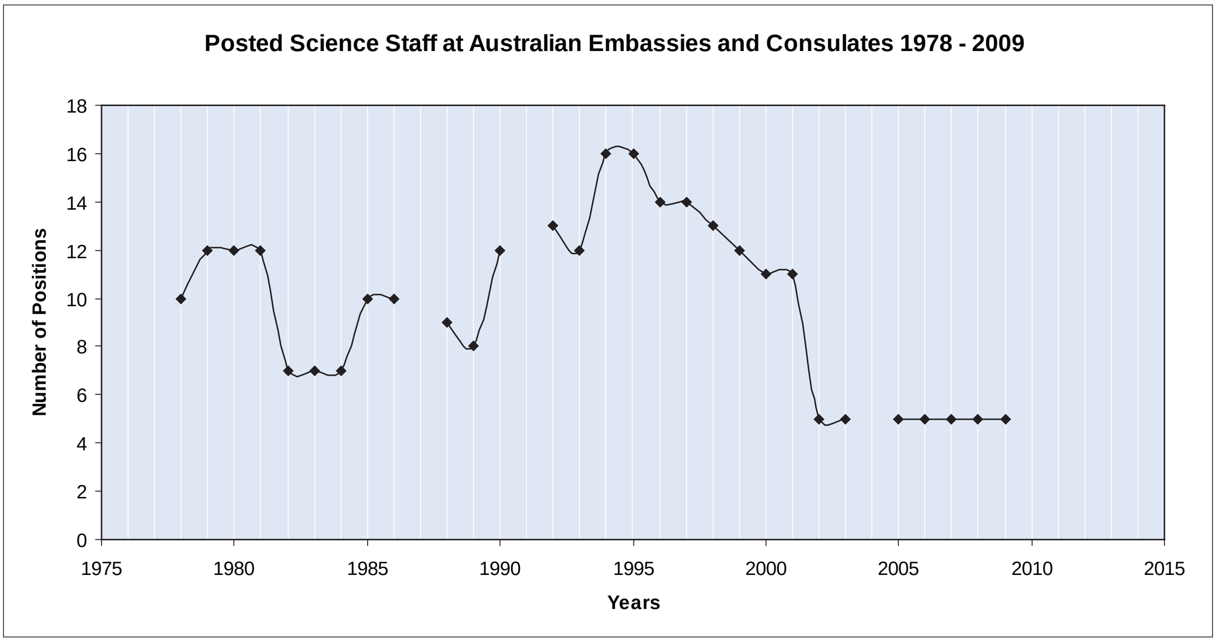
Significant costs can also be expected to revitalise our international science efforts if Australia's our established linkages lose momentum. As continuity and consistency are particularly valued in Asia, reducing Australia's participation under its memoranda of understanding with China, Japan, Korea and Taiwan could adversely affect Australia's credibility and influence commitments to other programs.

The Prime Minister also said at the announcement of the Australia–India Strategic Research Fund that:

> There is a need for collaboration, unprecedented in human history.[24] This will help in engaging with India on a long-term, strategic basis and recognises the central role of science and technology collaboration that will help address some of the pressing challenges that both countries face
>
> Collaboration partnership is what is needed if the nations of the world are to bring about real results on sustainable development and more broadly on climate change …[25]

Participation in global scale science projects requires the building of bilateral and multilateral relationships and an awareness of emerging opportunities. As discussed in Section 6 other countries have recognised the importance of locating science specialist staff at embassies and consulates in this context. These officers, whether science department officials, locally engaged or members of the diplomatic service, add value to diplomatic activities and facilitate access to science networks, funding and collaborative opportunities to help their researchers and institutions take advantage of potential synergies as they arise.

Over the last 15 years there has been a regrettable decline in the number of Australian Government science officers working at Australia's overseas posts (see Figure 3). From the 1970s to early 1980s, the CSIRO posted specialist science staff overseas to represent Australia's scientific and national interests. Responsibility for the representation and facilitation of Australian science then moved to the federal department responsible for science, and some research agencies, such as DSTO and ANSTO, elected to have their own dedicated representatives. International representation peaked in 1995 with the then Department of Industry, Science and Technology posting officers to Brussels, Paris, Bonn, Jakarta, Tokyo, Seoul, Kuala Lumpur, London and Washington.



Source: Annual reports of Australian Government agencies (gaps depict incomplete data).

Figure 3 Specialist science representation at Australian posts

Australian science staff at posts have responsible for a diverse range of activities, including maintenance of awareness of local scientific developments, introductory services, facilitation of collaborative research, events and exchanges, and high level bilateral and multilateral cooperation.

When the science portfolio was moved from the former Department of Education, Science and Technology to the Department of Education, Employment and Workplace Relations in 2007, a decision was taken to replace science counsellors with education counsellors. This left only one science counsellor in the Australian Embassy and Mission to the European Communities in Brussels, who also retained responsibility for liaison with the OECD in Paris. DIISR also employs two locally engaged staff with science responsibilities in Brussels and one each was subsequently appointed to the embassies in Delhi and Beijing. More recently, a senior officer for science research and innovation was appointed to Australia's embassy in Washington DC.

Previous science counsellors encountered difficulties operating in isolation in their respective countries and in achieving action on the information that they gathered. In order to improve the effectiveness of any investment in such out-of-country postings, and noting that the US has recently established three science envoys to advance US scientific and diplomatic interests (see Section 6.1), consideration could be given to the establishment of an Australian 'envoy for science' (Box 2). Recent examples of the appointment of specialist envoys in Australia include Special Envoy on Whale Conservation (Mr Sandy Hollway), a Special Envoy for the Asia Pacific Community (Mr Richard Woolcott) and Special Envoy for Afghanistan and Pakistan (Mr Richard Smith).[26]

Box 2 Australian envoy for science

An Australian envoy for science would liaise with the international scientific community, international agencies and foreign government science officials in order advise the Australian Government on priorities for participation in science diplomacy, and to identify bilateral and multilateral collaboration opportunities for Australian science, technology and innovation. The envoy should be supported by a network of specialist science staff at strategically important embassies and consulates. To enable ready access to leading international science bodies and with the world's highest ranking scientists and officials, an Envoy for Science would be an Australian with recognised international science standing and knowledge of international science networks and programs.

8 Academy recommendations

The commendable recent developments discussed in the previous section are applauded by Australia's scientific community and will help stimulate engagement of Australian science with the international scientific community. What is still lacking, and needs to be developed, is an integrated national strategy that focuses and supports international science efforts across Australian Government departments and agencies to ensure continuity in strategic scientific relationships, and provide a competitive basis for Australia's international long-term scientific engagement in the 21st century.

The strategy would recognise that there are long- and short-term objectives; that there are different partners to consider; that a diversity of scales of operation will be required; and that there will be diversity in the types of overseas partnerships necessary – bilateral, multilateral and global linkages.

The Australian Academy of Science considers that a whole of government science internationalisation strategy would provide:

- identification of international scientific engagement opportunities, threats and priorities
- coordination of Australia's collective international science efforts with respect to the recent growth in international science and collaborative efforts
- flexibility to respond in a timely way to emerging issues and challenges
- mechanisms for priority setting according to Australian research strengths, identified potential and government priorities
- encouragement of both basic and applied research as well as innovation and the bringing of outcomes to market
- engagement with developed and developing countries alike recognising that our major collaboration partners and major emerging science nations require senior-level government attention
- engagement with Australian and international industry to maximise links between academic and industrial research and innovation.

Starting from the bottom up, proposed government programs and initiatives to enact the strategy would:

- continue support for early- to mid-career researchers via competitive funding programs for travelling scholarships, fellowships and exchanges to access expertise and facilities in countries and areas of identified strategic interest
- promote Australian participation in the planning meetings of international science bodies directed to the resolution of regional and global problems
- support a proactive role in global observation programs, especially where particularly relevant to the Australian region

- provide a process for prioritising and funding Australian participation in specific large-scale international infrastructure development and the associated science
- establish a science, research and innovation network of officers at Australia's overseas missions, specifically:
    - senior Australian Public Service officers (Minister Counsellors) at missions to countries that are major science collaborators or major emerging science nations, eg US, UK, Brussels, India and China
    - locally engaged staff (science attachés) at missions to countries that are currently or potentially highly significant science collaborators, eg South Korea, Switzerland, Indonesia, France, Japan, Germany and Singapore
    - appoint an Australian Envoy for Science to enhance the contribution of science to Australia's diplomatic efforts and increase opportunities for international science collaboration.

Appendices

Appendix 1 Notes on international research and development expenditure

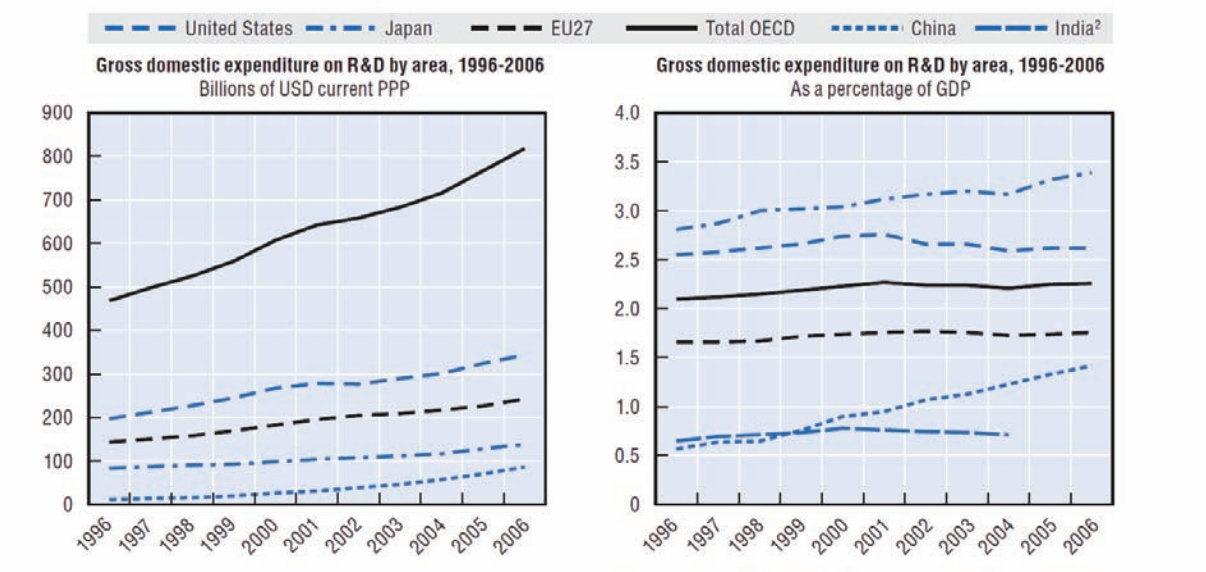


Figure 1 R&D trends, 1996-2006

Source: OECD, *Main Science and Technology indicators (MSTI) Database 2008/1*. India: national sources, 2008 (www.oecd.org/document/41/0,3343,en_2649_34273_41546660_1_1_1_1,00.html)

The DOI System www.doi.org/ (Stat link: http://dx.doi.org/10.1787/450457475732)

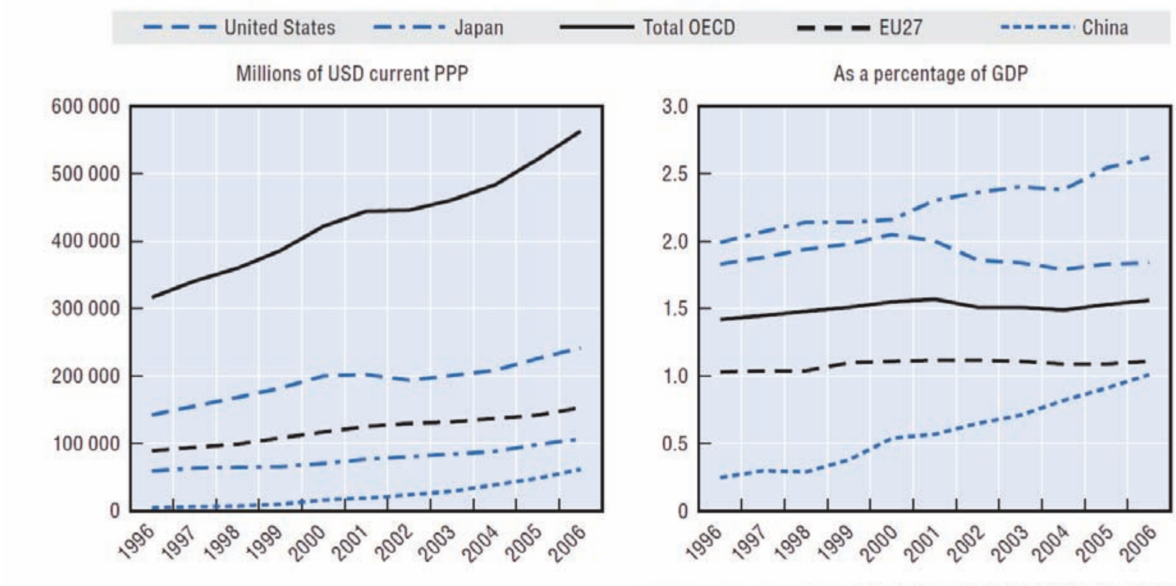


Figure 2 Business R&D spending by area, 1996-2006

Source: OECD, *Main Science, Technology Indicators (MSTI) Database 2008/1*
(www.oecd.org/document/33/0,3343,en_2649_34451_1901082_1_1_1_37417,00.html)

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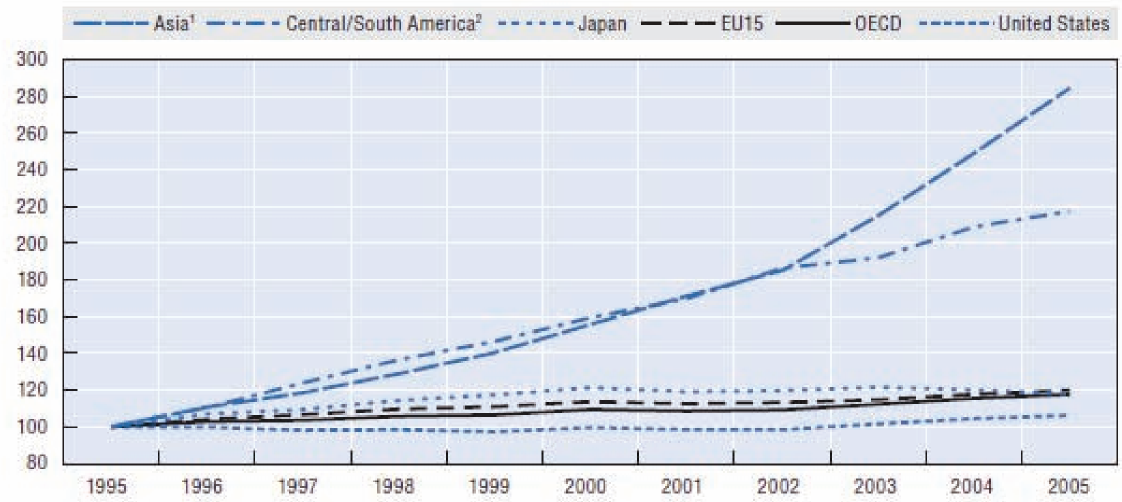

1. Excluding Japan and Korea
2. Excludng Mexico

Figure 3 Growth of scientific articles by area, 1995-2005
Index 1995=100

Source: National Science Foundation, *Science and Engineering Indicators 2008*
The DOI System www.doi.org/ (Stat link: http://dx.doi.org/10.1787/451261523635)

Summary Section, Chapter 1. Global Dynamics in Science, Technology and Innovation in OECD Science, Technology and Industry Outlook, 2008:

> The evidence presented in this chapter suggests that performance in science, technology and innovation has continued to strengthen in recent years, in OECD and related economies. Against the background of continued diversity within the OECD area, a number of major trends emerge. The absolute growth of R&D and innovation-related activities is leading to continuing growth of the Human Resources in Science and Technology labour force, an increasing need for highly skilled workers across the economy as a whole, and to greater international mobility of researchers and highly skilled people. Continued rapid growth in China has been accompanied by a dramatic increase in R&D and R&D employment, while future targets for Chinese R&D intensity imply that growth will continue. However, China is only part of the story of changes in the developing world. The rise of the BRICS [Brazil, Russia, India, and China] economies and some less developed OECD countries in S&T suggests shifts in the geographical composition of world science and technology activity. Alongside this trend is the continued globalisation of R&D, which also appears to be moving towards worldwide sourcing of technological capabilities. Taken together, the evidence suggests major shifts in the world economy in the years ahead.

China

China's expenditure on R&D has been growing at greater than 18% per year – vastly more than the other top three R&D spenders (the US and Japan), which have grown 2.9% per year in real terms.

China has set a target of raising R&D intensity to 2% by 2010 and to 2.5% or above by 2020. This is an extremely ambitious target, particularly when the rate of growth of GDP is taken into account. Implicitly, this means R&D expenditure will need to continue to increase by at least 10–15% annually.[27]

United States

President Obama, in an address to the National Academy of Science on 24 April 2009, said:

> I am here today to set this goal: we will devote more than three percent of our GDP to research and development. This includes a doubling of the budgets of key agencies, including the National Science Foundation … and the National Institute of Standards and Technology … And my budget doubles funding for the Department of Energy's Office of Science …

The doubling of these agency budgets is a 10-year plan for 2006–16.[28]

International science activities are coordinated through the White House Office of Science and Technology Policy and through the State Department. The State Department's Congressional Budget Justification Fiscal Year 2010 reported that:

> This increase in funds will enable the Department to represent US interests overseas, to face increasing international demands … Other new and evolving areas include: … reinforcing alliances with strategic partners through a growing range of bilateral Science and Technology agreements, leading global responses to tropical and chronic infectious diseases and global health care worker shortages, building critical cooperation on space with China, Korea, Japan and India [p. 52].
>
> [the] Department is working to strengthen its capacity to influence science policy debates internally and externally. Science and technology are key drivers of global development today and will be increasingly so in the future [p. 57].[29]

Appendix 2 Science specialist staff at international embassies and consulates

United States

The US State Department Office of Science and Technology Cooperation manages scientific engagement according to the following rationale:

> S&T cooperation helps to ensure that US scientific standards and practices play a substantial role in the establishment of international benchmarks. It also has significant indirect benefits as well, contributing to solutions which encourage sustainable economic growth by: promoting good will, strengthening political relationships, helping to foster democracy and civil society, and advancing the frontiers of knowledge for the benefit of all.
>
> The Department of State's Bureau of Oceans, and International Environmental and Scientific Affairs, Office of Science and Technology Cooperation (OES/STC) pursues efforts through the establishment of binding bilateral and multilateral science and technology Agreements. These Agreements promote the precepts of sustainable development, enhancement of the role of women in science and society, science-based decision-making, good governance, and global security.
>
> Thirty US S&T Agreements worldwide establish bilateral frameworks to facilitate the exchange of scientific results, provide for protection and allocation of intellectual property rights and benefit sharing, facilitate access for researchers, address taxation issues, and respond to the complex set of issues associated with economic development, domestic security and regional stability. S&T cooperation supports the establishment of science-based industries, encourages investment in national science infrastructure, education and the application of scientific standards, promotes international trade and dialogue on issues of direct import to global security, such as protection of the environment and management of natural resources. S&T collaboration assists USG agencies to establish partnerships with counterpart institutions abroad. These relationships enable them to fulfill their individual responsibilities by providing all parties with access to new resources, materials, information, and research. High priority areas include such areas as agricultural and industrial biotechnology research (including research on microorganisms, plant and animal genetic materials, both aquatic and terrestrial), health sciences, marine research, natural products chemistry, environment and energy research.[30]

The main activities of the US Environment, Science and Technology and Health (ESTH) officers at post include:

- engagement on the full range of ocean, environmental and science issues, such as oceans and fisheries; conservation; protection of marine mammals and wildlife; water; cooperation on satellites and global positioning systems; bilateral science cooperation; health policy; environmental capacity building under our free trade agreements; and climate change and renewable energy, among others
- representing US positions in multilateral forums at the US missions to the United Nations in New York City and Geneva, and at the US mission to the European Union

- working closely with other US government agencies and supporting their efforts by raising key issues at the diplomatic level
- cooperating with non-governmental organisations to raise awareness of ESTH issues, promoting good environmental governance and public participation, and advocating the use of ESTH core issues to strengthen diplomatic relations.

United Kingdom

The UK science and innovation network works closely with colleagues in UK Trade and Investment, the British Council, and Research Councils UK to:[31]

- facilitate scientific collaboration between UK universities and research laboratories and the best public and private-sector counterparts in the US
- facilitate R&D partnerships and technology transfer, attracting R&D intensive international investment, and helping to access and benchmark against US technologies
- use science and innovation as a means of influence across the range of the UK's international strategic priorities, such as climate change, energy security, poverty, infectious diseases and counter terrorism
- help policymakers develop best practice in science and innovation policy, and develop international frameworks in breakthrough technologies such as stem cell research.

The main activities of the United Kingdom's science and innovation officers and network are:

- facilitating collaboration between UK universities and research laboratories and public and private-sector counterparts abroad; working to increase access to foreign funding for UK researchers; bilateral scientific workshops, conferences and other networking activities
- raising awareness of the UK as a global leader in science and innovation; providing expert advice and leadership in support of R&D investment projects; working with UK Trade and Investment colleagues to help technology-intensive UK-based companies penetrate the supply chains of multinational enterprises and global markets; providing intelligence to UK innovation networks on overseas science and technology advances; helping UK companies to access and benchmark overseas technologies
- gathering and disseminating best practice in science and innovation policy; for example, how money is spent on science and innovation; developing international frameworks in breakthrough technologies such as stem cell research; promoting UK excellence in science with key international decision-makers
- promoting the use of science and innovation for evidence-based policy-making covering the range of the UK's international priorities; for example, how to respond to climate change, poverty, infectious diseases, technologies to support counter-terrorism, new energy technologies to increase climate and energy security, innovation to boost EU competitiveness and support the Lisbon Agenda; using science and innovation to contribute to the UK's wider bilateral priorities with other countries.

Denmark

The Danish Minister of Science, Technology and Innovation, Helge Sander, provides the following account of the science and technology attachés – services offered to Danish research and innovation environments:

> In 2006 the Danish Ministry of Science, Technology and Innovation and the Trade Council of Denmark, the Ministry of Foreign Affairs of Denmark, have set up three innovation centers in strong, international knowledge environments in Silicon Valley (USA), Shanghai (China) and Munich (Germany).
>
> The purpose of innovation centers is to contribute to increase the internationalisation of Danish research and enhance the innovative and competitive strength of Danish business by assisting Danish research environments and knowledge-intensive enterprises seeking access to network, knowledge, technology, markets and capital abroad.
>
> The Danish Ministry of Science, Technology and Innovation has posted a science and technology (S&T) attaché at each of the three innovation centers. Each attaché provides services to Danish researchers, universities, research institutions and innovative environments and forms part of a team of other advisers posted by the Trade Council of Denmark.
>
> The overall strength of the S&T attachés is their local presence, which is decisive to be able to set up a solid network of key persons in the relevant research, innovation and business environments.
>
> The following pages present our three attachés and their specific services.
>
> I would like to encourage all Danish researchers who wish to obtain access to leading research environments and networks in the innovation center areas to use these attachés and let them assist in targeting and qualifying the contact.
>
> The innovation centers are a central initiative in the Danish government's globalisation strategy of progress, innovation and cohesion ('Fremgang, Fornyelse og Tryghed') which was launched in April 2006. The objective of the strategy is to ensure Denmark's future position in an increasingly globalised world and, among other things, it aims at strengthening the access of Danish researchers and enterprises to world-leading knowledge centers outside Denmark.[32]

The Innovation Center Denmark idea has three components:

- networking and knowledge sharing in terms of common challenges and updates
- an advisory board that directs the center's activities, offerings and projects and work as a communication channel back to Denmark
- joint projects: market screenings, government priorities, talent hunting and development.[33]

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